

**APACHE CANADA  
LIMITED**

**HAMBURG 2-6  
COMPRESSOR STATION**

**HAMBURG ALBERTA**

**SO# 99404**

LSD: 02-06-097-11 W6M

SEPTEMBER, 2000

OPERATING MANUAL

**VOLUME 1**

**APACHE CANADA LIMITED**

**LSD: 02-06-097-11 W6M**

**2-6 Hamburg 1478 hp Compressor Package**

**Propak Systems Unit #99404**

**Waukesha L7042GL / Dresser-Rand 6HOS-3**

**Operations and Maintenance Manual**





TABLE OF CONTENTS

(INDEXED IN ALPHABETICAL ORDER BY TAG NUMBER)

<u>SECTION</u>	<u>TITLE</u>
VOLUME 1	
1.	HAZARD WARNING
2.	PRODUCT AND SERVICE BULLITIN
3.	BASIS OF DESIGN
4.	DESIGN DESCRIPTION
5.	STANDARD WRITE-UPS: DESCRIPTION
6.	PROCESS
7.	EQUIPMENT
VOLUME 2	
7.	EQUIPMENT - CONTINUED
8.	INSTRUMENTATION
VOLUME 3	
8.	INSTRUMENTATION - CONTINUED
VOLUME 4	
9.	ELECTRICAL
10.	DRAWINGS:
	- MECHANICAL FLOWSHEET
	- GENERAL ASSEMBLY



**SECTION 1: HAZARD WARNING****CAUTION****CAUTION****CAUTION**

**BEWARE! GAS PROCESSING UNITS ARE COMPLICATED AND DANGEROUS PIECES OF EQUIPMENT IF YOU ARE NOT FULLY TRAINED AND FAMILIAR WITH THEIR OPERATION.**

**BEFORE STARTING THIS UNIT  
FAMILIARIZE YOURSELF WITH THE UNIT**

**A gas/air mixture under pressure can explode!!!  
Sour gas is extremely poisonous!!!  
You can be severely injured or killed.**

**Make sure the unit is sufficiently purged of any explosive mixture and there are no gas leaks before starting.  
Unit startup/shutdown procedure to be carried out by trained, authorized personnel only.**

**Operational inquiries can be directed to Propak.  
For replacement parts / maintenance assistance contact Propak.  
After completing the above, begin proper starting procedure.**

**CAUTION****CAUTION****CAUTION**





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## BASIS OF DESIGN

The following describes a modularized and packaged gas compressor, designed and fabricated for Apache Canada Limited, consisting of a compressor, natural gas driven engine and aerial cooler being used for the compression of a natural gas mixture for installation the Hamburg gas processing facility, LSD: 02-06-097-11 W6M.

The inlet flow is a natural gas mixture. Three stages of compression deliver the gas to the pipeline at 1200 kPag (minimum), and 49 °C. The gas mixture consists of the following components;

<b>COMPONENT</b>	<b>MOLE FRACTION</b>
<b>HYDROGEN</b>	0.0
<b>HELIUM</b>	0.0003
<b>NITROGEN</b>	0.0063
<b>CARBON DIOXIDE</b>	0.0233
<b>METHANE</b>	0.9201
<b>ETHANE</b>	0.0360
<b>PROPANE</b>	0.0073
<b>I-BUTANE</b>	0.0012
<b>N-BUTANE</b>	0.0015
<b>I-PENTANE</b>	0.0010
<b>N-PENTANE</b>	0.0005
<b>HEXANE</b>	0.0005
<b>HEPTANE +</b>	0.0021
<b>HYDROGEN SULFIDE</b>	8 – 10 ppm
<b>TOTAL</b>	1.0000



## DESIGN DESCRIPTION

### PROCESS

All process piping and vessels have been designed for sour gas service, with 1/8" corrosion allowance.

Stage one suction has been designed for a pressure of 4516 kPag at 149°C. Stage one discharge has been designed for a pressure of 4447 kPag at 176°C and has a full flow relief valve set at 3412 kPag.

Stage two suction has been designed to 4516 kPag at 149°C. The second stage discharge PSV has been designed for full flow and has been set at 8720 kPag.

Stage three suction has been designed to 9067 kPag at 149°C. The second stage discharge PSV has been designed for full flow and has been set at 11377 kPag.

### INSTRUMENT AIR

The instrument air system is designed for a maximum pressure of 1034 kPag. Protection for this system must be provided upstream of the compressor skid edge.

### ENGINE FUEL AND START GAS

The engine fuel supply line is designed for a maximum pressure of 1034 kPag. Protection for this system must be provided upstream of the compressor skid edge.

The engine start gas has been designed for 1034 kPag start gas supply pressure. Protection for this system must be provided upstream of the compressor skid edge.



**APACHE CANADA LIMITED**

**LSD: 02-06-097-11 W6M**

**2-6 Hamburg 1478 hp Compressor Package**

**Propak Systems Unit #99404**

**Waukesha L7042GL / Dresser-Rand 6HOS-3**

**Operations and Maintenance Manual**

## TABLE OF CONTENTS

Operations and General Description	<u>page</u>
1.0 Overview.....	4
2.0 Performance.....	5
2.1 Compressor Performance Data Sheet.....	6
2.2 Capacity Control System.....	9
3.0 Compressor.....	10
3.1 Compressor Running Gear Lubrication.....	11
3.2 Compressor Cylinder & Packing Lubrication.....	12
3.3 Compressor Frame and Cylinder Cooling System.....	13
4.0 Engine.....	14
4.1 Engine Lubrication System.....	15
4.2 Drive Coupling.....	16
4.3 Engine Fuel Gas System.....	16
4.4 Engine Starting Motor.....	17
4.5 Engine Exhaust System.....	17
4.6 Engine Electrical Controls.....	18
4.7 Engine Pre-Lubrication.....	18
4.8 Engine Cooling.....	18
5.0 Air Cooler Assembly.....	19
5.1 Process Gas Cooling System.....	20
5.2 Engine Jacket Water Cooling System.....	20
5.3 Auxiliary Jacket Water Cooling System.....	21
5.4 Air Recirculation System.....	21
6.0 Pulsation Bottles.....	22
7.0 Inlet Gas Scrubbers.....	23
8.0 Pressure Piping System.....	23
9.0 Local Compressor PLC Control Panel.....	25
9.1 Automatic Mode.....	26
9.2 Manual Mode.....	26
9.3 Quick Panel Operator Interface.....	27
10.0 Compressor Package Start-up Sequencing and Control Logic.....	27
10.1 Control Panel Prestart Checks.....	27
10.2 Start-Up Compressor.....	28
10.3 Engine Start Sequence.....	28
11.0 Compressor Start and Shutdown Sequencing.....	29
11.1 Compressor Stop.....	29
11.2 Compressor Shutdown.....	30
11.3 Compressor ESD or Plant ESD.....	30
12.0 Major Component Serial Number Record.....	31

13.0	APPENDIX "A".....	32
	HMI Flow Sheet.....	33
	Local PLC – Alarms/Shutdowns.....	34
	Compressor Star-Up Check List.....	36
	After Start-Up Check List.....	39

**Apache Canada Limited**  
**LSD: 02-06-097-11 W6M**  
**2-6 Hamburg 1478 hp Compressor Package**

**Operations and Maintenance Manual**  
**Propak Systems Unit #99404**

The following text describes a packaged gas compressor unit, designed and fabricated for Apache Canada Limited at the Hamburg Compressor Station, LSD: 02-06-097-11 W6M. Compression of the gas stream is provided by a 1478 hp gas engine driven, three throw reciprocating compressor.

***CAUTION:** Operation and adjustment of this equipment should only be attempted by qualified personnel, and accordingly the equipment descriptions and operating procedures contained herein assume a thorough working knowledge of gas compression systems, equipment, and safety procedures. Please refer to the standard instructions contained in tab A of the Dresser-Rand Instruction and Parts list, enclosed in the "Compressor" section of this manual for additional information.*

***WARNING!!** Service to this equipment should never be undertaken other than by fully qualified personnel, with specific training in the safety procedures required to work in explosive or toxic gas (H<sub>2</sub>S) environments, and using only appropriate tools and safety equipment. In no instance should any pressure component, instrument, valve, or other part exposed to the process gas stream be removed, disassembled, opened, or otherwise disturbed causing process gas to escape inside the compressor building without first depressurizing, fully purging with non-toxic gas, and positively isolating all process gas piping system connections from the compressor building. Approved breathing apparatus must always be worn to prevent personal injury or death.*

*Equipment safety alarms including electronic fire, and combustible gas detection systems, should never be bypassed or defeated.*

## **1.0 OVERVIEW**

The compressor unit described herein is designed to compress a gas mixture in three stages from a suction pressure range of 25-200 psig, to a discharge pressure of approximately 1200 psig.

The new unit is a fully packaged modular gas compressor. All equipment is mounted on a concrete filled structural steel skid, c/w cooling and lubrication systems, controls, gas scrubbers, pulsation bottles, pressure piping and appurtenances. A self framing, insulated steel building is installed on the skid base to enclose the equipment and c/w a bridge crane for field service of heavy lift components. Care has been taken in the design and detail of the equipment to ensure safe and reliable performance within the design parameters. Unless stated specifically herein, never disarm or disable any safety switches or alarms without first consulting the manufacturer. Always consult the manufacturer prior to changing the operating parameters or loading configurations to those outside the design performance envelope. The manufacturer should be consulted immediately in the event of severe vibration, unusual mechanical noise, or other abnormality. Among other various shutdown devices, process pressure transmitters and temperature thermocouples are provided for both real-time indication and to protect the compressor from extreme operating conditions, and to cause the unit to shutdown in the event of process upset conditions (i.e. loss of inlet pressure, blocked discharge line, failed valve, etc.). The pressure transmitters are mounted locally at the process connection (inlet pulsation bottle nozzle and pressure piping downstream of each of the discharge pulsation bottles) and are equipped with isolating block and bleed needle valves<sup>1</sup> at the process pressure sensing point. The process thermocouples are installed in the inlet suction piping to each stage and in the discharge pulsation bottle nozzles.



**CAUTION:** *These needle valves<sup>1</sup> are installed for service only and should always remain fully opened. Never operate the unit with the needle valves closed, or the control panel safety protection and shutdown system will become disabled.*

## **2.0 PERFORMANCE**

Stages 1, 2 & 3 compress inlet gas from the suction range 25-200 psig to approximately 1200 psig. Compressor discharge pressure is a function of the resistance of the flow system downstream of the compressor.

Separate performance curves for stg-1, 2 & 3 are included in the "PROCESS" section and are calculated at varying inlet pressures and VVCP settings. The discharge pressure and engine speed are fixed for each performance curve, inlet pressure (psig) varies across the x-axis, capacity (mmscf/d) and horsepower (bhp) vary on the y-axis of the graph. Lines are alphanumerically labeled and each represents a different setting (percent of total extension) of the VVCP (variable volume clearance pocket). The compression horsepower read from the performance curves does not include the approximately 58 bhp required to drive the cooler fan. This should be added to the aggregate of the stg-1, 2 & 3 horsepower to obtain the total brake horsepower for a given condition. Performance is calculated at rated speed, capacity and horsepower may be corrected for actual operating speed as follows:

$$\frac{\text{actual engine speed (rpm)}}{1200 \text{ rpm}} \times \text{mmscf/d or bhp} = \text{corrected mmscf/d or bhp}$$

Refer to the Section 6 of this manual for the "PROCESS" section included with this overview for flowrates at individual suction pressures.

## 2.1 COMPRESSOR PERFORMANCE DATA SHEETS

The following is a sample performance data sheet:

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-1997 V1.2)

PACKAGER: Propak Compression	DATE: Jul 28, 1998
LOCATION: Alberta	FILE: C17006H3.DAT " 1"
JOB/REF : 1700 Bhp Stock Unit	CALC BY: Propak Engineer
JOB SITE : Amb T (F) : 95.	Alt. (FT) : 3000. Atm ( PSIA): 13.17
Ref. Pressure ( PSIA) : 14.70	Ref. Temp.(F) : 60.
COMPRESSOR: Frame : 6 HOS 4	Stroke (IN): 6.0 Rod Dia(IN): 2.500
.....Calc RPM : 1000.0	Max RPM : 1200.0 Cooler (HP): 70.0
DRIVER: Type : Gas Engine	Avail (HP) : 1715.0 Model: G3606TALE

		1	2	3	
( 1 )	Stage Number				
( 2 )	Gas	Natural	Natural	Natural	Ps= 150 psig
( 3 )	Dry Gas Mol. Weight	18.827	18.827	18.827	Pd= 1400 PSIG
( 4 )	Dry Gas Spec. Gravity	.650	.650	.650	
( 5 )	Cp/Cv @ 14.7/60	1.277	1.277	1.277	(1) stg 1 cyl N.A.
( 6 )	Avg. Temp. Expon. (K)	1.268	1.256	1.275	
( 7 )	Avg. Vol. Expon. (N)	1.257	1.253	1.295	
( 8 )	Gas Crit. Temperature	R 384.092	384.092	384.092	
( 9 )	Gas Crit. Pressure	PSIA 675.549	675.549	675.549	
( 10 )	Z Standard	.998	.998	.998	
( 11 )	Z Suction	.970	.962	.915	
( 12 )	Z Discharge	.965	.961	.923	
( 13 )	Inlet Temperature	F 60.00	120.00	120.00	
( 14 )	Inlet Press. @ Cyl Flg	PSIG 147.75	284.08	654.39	
( 15 )	Interstage Press. Drop	% 2.00	1.50	1.00	
( 16 )	Disch. Press. @ Cyl Flg	PSIG 290.14	664.55	1414.00	
( 17 )	Ratio of Compression	1.885	2.280	2.138	
( 18 )	Adiabatic Disch. Temp.	F 134.59	226.20	223.27	
( 19 )	Est. Actual Disch. Temp	F 146.98	239.38	232.03	
( 20 )	Stg. Piston Displ.	CFM 904.7	704.3	250.2	
( 21 )	Stg. Inlet Capacity	ACFM 754.6	452.2	191.4	
( 22 )	CAPACITY ACTUAL WET	MMSCFD 12.24	12.24	12.24	
( 23 )	CAPACITY ACTUAL DRY	MMSCFD 12.22	12.22	12.22	
( 24 )	TOTAL COMPRESSOR POWER	HP 1645.00			

		1/1	1/1	2/2	3/3
( 25 )	Stage number at (HE/CE)				
( 26 )	Frame Ext/Cyl. Bore	#/IN 1/13.000	3/13.000	2/11.500	4/ 7.000
( 27 )	Cylinder Pattern	G12202	G12202	G12201	G12197
( 28 )	RDP	PSIG 585.0	585.0	775.0	1500.0
( 29 )	MAWP	PSIG 644.0	644.0	855.0	1650.0
( 30 )	Cyl. Action/HE Rod Dia. Act./IN	NA/ .00	DA/ .00	DA/ .00	DA/ .00
( 31 )	Brake power / Cylinder	HP 11.8	432.2	614.9	545.9
( 32 )	HE Disch. Vol. Eff.	% .00	49.52	26.50	41.32
( 33 )	CE Disch. Vol. Eff.	% .00	51.26	40.38	43.97
( 34 )	HE Inlet Vol. Eff.	% .00	82.00	51.14	74.29
( 35 )	CE Inlet Vol. Eff.	% .00	84.87	77.93	79.05
( 36 )	Avg. Inlet Vol. Eff.	% .00	83.43	64.54	76.67
( 37 )	HE Clearance Req'd.	% 17.80	22.08	48.61	27.27
( 38 )	HE Clearance Min.	% 17.80	17.80	18.80	17.70
( 39 )	HE Pocket Open	% .00	3.95	35.00	10.00
( 40 )	HE Clearance Added	IN3 .0	34.1	185.8	22.1
( 41 )	CE Clearance Req'd.	% 17.70	17.70	19.80	21.30
( 42 )	CE Clearance Min.	% 17.70	17.70	19.80	21.30
( 43 )	CE Clearance Added	IN3 .0	.0	.0	.0
( 44 )	Valve Model - HE	PF67	PF67	PF60	PF48
( 45 )	Valve Model - CE	PF67	PF67	PF60	PF48
( 46 )	Valves / Corner (HE/CE)		2/2	2/2	1/1
( 47 )	Valve Lift - HE	IN .080	.080	.080	.080
( 48 )	Valve Lift - CE	IN .080	.080	.080	.080
( 49 )	Valve Lift Area - HE	SQIN 10.420	10.420	7.360	5.640

( 50 )	Valve Lift Area - CE	SQIN	10.420	10.420	7.360	5.640	
( 51 )	API Inlet Vlv Vel Avg.	FPM	6251.3	6251.3	6889.6	6388.3	
( 52 )	Flange Gas Load - T	LBF	-725	17476	36257	22292	
( 53 )	Flange Gas Load - C	LBF	-725	-19626	-40914	-32446	
( 54 )	Max. Allow. Gas Load	LBF	60000	60000	60000	60000	
( 55 )	Combined Rod Load - T	LBF	37587	28123	32265	22277	
( 56 )	Combined Rod Load - C	LBF	-26939	-27222	-30896	-33149	
( 57 )	Max Allow Rod Load	LBF	60000	60000	60000	60000	
( 58 )	Recip. Weight @ XHD Pin	LB	379.0	379.0	379.0	379.0	
( 59 )	Reversal @ XHD Pin	DEG	160.0	175.0	175.0	170.0	

Following is a line by line chart for interpretation of the performance data sheets:

LINE #	NAME	DESCRIPTION
1	stage number	data for each stage of compression follows in vertical columns
2-12	gas description	gas properties: i.e.; molecular weight, specific gravity, ratio of specific heats, pseudo critical properties, compressibility, etc.
13	inlet temperature	$T_{s_n}$ = gas inlet temperature to each stage (°F.)
14	inlet pressure	$P_{s_n}$ = gas inlet pressure at the cylinder flange (psig)
15	interstage $\Delta P$	$\Delta P_n$ = estimated pressure drop (percent) through the interstage gas cooler and scrubber
16	discharge pressure	$P_{d_n}$ = gas discharge pressure at the cylinder flange (psig)
17	ratio of compression	$R_{c_n}$ = $P_d/P_s$ for each stage, ratio of absolute pressures
18	adiabatic discharge temperature	$T_{d_n}$ = adiabatic gas discharge temperature for each stage (°F.)
19	estimated actual discharge temperature	temperature based on known efficiencies (°F.)
20	piston displacement (ft <sup>3</sup> per minute)	cfm = total piston displacement or swept volume for each stage at the calculated operating speed
21	inlet capacity (actual ft <sup>3</sup> per minute)	acfm = gas flowrate at inlet conditions, swept volume (cfm) x volumetric efficiency = acfm
22	actual capacity (wet)	gross rated capacity wet (mmscf/d $\pm 3\%$ at 14.65 psia & 60°F.)
23	actual capacity (dry)	gross rated capacity dry (mmscf/d $\pm 3\%$ at 14.65 psia & 60°F.)
24	total compressor power (brake horsepower)	total compressor bhp at the specified operating condition, (includes frictional hp and auxiliary hp)
25	Stage number at (HE/CE)	Stage of compression for each cylinder end.
26	frame extension / cyl. bore diameter (inches)	compressor frame extension number (crank throw) and cylinder bore diameter (inches)
27	cylinder pattern	Dresser-Rand cylinder pattern number or casting reference number
28	RDP	cylinder rated discharge pressure – maximum operating pressure (psig)
29	MAWP	cylinder nameplate maximum allowable working pressure (psig) maximum safety relief valve setpoint
30	cylinder action / HE rod diameter (inches)	DA=double acting; NA=non-acting; SACE=single acting crank end; SAHE=single acting head end / HE piston rod dia. (if used)
31	brake power per cylinder	compressor brake horsepower (bhp) per cylinder
32	percent H.E. discharge volumetric efficiency	cylinder head end $VE_{d_n\eta}$ = calculated degrees of crank rotation where the cylinder HE discharge valves are opened $\div 180^\circ$
33	percent C.E. discharge volumetric efficiency	cylinder crank end $VE_{d_n\eta}$ = calculated degrees of crank rotation where the cylinder CE discharge valves are opened $\div 180^\circ$
34	percent H.E. inlet volumetric efficiency	cylinder head end $VE_{I_n\eta}$ = calculated degrees of crank rotation where the cylinder HE suction valves are opened $\div 180^\circ$
35	percent C.E. inlet volumetric efficiency	cylinder crank end $VE_{I_n\eta}$ = calculated degrees of crank rotation where the cylinder CE suction valves are opened $\div 180^\circ$
36	percent average inlet volumetric efficiency	the numerical average of line 32 & 33; or $ACFM \div CFM$ =average inlet volumetric efficiency
37	H.E. clearance volume required (%)	total required head end clearance volume at the specified design condition (inherent clearance plus added clearance)
38	H.E. clearance volume minimum (%)	cylinder minimum or inherent head end clearance volume
39	H.E. pocket open (%)	variable volume clearance pocket (VVCP) percent open

LINE #	NAME	DESCRIPTION
40	H.E. clearance volume added (cubic inches)	total in <sup>3</sup> of clearance volume added to the head end of the cylinder
41	C.E. clearance volume required (%)	total required crank end clearance volume at the specified design condition (inherent clearance plus added clearance)
42	C.E. clearance volume minimum (%)	cylinder minimum or inherent crank end clearance volume
43	C.E. clearance volume added (cubic inches)	total in <sup>3</sup> of all clearance volume added to the crank end of the cylinder (fixed spacers, clearance plugs, or VVCP)
44	valve model H.E.	cylinder head end valve model number, size or type (description)
45	valve model C.E.	cylinder crank end valve model number, size or type (description)
46	valves per corner H.E. / C.E.	number of valves installed in the cylinder H.E. / C.E. (minimum 2, one suction and one discharge)
47	valve lift H.E. (inches)	head end valve plate design lift (inches)
48	valve lift C.E. (inches)	crank end valve plate design lift (inches)
49	valve lift area H.E. (in <sup>2</sup> )	head end fully opened valve lift area (sq. in.)
50	valve lift area C.E. (in <sup>2</sup> )	crank end fully opened valve lift area (sq. in.)
51	API average inlet valve velocity (fps)	average inlet valve gas velocity (feet per second) calculated using API formulae
52	flange gas load - T (lbf)	static piston rod load (lbs force in tension) that result from gas pressure measured at the cyl flange, acting on the piston area
53	flange gas load - C (lbf)	static piston rod load (lbs force in compression) that result from gas pressure measured at the cyl flange acting on the piston area
54	maximum allowable gas load (lbf)	maximum static piston rod load (calculated in lbs force) that may be applied to the frame (specified by the manufacturer)
55	combined rod load - T (lbf)	is the actual piston rod load (lbs force in tension), ie; the sum of all static (gas) loads and inertial forces at the calculated rpm
56	combined rod load - C (lbf)	is the actual piston rod load (lbs force in compression); the sum of all static (gas) loads and inertial forces at the calculated rpm
57	maximum allowable rod load (lbf)	the manufacturer's rated maximum permissible piston rod or frame load (lbs force)
58	reciprocating weight (lbs) at X-head pin	total weight (lbs) of the reciprocating mass, measured at the crosshead pin (includes the M <sub>recip</sub> component of the con rod assy)
59	degrees reversal at the X-head pin	the calculated degrees (crank rotation) of crosshead pin load reversal (180° = 50%, equal or perfect load reversal)

## 2.2 CAPACITY CONTROL SYSTEM

The compressor is equipped with an automatic stage-1/3 gas bypass system that recycles stage-3 aftercooled gas back to stage-1 suction. Compressor suction pressure is monitored via pressure transmitter (PT-100) at the inlet to the compressor. This signal is used by the PLC to control the engine speed (I/P-219), and the bypass pressure control valve (PCV-100). The goal is to maintain a constant suction pressure. Under normal operating conditions, the engine is running at full speed (1200 RPM) and PCV-100 fully closed. Setpoints allow the engine speed to react to the first 50-60% of the signal and the bypass valve (PCV-100) to react during the remaining portion of the signal. Some overlap is normal, ie: on a falling signal the engine speed may decrease to approximately 900 rpm before the bypass valve begins opening. As the suction pressure drops, the engine speed will respond by decreasing, followed by the bypass valve opening to maintain the suction pressure set point at PT-100. As described in the start sequence, once the unit is warmed up, the bypass control valve (PCV-100) PID and the engine speed controller (SS-229) PID are switched by the operator to automatic control.

Each compressor cylinder is a double acting design and the stg-1 and stg-2 cylinders are complete with a manually adjustable head end variable volume clearance pocket (VVCP). VVCP's enable the addition of clearance volume to the head end of the cylinder, reducing the volumetric efficiency and thus reducing the flowrate and load. The effect of adding clearance with the VVCP's is shown on the performance curves enclosed in the "PROCESS" section of this manual. Additional fixed clearance can be added to the cylinder by installation of spacer rings, valve spacers, or clearance plugs. The cylinders can also be operated in a non-acting or single acting mode by removing the suction valves from one end, or both the head and crank ends of the cylinder, to provide large increments of capacity control.

**CAUTION:** *The manufacturer should be consulted prior to removal of valves or changing any cylinders to a single acting mode to ensure sufficient rod reversals exist to provide lubrication, and also to ensure dynamic load limits are not exceeded. Severe damage to the equipment may result from improper loading configuration.*

### **3.0 COMPRESSOR**

The compressor is a Dresser-Rand 6HOS-4, three cylinder, balanced, horizontally opposed reciprocating gas compressor, s/n: 6HF853. The compressor crankshaft is forged alloy steel and has a 6.0" stroke, with a maximum rated operating speed of 1200 rpm. The package maximum speed limit is 1200 RPM and comes with a Metrix, non-indicating vibration transmitter, (VT-288) mounted on the compressor to shut the package down if any abnormal conditions occur that would cause excessive vibrations during operation. The compressor cylinder bore diameters and component serial numbers are specified in the following table and should be used for reference when ordering parts:

<b>bore dia. (in)</b>	<b>stage #</b>	<b>type</b>	<b>crank throw</b>	<b>VVCP</b>	<b>MAWP (psig)</b>	<b>serial number</b>
15.00" $\phi$	1	d/a	#1	yes	495	6HC2654
9.50" $\phi$	2	d/a	#2	yes	1265	6HC2655
balance	-	-	#3	-	-	-
6.00" $\phi$	3	d/a	#4	yes	1925	6HC2656

Each cylinder is double acting, the 15" cylinder contains Dresser-Rand "PF67" series plate type suction and discharge valves on both the head and crank end, the 9-1/2" cylinder contains Dresser-Rand "PF48" series valves, and the 6" cylinder also contains Dresser-Rand "PF48" valves. Process gas is admitted to the cylinder volume (at cylinder flange suction pressure) through the suction valves. As horizontal piston movement displaces volume in either the head end or crank end of a given cylinder, the pressure of gas contained within the cylinder by the compressor valves (acting as one way check valves) is increased to the discharge pressure of that stage, then is displaced through the discharge valve for the duration of the stroke. The cylinder castings are all nodular iron and gas cooled. All cylinder bores and pressure packings are force feed lubricated by a positive displacement injection system. The pistons are cast iron c/w combination rider bands/compression rings, piston rods are AISI 4142 annealed carbon steel c/w rolled threads and 8-18 RMS finish in the packing travel area. The cylinders are c/w standard single compartment distance pieces that are

vented to the atmosphere (building eave) outside the compressor building (after passing through the Packing Vent & Drain Seal Pot, T-130).

Care should be taken when ordering replacement service parts for the compressor in that many common parts have been designed with special metallurgical consideration that may not be readily apparent. It is recommended that the operator familiarize himself with the compressor and its parts by reading the Dresser-Rand Instruction and Parts Lists located in Section 7 under the heading "Compressor" of this manual. To ensure the correct and genuine Dresser-Rand factory replacement parts and for authorized warranty service, Contact Propak Compression at 1-800-408-4434 or (403) 912-7000 (24 hours).

### **3.1 COMPRESSOR RUNNING GEAR LUBRICATION**

Long compressor service life and reliability is highly dependent on an adequate supply of clean lubricant. Please refer to the "Compressor" section of this manual for the manufacturer's recommended crankcase lubricating oil specifications.

The compressor frame running gear (crankshaft main and connecting rod bearings, crossheads, pins and bushings) are lubricated by way of an integral positive displacement gear pump that is direct driven from the compressor crankshaft. The oil pump supply is drawn from the compressor crankcase sump (approximately 216 liter capacity) and circulated through a shell & tube type lube oil cooler (E-277) and 10 micron full flow oil filter assembly (F-250). The oil filter is equipped with a local differential pressure gauge (DPI-250), which is a canister type with a replaceable element and is frame mounted. A pipe plug is provided and the bottom of the filter housing to allow it to be drained. An externally adjustable oil pressure regulating valve (set @ approximately 414 kPag), and a non-adjustable pressure relief valve (set @ 620 kPag) are provided to maintain a constant oil flow and pressure, and to protect the equipment from overpressure. Cooled and filtered lube oil is returned to pressurize the main oil gallery at approximately 345 to 414 kPag. Lube oil temperature and pressure is continuously monitored by the unit control panel with low pressure shutdown protection set for 241 kPag falling, and high oil temperature shutdown protection set for



82°C rising. Locally mounted temperature gauges are also installed on the cooler inlet and outlet for indication.

A WILDEN, model T2, pneumatic diaphragm pump (P-276) is provided for timed and permissive prelube and timed postlube services. The unit control panel logic ensures that the permissive has been satisfied before the “OK to Crank” signal is given. Timers are adjustable by programmed logic in the control panel, however they are preset and should require no adjustment. The pump is automatically activated from the control panel via a shuttle valve (SV-276). The compressor frame oil level is regulated by a Kenco LCE-9 automatic level controller (LC-270), c/w low oil level shutdown switch and level indicator. Clean crankcase lube oil is supplied from the 400 liter daytank (integral to the upper bridge crane rail) through a disposable, 17 micron spin on oil filter (F-270) that requires only annual replacement to ensure free flow to the level controller. A second pneumatically operated WILDEN T2 diaphragm pump (P-270), is included c/w barrel fill hose to facilitate refilling the overhead storage tank. Used crankcase oil is drained to an 800 liter waste oil storage tank located between the main skid members behind the compressor inside the building, through a manual gate valve.

**NOTE:** Compressor oil should be sampled and analyzed monthly to establish service intervals. The compressor oil filter should be serviced at every oil change.

### **3.2 COMPRESSOR CYLINDER AND PACKING LUBRICATION**

The compressor is equipped with a force-feed injection lubricator driven by the compressor main oil pump driveshaft. Oil is injected into the cylinder bore at high pressure to lubricate the piston rings and valves, and into the pressure packing to lubricate the piston rod and provide sealing oil for the packing rings. Each compressor cylinder has a top and bottom connection that enables lubricant to enter the cylinder bore, and a pressure packing lube oil feed connection. Excess cylinder lubricant is entrained in the discharge gas flow and a packing drain line enables excess packing oil to drain into the Packing Vent & Drain Seal Pot (T-130), which will periodically need to be drained into the on-skid waste oil storage tank (T-284). The system is a distributor block design which manifolds the individual pump outlets from the lubricator into a single master distributor block, and then divides the oil flow into two distribution blocks

servicing the various cylinder bore and packing injection points. Stainless steel instrument tubing is used to direct the oil to from the distributor block to a check valve installed at each injection point, that prevents high pressure gas from bubbling back into the oil lines. Each injection pump in the lubricator box has an adjustable output, and by varying the effective plunger stroke, the pump displaces an increasing or decreasing quantity of oil to the master distributor block. The total flow rate can be monitored by observing the cycle pin on the master distributor block **or by counting the rate of oil drops visible in the sight glass of each individual pumping unit.** A Manzel Lube Line Alert no-flow shutdown switch monitors the oil outlet flow from the pump manifold to the master distributor block and the control panel will shut down the unit if the switch senses a loss of oil flow. The cylinder lubricator oil supply is taken from the compressor crankcase oil supply line (downstream of the oil filter, F-250).

Compressor piston ring and valve life are dependent upon a supply of clean lubricant that is injected directly into the cylinder bore at high pressure. A properly lubricated cylinder will have a uniformly wetted bore when inspected through an open valve cover, and residual oil will not collect or form a pool in the lower part of the cylinder bore. Excessive cylinder oiling may cause discharge valve plate and spring damage. Likewise, injected lubricant is necessary for proper pressure packing sealing and service life. Insufficient packing lube will result in gas leakage into the distance piece, high temperatures, premature packing ring and piston rod wear. Prior to start up, ensure the lubricator box has an oil level visible in the sight glass. During initial commissioning or after an extended shutdown, each lubricator should be primed using the hand plunger and the tubing lines bled of entrapped air. Please refer to the "Compressor" section of this manual for a detailed description of the recommended service and maintenance to the lubricator injection pump system.

### **3.3 COMPRESSOR FRAME AND CYLINDER COOLING SYSTEM**

To minimize the formation of carbon deposits on the discharge valves, the maximum process gas temperature of lubricated cylinders should be kept below 163°C (325°F), a temperature that is well below the operating limits for the cylinder casting, piston, rings,

and valve materials. High discharge temperatures often indicate the onset of a compressor valve failure. The discharge cylinder temperatures are monitored by the unit control panel logic. Alarm setpoints are set at 149°C (300°F) rising for each cylinder and shutdown setpoints are set at 163°C (325°F) rising.

Coolant flow through the tubeside of the compressor lube oil cooler (E-480) is manually regulated with a 1-1/2" globe valve. Locally mounted temperature gauges are provided on the inlet and outlet sides of the shell side of the cooler. The compressor lube oil cooler should be inspected for corrosion or fouling during annual or other major inspections. The cooler end bonnets can be removed for internal inspection and cleaning of the tubes. Proper treatment and maintenance of the auxiliary water system will prevent premature tube corrosion or fouling.

All cylinders are gas cooled, whereby most of the frictional heat and heat generated during the compression process is carried into the discharge gas stream. A smaller percentage of this heat energy is rejected to the atmosphere through the cylinder walls.

#### **4.0 ENGINE**

The compressor prime mover is a Waukesha L7042GL natural gas fueled engine (S/N: C-12970/1), with a rated maximum continuous load of 1478 bhp @ 1200 rpm. The engine is a heavy duty, V-12 cylinder, turbocharged and intercooled, four cycle overhead valve design. Refer to the engine manufacturer's detailed operation and service instructions located in "Engine" heading under Section 7 of this manual for detailed starting and maintenance procedures.

Always start the engine with the compressor start up bypass valves fully opened and allow a sufficient warm up period before loading the engine. The engine is equipped with a replaceable dry element air filter on each turbocharger inlet air housing, and the intake air piping system draws cool air from outside the building. A manually operated air diverter valve enables drawing (or mixing) warm air from the cooler discharge air plenum during cold seasons.

It is advisable to allow a brief cooling down period at 700-800 rpm with the compressor unloaded prior to stopping the engine. This will ensure the exhaust turbocharger and cylinder head temperatures are reduced and ultimately extend engine service life. Frequent emergency or rapid shutdowns at full load can result in overheating of the turbocharger shaft bearings as the cooling oil flow ceases, and coolant boiling inside the cylinder head jacket water passages resulting in thermal stress cracking of the cylinder head flame deck or exhaust valve ports. The unit control panel controls the engine stop and start functions, pre-post lube cycle, and monitors the engine oil pressure, oil level, oil and water temperature, vibration, and high exhaust temperature shutdown switches. Engine speed (rpm) and total run time hours can be displayed on the unit control panel display screen.

#### **4.1 ENGINE LUBRICATION**

The engine main bearings, connecting rod bearings, piston pins, camshaft bearings, valvetrain, and other internal components are pressure lubricated from the main engine oil pump (P-250), which is gear driven from the engine crankshaft. Lubricating oil is circulated through the remote mounted shell & tube oil cooler (E-241) and the full flow oil filter (F-253). The oil filter is equipped with a local differential pressure gauge (DPI-253) and a removable end closure to facilitate service and removal of the filter elements. A 3-way thermostatic valve bypasses oil flow around the oil cooler during the engine warm up period to maintain the minimum recommended oil temperature. A pneumatic vane pump (P-226) is installed on the engine for timed and permissive prelube (PT-257 set @ 70 kPag ↑) & timed postlube services. The unit control panel logic ensures that the permissive switch has been satisfied at the expiration of the prelube timer before the "OK to Crank" signal is given. Timers are adjustable by programmed logic in the unit control panel, however they are pre-set and should require no adjustment. The pump is automatically activated from the control panel via a solenoid valve (SOV-228) to the engine shuttle valve.

The engine crankcase oil level is regulated by a Kenco LCE-27 automatic level controller (LC-262), c/w low oil level shutdown switch. Clean crankcase lube oil is supplied from the 400 liter daytank (integral to the upper bridge crane rail) through a

disposable spin on oil filter (F-261) that requires only periodic replacement to ensure free flow to the level controller. Propak recommends frequent (monthly as a minimum) engine crankcase oil sampling and analysis to ensure no contamination of the lube oil exists. Engine oil is monitored with pressure and temperature transmitters, as well as local temperature indicators. Alarm and shutdown set points are programmed into the unit control panel to protect the engine. Engine oil filtration is handled with a primary and secondary filter. The primary filter (F-253) is remote mounted with differential pressure indicator (DPI-253) across the inlet and outlet of the filter. Filter elements are to be replaced when the DPI reads 83 – 103 kPa (the oil pressure drop through new filters is 14 – 21 kPa). Refer to the engine parts booklet for element part numbers. The secondary filter is mounted on the inlet to the engine and serves as a final strainer, straining the oil prior to reaching the internal injection points. The strainer has a washable magnetic element.

A pneumatically operated WILDEN T2 diaphragm pump (P-260) is included c/w barrel fill hose to facilitate refilling the overhead storage tank. Used crankcase oil is drained to an 800 liter waste oil storage tank located between the main skid members behind the compressor inside the building (note, this a common waste oil tank for the entire skid), through a manual gate valve. Engine oil should be sampled and analyzed monthly to establish service intervals, not to exceed 720 hours. More frequent service intervals may be required if impurities are present in the fuel gas. The oil filter should be serviced at every oil change.

#### **4.2 DRIVE COUPLING**

The compressor crankshaft is directly coupled to the engine crankshaft using a Thomas CMR-700 flexible disk coupling (CPL-295). Care should be taken not to misalign or substitute drivetrain components that might alter the torsional or mass elastic properties of the system. The drive coupling can be accessed for service or inspection by removal of the coupling guard. Excessive vibration often results from coupling misalignment, broken or damaged coupling bolts or disks. Drive coupling misalignment can lead to premature engine and/or compressor main bearing failure, and may present a serious operating hazard from flying debris in the event of coupling failure. Immediately have

the drive coupling and alignment inspected by a qualified serviceman if unusual vibrations are present or misalignment is suspected. The unit should be fully depressurized and engine starting and fuel gas systems positively shut off with locking valves prior to removal of the coupling guard and manually barring the engine.

**WARNING:** *Never operate the compressor without the coupling guard firmly secured to prevent personal injury or death from the rotating machine elements.*

### **4.3 ENGINE FUEL GAS SYSTEM**

Clean, dry fuel gas is to be supplied at site to the skid edge connection. The fuel gas supply pressure is to be regulated to 1034 kPag maximum pressure prior to entering the skid. A skid edge ball valve enables isolation of the entire fuel gas supply system. A fuel gas filter (F-220) has been provided and sized to remove 95% of particles in the gas, 0.1 microns and larger. Periodic inspection of the filter is required and replacement filter elements are readily available. Ensure the supply valve is fully closed, open the manual drain valve and verify the gas pressure has been fully depleted from the piping and vessel prior to inspecting or replacing the filter element.

A low pressure regulator supplies engine fuel gas at 172 kPag to the fuel gas shutoff valve (FCV-223) that is automatically opened by a solenoid valve in unit control panel. The fuel gas shutoff valve is a 'fail-safe' valve that will close on loss of power, ESD, or shutdown signal, and will vent residual fuel gas from the downstream side to the engine. The engine is equipped with a Fisher low pressure regulator for each cylinder bank at the carburetor fuel inlet (c/w engine). Please refer to the detailed operating description and service instructions for the fuel system, enclosed in the "Engine" section of this manual.

### **4.4 ENGINE STARTING MOTOR**

Sweet dry start gas is supplied to a skid edge connection, and can be isolated with a manual 2" ball valve, with an isolating ball valve to prevent accidental engagement of the starter motor while servicing the engine or compressor. Upon a crank signal from

the unit control panel and following a satisfactory pre-lube cycle, a pilot valve (FCV-227) will open and gas will flow through the turbine type starter, a TDI TURBO TWIN model T112-60001-B1R pneumatic starter (STR-227). As the gas flows through the starter, the engine will begin to turn over. At an engine speed between 30 and 100 RPM, the ignition will be enabled, followed by the opening of fuel gas valve, FCV-223. As the cylinders begin to fire, the engine speed will increase. At an engine speed between 100 and 200 RPM, the crank signal will be disabled. A wye strainer is installed upstream of the starter, and should be frequently inspected to maximize the starter motor service life. The starter motor gas is exhausted above the building eave through a 3" vent line.

#### **4.5 ENGINE EXHAUST SYSTEM**

The engine exhaust is routed outside the building from the turbocharger outlet using a stainless steel exhaust system with stainless steel expansion joints to allow for thermal expansion of the piping system. The tubing is specifically designed for exhaust system temperatures and flows, and has been insulated inside the compressor building with ceramic wool and aluminum cladding for personnel protection and to keep excess heat from radiating into the building on warm days. Care should be taken not to damage the outer cladding of the exhaust system when handling the exhaust piping. Never apply force or strain when reinstalling the piping to align the turbocharger flange bolts (excess strain will cause distortion of the housing and premature turbocharger failure). Consult the manufacturer's detailed operating and service instructions enclosed in the "Engine" section of this manual. The package is equipped with a Silex model JAT-14 'critical' grade exhaust silencer (KS-225), located near the air cooler on a separate structural steel support, to provide the maximum attenuation of exhaust noise. The lower head of the silencer has a drain plug that can be opened to drain any accumulated water if the unit has been (or will be) shut down for an extended period.

#### **4.6 ENGINE ELECTRICAL CONTROLS:**

The engine electrical controls consist of Waukesha Custom Engine Controls, Ignition Module and Detonation Sensing Modules. The detonation sensing module monitors

cylinder firing and can adjust the individual cylinder timing to improve fuel economy and protect the engine against miss-firing, pre-ignition, etc. There is an alarm and shut down switch to prevent any damage to the engine in the event of excessive detonation.

#### **4.7 ENGINE PRE-LUBRICATION**

Both the engine and compressor are pre-lubricated prior to each startup and post lubricated following a shutdown. The engine pre-lube pump consists of a lubricator and a gear pump, driven by an instrument gas motor. The lubricator needs to be filled manually with oil, prior to start up and checked periodically, between start-ups. Engine pre-lube is enabled by a PLC signal to energize solenoid valve, SOV-228, and the engine oil system is pressured up. The engine pre-lube cycle is satisfied once the timer expires, initially set for 1 minute at the time the package was built.

#### **4.8 ENGINE COOLING SYSTEM:**

The engine Jacket Water system is designed to cool the engine block, and has local temperature indicators mounted on the piping. The auxiliary water system provides cooling to the engine turbocharger inter-cooler, engine lube oil and compressor lube oil. The auxiliary water also has local temperature indicators installed to the piping system. The glycol surge tank, T-235A/B, provides adequate expansion for each water system, as well as having low-level shutdown switches mounted to maintain adequate water volumes for cooling.

#### **5.0 AIR COOLER ASSEMBLY**

A Propak model 1-SV-1-156-312-F process cooler assembly is installed on a separate skid to provide intercooling and aftercooling of the process gas downstream of each stage of compression, as well as glycol cooling for the Engine Jacket Water and Auxiliary Water systems. The cooler is a sloped vertical bundle, forced draft fin tube design with a Moore class 5000 model 60ED-VT 13' (156") diameter, 11 blade aluminum fan. The fan is belt driven via a jackshaft assembly from the engine crankshaft front pulley. The jackshaft transmits power to the fan sheaves and is mounted below the skid floor grating on sealed, self aligning pillow block bearings. The



cooler fanshaft bearings and jackshaft bearings have grease **connections manifolded to a common point for ease of service**, idler sheaves enable adjustment of the drive belt tension. The fan blade pitch can be manually adjusted by loosening the u-bolts that fasten the blade shaft to the fan hub, rotating the blade to the desired angle (maximum pitch is 24°), and re-torquing the u-bolts to the specified value. These should be set and maintained within the cooler manufacturer's specified limits to ensure adequate cooling air flow and prevent overstressing the blades. The torque of the fan blade mounting u-bolts should be checked at routine service intervals to ensure they remain properly tensioned. Access to inspect and service the fanshaft is by a mandoor installed on the cooler structure.

The fan blades are installed on the drive hub using a clevis arrangement to enable blade pitch adjustment. Access to inspect and service the drive belt is by a removable guard. Mesh bug screen frames are affixed to the front of the cooler air inlet louver frame to facilitate removal for cleaning. Please refer to the "Cooler" section of this operating manual for manufacturer detailed operating and service specifications.

A Murphy VS2 vibration switch (VSH-225) is mounted on the cooler frame structure. In the event of a broken fan blade, or similar failure, the switch will trip and cause the unit control panel logic to shutdown the unit.

***WARNING:*** *To avoid serious personal injury or death, never operate the compressor without the fan guard firmly secured to the cooler structure, and never allow any persons to enter the cooler fan structure while the compressor is operating. Prior to entering the cooler structure for inspection or service, always ensure the cooler fan motor starter is positively locked out to prevent accidental or inadvertent engagement of the fan.*

## **5.1 PROCESS GAS COOLING SYSTEM**

Individual process gas cooling coils (AC-210, AC-211, AC-212) are installed downstream of each stage of compression, c/w SA-249 seamless steel tubes and post

weld heat treatment of the header box assemblies. The gas cooler headers are pressure vessels with Canadian Registration Numbers and ASME "U" stamps. Each header nameplate provides relevant material and design information and although the vessel requires no specific maintenance, the owner is responsible to undertake a corrosion surveillance program (usually by ultrasonic NDE inspection) and periodic internal inspection and cleaning as required.

**CAUTION:** *Gas cooler headers are heat treated pressure vessels. Never apply a flame heat source, strike an electric arc, or otherwise weld directly to the vessel wall.*

Automatic louvres are provided on each gas coil, c/w individual Kimray model T-12 temperature controllers (TC-210, TC-211 and TC-220) installed at each cooler outlet nozzle. The temperature controllers each sense the process cooler discharge temperature for each stage, which then operates individual discharge air louvers over each process gas cooling section. The normal design gas discharge temperature range is 100°-120°F.

## **5.2 ENGINE JACKET WATER COOLING SYSTEM**

The engine jacket water system absorbs heat from the engine block and cylinder heads and rejects it to the atmosphere through the engine jacket water fintube coil (AC-230). Coolant flows out of the cooler at 71°C, is circulated by the engine jacket water pump, and a high temperature shutdown switch (TE-233) set at 93°C.↑ protects the system from overheating. The primary temperature control is the thermostat installed on the jacket water outlet manifold of the engine, and manually adjustable aluminum louvers are provided on the fintube cooling coils.

A jacket water surge tank allows for thermal expansion of the coolant and system make up, c/w a visual sight glass and 7 psig pressure cap that vents to the atmosphere. A liquid level switch (LS-230) will annunciate a shutdown at the unit control panel in the event of low coolant level. When refilling the system, first ensure the surge tank pressure cap is removed to vent any entrapped air from the system. The

recommended coolant is an inhibited 50% mixture of water and ethylene glycol, and should be sampled and analyzed semi-annually to ensure purity and existence of corrosion inhibiting additives.

### **5.3 AUXILIARY JACKET WATER COOLING SYSTEM**

The auxiliary jacket water system absorbs heat from the engine turbocharger aftercooler, engine lube oil cooler and compressor lube oil cooler, and rejects it to the atmosphere through the auxiliary jacket water fintube coil (AC-220). Coolant flow out of the cooler at 54°C. is circulated by the engine auxiliary water pump. Temperature control is by the manually adjustable aluminum louvers are provided on the fintube cooling coils.

A jacket water surge tank allows for thermal expansion of the coolant and system make up, c/w a visual sight glass and 7 psig pressure cap that vents to the atmosphere. A liquid level switch (LS-220) will annunciate a shutdown at the unit control panel in the event of low coolant level. When refilling the system, first ensure the surge tank pressure cap is removed to vent any entrapped air from the system. The recommended coolant is an inhibited 50% mixture of water and ethylene glycol, and should be sampled and analyzed semi-annually to ensure purity and existence of corrosion inhibiting additives.

### **5.4 AIR RECIRCULATION SYSTEM**

A cooler air recirculation system is installed on the cooler fan structure that enables the warm discharge airflow to be re-directed over the face of the cooler and back to the fan inlet at low ambient temperatures. This system is designed to minimize the risk of hydrate formation or condensed water freezing off the gas coil tubes in cold weather. A Fisher temperature controller automatically opens or closes the recirculation louvers. Nylon mesh bugscreens are affixed to velcro strips on the face of the cooler fanguard to facilitate removal for cleaning. Removable shoulder plugs with gaskets are installed in the outside of the gas header boxes (plug sheets) that can be removed to inspect or clean the tubes, tapered npt plugs are used in the jacket water headers. Please refer to

the “Cooler” section of this operating manual for the manufacturer’s detailed operating and service specifications.

## **6.0 PULSATION BOTTLES**

Gas pulsation bottles (V-121, V-122, V-123, V-124, V-125 and V-126) are installed on the suction and discharge of each compressor cylinder, and are acoustically designed to limit induced vibration by dampening gas pulsation to acceptable levels. These vessels are constructed from carbon steel and contain internal choke tubes. The pulsation bottles have no adjustable controls or instruments. The pulsation bottles should be removed for visual internal inspection through the inlet and outlet process gas nozzles or through the supplied inspection connection. A plugged drain connection is installed on the lowest point of the discharge pulsation bottles. Suction screens (stainless steel mesh over a carbon steel cage) are installed upstream of each inlet pulsation bottle to prevent foreign matter from entering the compressor cylinders. These screens are to be removed for inspection and cleaning at the first (500 hour) service interval. Although these screens are often considered to be temporary “start up” screens, we recommend leaving the screens installed permanently. As part of a regular maintenance program, these screens should be periodically removed and any accumulated debris removed from the piping and screen. The pulsation bottles are pressure vessels with Canadian Registration Numbers and ASME “U” stamps. Each vessel nameplate provides relevant material and design information, and will state the design corrosion allowance (0.1250”). The vessel requires no specific maintenance, however the owner is responsible to undertake a corrosion surveillance program (usually by ultrasonic NDE inspection) and periodic internal inspection and cleaning as required.

***CAUTION:*** *Pulsation bottles are heat treated pressure vessels. Never apply a flame heat source, strike an electric arc, or otherwise weld directly to the vessel wall*

## **7.0 INLET GAS SCRUBBERS**

A vertical inlet gas scrubber (V-100, V-110, and V-120) is provided upstream of each stage of compression, utilizing a non-replaceable stainless steel mesh pad demister

element to remove any free liquid droplets prior to entering the compressor. Each gas scrubber has been fitted with a liquid level sight glass, 1" npt manual drain valve, 1" npt automatic drain, 1-1/2" pneumatic liquid level controller and a high liquid level switch or level transmitter. The high liquid level shutdown function is hard wired to the unit control panel. The scrubber manual drain valves should be opened periodically to blow out any sediment that might collect at the bottom of the vessel, and should be opened to fully depressurize the vessel prior to servicing any of the scrubber controls. The level sight glass should also be periodically blown down to keep the gauge glass clear and prove the connections. The Inlet gas scrubbers are pressure vessels with Canadian Registration Numbers and ASME "U" stamps. Each vessel nameplate provides relevant material and design information, and will state the design corrosion allowance (0.1250"). The vessel requires no specific maintenance, however the owner is responsible to undertake a corrosion surveillance program (usually by ultrasonic NDE inspection) and periodic internal inspection and cleaning as required.

***CAUTION:*** *Inlet gas scrubbers are heat treated pressure vessels. Never apply a flame heat source, strike an electric arc, or otherwise weld directly to the vessel wall.*

## **8.0 PRESSURE PIPING SYSTEM**

The on-skid process pressure piping system is designed and fabricated in accordance with ANSI B31.3 specifications, and applicable Provincial codes and standards. Process piping connections terminate at the skid edge.

A 60mm 300# RF x 89mm 150# RF, spring operated, pressure safety relief valve (PSV-200) is provided on the discharge of stage one. The car sealed lockwire on the PSV must be intact to indicate the setpoint (3412 kPag) has not been adjusted or tampered with. The PSV should be cleaned and reset periodically to ensure reliable operation in the event of equipment failure.

A 48mm 600# RF x 60mm 150# RF, spring operated, pressure safety relief valve (PSV-420) is provided on the discharge of stage two. The car sealed lockwire on the PSV

must be intact to indicate the setpoint (8720 kPag) has not been adjusted or tampered with. The PSV should be cleaned and reset periodically to ensure reliable operation in the event of equipment failure.

A 48mm 900# RF x 73mm 300# RF, spring operated, pressure safety relief valve (PSV-420) is provided on the discharge of stage two. The car sealed lockwire on the PSV must be intact to indicate the setpoint (11377 kPag) has not been adjusted or tampered with. The PSV should be cleaned and reset periodically to ensure reliable operation in the event of equipment failure.

The PSV outlets are manifolded to a 114mm 150# RF high pressure vent header that terminates at the skid edge.

An automatic, 33mm 900# RF, control valve (PCV-100) is provided to bypass from the after-cooler to the initial suction. The bypass control valve is controlled from the unit control panel.

A manual ball valve for start up bypass is also provided on the stg-3 discharge to stg-1 suction line. This start up bypass valve should be fully opened prior to starting the unit.

The process gas piping system also contains one manual depressurization (blowdown) valve installed on the stg-3 discharge system and an automatic blowdown valve (ESDV-101). When opened, the manual blowdown valve will fully depressurize the unit by venting gas to the high pressure vent header.

**WARNING:** *Always verify that the unit has been purged and fully depressurized prior to servicing any pressure containing components.*

## **9.0 LOCAL COMPRESSOR PLC CONTROL PANEL**

The compressor unit has an on-skid Modicon programmable logic control (PLC) panel, built by Propak Systems Ltd., which utilizes an Modicon Micro 110CPU61200 processor

and a color Quick Panel Junior Touch-Screen operator interface. The PLC will perform automatic control for the engine speed, and capacity control bypass valve, as well as unit start-up and shutdown control and provide local operator interface of the unit.

The PLC input cards accept discrete (on/off) non-incendive inputs from local skid shutdown switches and accepts and displays analog inputs from locally mounted pressure transmitters, temperature elements (thermocouples) and vibration transmitters. When the PLC logic circuitry senses a fault input from one of the transmitters, it will initiate a unit alarm and will initiate a shutdown by grounding the ignition and closing the engine fuel gas valve. The Quick Panel display will display all alarm and shutdown status, and annunciate the "first out" channel until cleared by the operator. Each of the discrete input channels can be configured as class A, B, b, or C. There is one mode of shutdown described as "ESD".

The "ESD" mode is the Emergency shutdown mode where the compressor is shutdown and depressurized. The "ESD" mode will occur if the local "ESD" button on the PLC panel is depressed, the local "ESD" button at either entrance to the building, a remote ESD signal is received from the Plant PLC, any other shutdown listed on the shutdown key in Appendix "A" occurs, or if the power fails.

Class "A" inputs are the most critical inputs. They are always monitored and never bypassed, even when the machine is stopped. Class "A" shutdowns initiate a shutdown immediately and will prevent start-up.

Class "B" inputs become healthy during start-up, such as oil flow and vibration. During the Class "B" timer, these inputs are individually monitored as they become healthy. After the Class "B" timer expires, all Class "B" inputs are monitored.

Class "b" inputs are inputs that must become healthy a short period after start-up, such as lube oil pressure. They are monitored only after the Class "b" timer expires.

Class “C” inputs are individually monitored as they become healthy (e.g. rise above the “falling” setpoint) for the first time. No timer is associated with Class “C” inputs.

Refer to the “ELECTRICAL” section of this manual (SECTION 9) for compressor panel details.

### **9.1 AUTOMATIC MODE**

Compressor suction pressure is monitored via pressure transmitter (PT-100) at the inlet to the compressor. This signal is used by the PLC to control the engine speed (I/P-219), and the bypass pressure control valve (PCV-100). The goal is to maintain a constant suction pressure. Under normal operating conditions, the engine is running at full speed (1200 RPM) and PCV-100 fully closed. As the suction pressure drops, the engine speed will respond by decreasing, followed by the bypass valve opening to maintain the suction pressure set point at PT-100. As described in the start sequence, once the unit is warmed up, the bypass control valve (PCV-100) PID and the engine speed controller (SS-229) PID are switched by the operator to automatic control.

### **9.2 MANUAL MODE**

The engine speed (SIC-229) can be manually controlled, if desired, by calling up the PID screen on the Quick Panel display for the engine speed and pressing the “manual” mode soft key. The driver speed may be varied by changing the controller output via the soft-keys on the Quick Panel display. The output (0-100%) is displayed on the screen while the speed is being manually adjusted. When the control is returned to the “automatic” mode, the engine speed will return to its automatic control set point position in a smooth “bump less” transfer.

The bypass control valve (PCV-100) can be manually controlled, if desired, by calling up the PID screen on the Quick Panel display for the bypass valve and pressing the “manual” mode soft-key. The bypass control valve position may be varied by changing the controller output via the soft-keys on the Quick Panel display. The PID output (0-100%) is displayed on the screen while the valve is being manually operated. When



the control is returned to the “automatic” mode, the bypass control valve will return to its automatic PID control set point position in a smooth “bump less” transfer.

### **9.3 QUICK PANEL OPERATOR INTERFACE**

See Appendix “A” for HMI flow sheet.

## **10.0 COMPRESSOR PACKAGE START UP SEQUENCING AND CONTROL LOGIC**

The following procedure outlines only the basic steps required prior to a routine cold start of the unit. It is assumed the operator is familiarized with the equipment and has thoroughly read the manufacturer’s operating and safety instructions for each piece of equipment that forms the compressor package. A qualified compressor technical service representative or field engineer should be present when starting the unit for the first time or after an extended shutdown period.

**Prior to following the instructions below, the “Compressor Start-Up Check List” and “After Start-Up Check List” from Appendix “A” must be read and understood.**

It is recommended that a photocopy of the checklists in Appendix “A” be made in order that a “clean” copy is available at all times.

### **10.1 CONTROL PANEL PRE START CHECKS**

Before attempting to start, the operator must ensure that all shutdown devices on the compressor skid are cleared. The Modicon “pull to start” ESD buttons locally mounted on the engine, must both be pulled out. These buttons should only be pressed in an Emergency situation, because manual intervention to pull them out again, prior to the next start, is required. DO NOT use these buttons to stop the engine, if there is no emergency, as this is not the normal shut down sequence. Confirmation that all shutdowns have been cleared, can be achieved by viewing the Quick Panel “Compressor Start” screen, where if all shutdowns are clear a “No shutdowns present” message will be displayed. The final discharge to stage 1 suction automatic bypass control valve (PCV-100) is in the open position at this point.

## **10.2 START UP - COMPRESSOR**

Press the "START" button and the following startup sequence will occur as displayed in the "Compressor Start" screen (provided no shutdowns are present and the engine is ready, i.e. no Plant ESD):

- A) The Quick Panel screen will change to the compressor start screen and the engine speed and bypass valve will automatically be switched to manual control.
- B) Once a manual purge and pressurization has been completed the "Purge CMPLT" soft key should be pressed to confirm that the purge was completed (once this button has been pushed it will disappear).
- C) The engine and compressor prelube cycle is started. The prelube and postlube timers are configurable through the Quick Panel.
- D) Once the prelube timer has expired and the compressor oil pressure (PT-281) is satisfactory the engine will begin to crank (energize SOV-223).
- E) Upon a satisfactory pre-lube, the start sequence continues on to the engine crank cycle.

## **10.3 ENGINE START SEQUENCE**

ENGINE CRANK CYCLE:

- A) Engine speed control is set by the PLC for manual control to IP-219 at 700 RPM.
- B) Signal sent from PLC to energize SOV-223 which opens the engine start valve, FCV-223. Flow of gas to the starter, STR-227 begins to crank the engine.
- C) At an engine speed of 50 to 100 RPM, a signal is sent from the PLC to: enable the engine ignition system and energize SOV-223. Energizing SOV-223 opens the fuel gas valve, FCV-223 and fuel gas flows to the engine carburetor.
- D) At an engine speed of 100 - 200 RPM, the crank cycle is satisfied and disabled (reset). Upon closing start gas valve, control gas is vented to atmosphere in the cooler plenum.
- E) The engine will ramp to minimum operating speed of 700 RPM, as controlled by the output to IP-219

$$4\text{mA} = 3 \text{ psig} = 700 \text{ RPM}$$

20mA = 15 psig = 1200 RPM

- F) SS-229 counts the flywheel teeth (208) and this frequency is converted to an analog signal for the PLC to read.
- G) At this point the warm up cycle starts, engine speed will be at minimum and the recycle valve will be fully open. This feature can be bypassed, if the unit is already warm. When the warm-up timer is timing, manual engine speed control will be disabled.
- H) Upon completion of the warm-up cycle, the bypass valve and engine speed will be set to auto control as described below, and the engine speed will be ramped up to 1200 RPM automatically. An auto-manual loading option is available in the local PLC control panel for the operator to disable the automatic signal and manually operate the capacity control bypass valve (see 9.2 "Manual Mode", page 26).

***WARNING!*** To prevent explosion, always ensure the compressor cylinders, piping system and vessels are fully purged of any entrapped air prior to starting.

## **11.0 COMPRESSOR STOP AND SHUTDOWN SEQUENCING**

### **11.1 COMPRESSOR STOP**

The compressor unit can be stopped normally, via the "compressor stop" soft key on the PLC Quick Panel display. During a normal stop sequence; the engine speed will ramp down to 700 RPM, the compressor will be unloaded with PCV-100 slowly opening, and the cool down timer will start, for 5 minutes (adjustable). Upon completion of the cool down cycle: a signal from the PLC will be sent to de-energize SOV-223, closing the engine fuel gas valve (FCV-223); the ignition will be disabled two to three seconds later, and the engine will start to slow down; the post lube cycle will start. The delay in ignition disabling allows the fuel to burn off. The post lube cycle operates the engine and compressor pre/post lubrication pumps for an adjustable time period, set initially for 2 minutes. The pumps will stop at the conclusion of the post-lube cycle, and the unit will remain pressurized until the unit is either restarted or the auto-blowdown timer expires, at which point, PCV-100 fails closed and the unit is automatically depressurized as ESDV-101 opens.

## **11.2 COMPRESSOR SHUTDOWN**

The PLC will initiate a shutdown sequence automatically if a discrete or analog shutdown setpoint is tripped. The shutdown sequence will follow the same steps as the compressor stop cycle described above.

## **11.3 COMPRESSOR ESD OR PLANT ESD**

The compressor emergency shutdown (ESD) is activated either locally via the ESD pushbutton on the PLC cabinet, either ESD pushbutton located at the entrance to the building, via a hard-wired ESD signal from the separate remote main plant PLC, or if there is a power failure. The ESD sequence is an emergency situation and will follow the same steps as the compressor stop cycle described above, with the following exceptions:

- The engine and compressor post-lube oil pump cycle will not start.
- The automatic blow down sequence will be initiated immediately.
- There will be no cool down cycle.

Integral timers and explosion proof output relays control the system purge, pre/post lube oil pumps, engine fuel gas valve, automatic blowdown valves, ignition system ground, and starter motor crank valve.

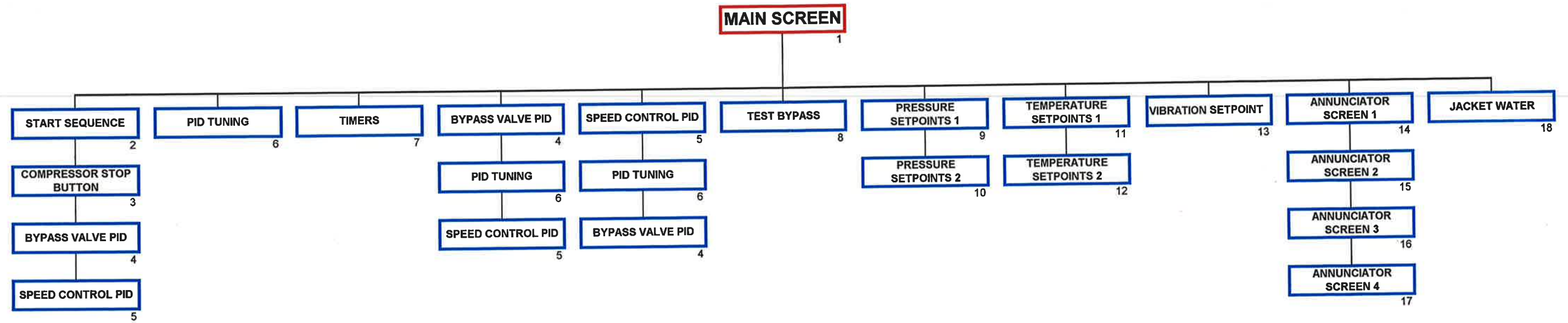
## 12.0 MAJOR COMPONENT SERIAL NUMBER RECORD

<b>Item #</b>	<b>Component Description</b>	<b>Manufacturers Serial number</b>
1	Waukesha L7042 GL gas engine	C-12970/1
2	Dresser-Rand 6-HOS-4 compressor frame	6HF853
3	Dresser-Rand 15.00" $\phi$ stage 1 cylinder	6HC2654
4	Dresser-Rand 9.50" $\phi$ stage 2 cylinder	6HC2655
5	Dresser-Rand 6.00" $\phi$ stage 3 cylinder	6HC2656
5	Stage 1 inter-cooler section (AC-210)	99404-210
6	Stage 2 inter-cooler section (AC-211)	99404-211
7	Stage 3 inter-cooler section (AC-212)	99404-212
8	Jacket Water section (AC-220)	99404-220
9	Auxiliary Water section (AC-230)	99404-230
10	Control Panel	99404-107
11	V-100 1 <sup>st</sup> Stage Suction Scrubber	99404-100
12	V-110 2 <sup>nd</sup> Stage Suction Scrubber	99404-110
13	V-120 3 <sup>rd</sup> Stage Suction Scrubber	99404-120
14	V-121 1 <sup>st</sup> Stage Suction Pulsation Bottle	99404-121
15	V-122 1 <sup>st</sup> Stage Discharge Pulsation Bottle	99404-122
16	V-123 2 <sup>nd</sup> Stage Suction Pulsation Bottle	99404-123
17	V-124 2 <sup>nd</sup> Stage Discharge Pulsation Bottle	99404-124
18	V-125 2 <sup>nd</sup> Stage Suction Pulsation Bottle	99404-125
19	V-126 2 <sup>nd</sup> Stage Discharge Pulsation Bottle	99404-126

**13.0 APPENDIX "A"**

# HMI FLOW SHEET

Apache Canada Limited - Job#99404



## COMPRESSOR START-UP CHECK LIST

Customer: \_\_\_\_\_ Start-up Date: \_\_\_\_\_

Propak Unit No. \_\_\_\_\_ LSD: \_\_\_\_\_

Serviceman: \_\_\_\_\_ Location: \_\_\_\_\_

Customer Contact: \_\_\_\_\_ Contact Phone: \_\_\_\_\_

Customer Unit No.: \_\_\_\_\_ Contact Fax: \_\_\_\_\_

Compressor Model: \_\_\_\_\_ Frame Serial No.: \_\_\_\_\_

Cylinder Serial No: 1: \_\_\_\_\_ 2: \_\_\_\_\_ 3: \_\_\_\_\_ 4: \_\_\_\_\_ 5: \_\_\_\_\_ 6: \_\_\_\_\_

Cylinder Size No. 1: \_\_\_\_\_ 2: \_\_\_\_\_ 3: \_\_\_\_\_ 4: \_\_\_\_\_ 5: \_\_\_\_\_ 6: \_\_\_\_\_

Compressor Crankcase Lube Oil : \_\_\_\_\_ Cylinder Lube Oil: \_\_\_\_\_

Driver Make: \_\_\_\_\_ Model: \_\_\_\_\_ Spec: \_\_\_\_\_

Rated RPM: \_\_\_\_\_ Engine Lube Oil: \_\_\_\_\_ Coolant Type: \_\_\_\_\_

### PRIOR TO STARTING

	<b>YES</b>	<b>NO</b>
1. Do you have parts books, instruction manual, special tools & spares?	_____	_____
2. Check compressor design limitations such as rod loads, speed, discharge pressures and temperatures. Determine what operating conditions are.	_____	_____
3. Determine the design operating conditions: Suction Pressure: _____ PSIG Suction Temp.: _____ Discharge Pressure: _____ PSIG Discharge Temp.: _____ Maximum RPM: _____ Minimum RPM: _____	_____	_____
4. Ensure unit is properly supported. Piles properly shimmed & welded on at least two sides	_____	_____
5. Have the driver feet been shimmed so unit is not twisted? Record pulldown readings.	_____	_____
Cooler End _____		
6. Have the compressor feet & crosshead guide supports been shimmed so the machine is not twisted or bent? Record pulldown readings	_____	_____
Coupling End _____		
7. Check crosshead clearances on all corners.	_____	_____
8. Record minimum crosshead clearances:		
_____		
1.                      2.                      3.                      4.                      5.                      6.		







## AFTER STARTUP CHECK LIST

	<b>YES</b>	<b>NO</b>
1. Start unit & take note of any unusual noises, pressures, temperatures or vibration.	_____	_____
<hr/>		
2. Check engine governor operation. Set Minimum speed: _____ RPM Set High Idle: _____ RPM Check governor compensation, no load Check & set Engine Overspeed: _____ RPM		
3. Bring unit up to speed and slowly load compressor. Watch pressures, temperatures and liquid levels in scrubbers etc.	_____	_____
4. Did the oil pressure come up immediately? _____ PSIG	_____	_____
5. Are the filter differential pressure gauges working?	_____	_____
6. Adjust lubricator rate to break in cycle. ( _____ Drops per Minute) Is the distribution block indicator pin moving?	_____	_____
7. Set low oil pressure shut down to 25 PSIG, falling.	_____	_____
8. Set engine ignition timing to spec. ( _____ Deg. BTDC)	_____	_____
9. Set engine fuel gas pressure to 5.5" - 6.0" H2O	_____	_____
10. Set carburetor to engine manufactures spec. Be sure engine is firing on all cyl.	_____	_____
11. Adjust cooler louvers to control at proper temperatures.	_____	_____
12. Let unit stabilize & adjust high discharge temp. shutdowns to approx. 2 deg. C. above operating temperature. Confirm safe operating temperature.	_____	_____
13. Check all engine temperature shutdowns to ensure correct shutdown points	_____	_____
14. Go through the operation on all controls to ensure proper operation: ____ Dump Valves      ____ Engine speed control      ____ Suction control ____ Auto/Manual stations      ____ Discharge controller      ____ By-Pass Controller ____ Blowcase controls      ____ ESD & Blowdown	_____	_____
15. Are the scrubber dump & high level shutdowns working?	_____	_____
16. How often do they dump ( _____ )minutes	_____	_____
17. <b>Have all panel functions been tested to assure shutdown of unit upon malfunction?</b>	_____	_____
18. Are the rod packing vents blowing? Feel tubing for heat.	_____	_____
19. Are the wiper packing draining excessively?	_____	_____
20. Check for oil leaks. <b>Shut down</b> , repair leaks Comments:	_____	_____
_____		
_____		
_____		
_____		

21. Check and record coupling alignment while unit is <b>hot</b> and record.	_____	_____
--	-------	-------



**LOCAL PLC - ALARMS / SHUTDOWNS**  
**PROPAK JOB # 99404**

Description	Device Location	Device Tag Number	Device Make/Model	Device Type	Alarm Setpoint	Shutdown Setpoint	Class
<b>PRESSURE SET POINTS</b>							
Stage 1 LOW suction pressure	STG 1 S	PT-100	Wika 892.23.510	analogue	345 kPag, F	172 kPag F	C
Stage 1 HIGH suction pressure	STG 1 S	PT-100	Wika 892.23.510	analogue	1380 kPag, R	1520 kPag, R	A
Stage 1 HIGH discharge pressure	STG 1 D	PT-210	Wika 892.23.510	analogue	2900 kPag, R	3070 kPag, R	A
Stage 2 HIGH discharge pressure	STG 2 D	PT-211	Wika 892.23.510	analogue	6970 kPag, R	7800 kPag, R	A
Stage 3 HIGH discharge pressure	STG 3 D	PT-212	Wika 892.23.510	analogue	9200 kPag, R	10200 kPag, R	A
Stage 1 HIGH differential pressure	STG 1	LOGIC	programmed	LOGIC	2100 kPag, R	2300 kPag, R	A
Stage 2 HIGH differential pressure	STG 2	LOGIC	programmed	LOGIC	5450 kPag, R	5600 kPag, R	A
Stage 3 HIGH differential pressure	STG 3	LOGIC	programmed	LOGIC	7580 kPag, R	8270 kPag, R	A
Engine Oil LOW pressure	engine mount	PT-257	Wika 892.13.500	analogue	172 kPag, F	138 kPag, F	B
LOW Compressor Oil Pressure	Local	PT-281	Wika 892.13.500	analogue	241 kPag, F	276 kPag, F	B
<b>TEMPERATURE SETPOINTS</b>							
Stage 1 HIGH suction temperature	STG 1 SUCT	TE-100	ATS Alltemp AI-8113	analogue	50°C, R	60°C, R	A
Stage 1 HIGH discharge temperature	V-122	TE-122A/B	ATS Alltemp AI-8113	analogue	149°C, R	163°C, R	A
Stage 2 HIGH suction temperature	STG 2 SUCT	TE-110	ATS Alltemp AI-8113	analogue	70°C, R	80°C, R	A
Stage 2 HIGH discharge temperature	V-124	TE-124	ATS Alltemp AI-8113	analogue	149°C, R	163°C, R	A
Stage 3 HIGH suction temperature	STG 3 SUCT	TE-120	ATS Alltemp AI-8113	analogue	70°C, R	80°C, R	A
Stage 3 HIGH discharge temperature	V-126	TE-126	ATS Alltemp AI-8113	analogue	149°C, R	163°C, R	A
Engine JW HIGH temperature	engine mounted	TE-233	-	analogue	88°C, R	93°C, R	A
Engine Oil HIGH temperature	engine mounted	TE-254	-	analogue	90°C, R	96°C, R	A
Engine Manifold (RHS) HIGH temperature	engine mounted	TE-271A	-	analogue	63°C, R	66°C, R	A
Engine Manifold (LHS) HIGH temperature	engine mounted	TE-271B	-	analogue	63°C, R	66°C, R	A
Compressor HIGH oil temperature	Local	TE-281	ATS Alltemp AI-8113	analogue	77°C, R	82°C, R	A
<b>VIBRATION SET POINTS</b>							
Compressor Vibration	Comp	VT-288	METRIX 5484C-123	analogue	1.2 ips	1.5 ips	B
Drive Motor Vibration	Motor	VT-205	METRIX 5484C-123	analogue	1.2 ips	1.5 ips	B
Cooler Vibration	Cooler Fan	VSH-225	MURPHY VS2EX	descrete	-	field set	B

**LOCAL PLC - ALARMS / SHUTDOWNS**  
**PROPAK JOB # 99404**

Description	Device Location	Device Tag Number	Device Make/Model	Device Type	Alarm Setpoint	Shutdown Setpoint	Class
OTHER SHUT DOWN SWITCHES							
Emergency Shutdown	PLC		Red Button	descrete		PUSH BUTTON	A
REMOTE SHUTDOWN	INPUT TO PLC	REMOTE CONTROL	TERMINAL	descrete		PLANT CONTROL	A
Stage 1 Level Shutdown HIGH	V-100	LIT-100	Rosemount 3051CD	descrete		on high level	A
Slage 2 Level Shutdown HIGH	V-110	LSH-110	Murphy 1100-SS	descrete		on high level	A
Stage 3 Level Shutdown HIGH	V-120	LSH-120	Murphy 1100-SS	descrete		on high level	A
Seal Pot Level Shutdown HIGH	V-130	LSH-130	Murphy 1100-SS	descrete		on high level	A
Engine JW Level Shutdown LOW	T-235A	LSL-235A	Murphy 1111	descrete		on low level	A
Engine AW Level Shutdown LOW	T-235B	LSL-235B	Murphy 1111	descrete		on low level	A
Compressor Crankcase LOW oil Level	Compressor	LSL-270	Kenco LCE 9	descrete		on low level	A
Compressor Cylinder No Flow Lube Oil	Lubricator	FSL-289	Manzel Lube Line Alert, P/N: M928	descrete		upon no flow	B
Engine Crankcase LOW oil Level	Engine	LSL-262	Kenco LCE 27	descrete		on low level	A
Engine Speed, LOW	Engine	SS-229	Dynalco P/N: M928		730 RPM, F	700 RPM, F	B
Engine Speed, HIGH	Engine	SS-229	Dynalco P/N: M928		1275 RPM, R	1320 RPM, R	B

NOTE: Setpoints are based on Design Point performance (see "Performance" section of the Operation & Maintenance manuals). These setpoints are for compressor protection against such conditions as valve failure or exceeding rod load limits. Should a shutdown occur, please consult the compressor operating manual and/or contact a Propak Compression service representative @ 1-800-408-4434 or (403) 912-7000.





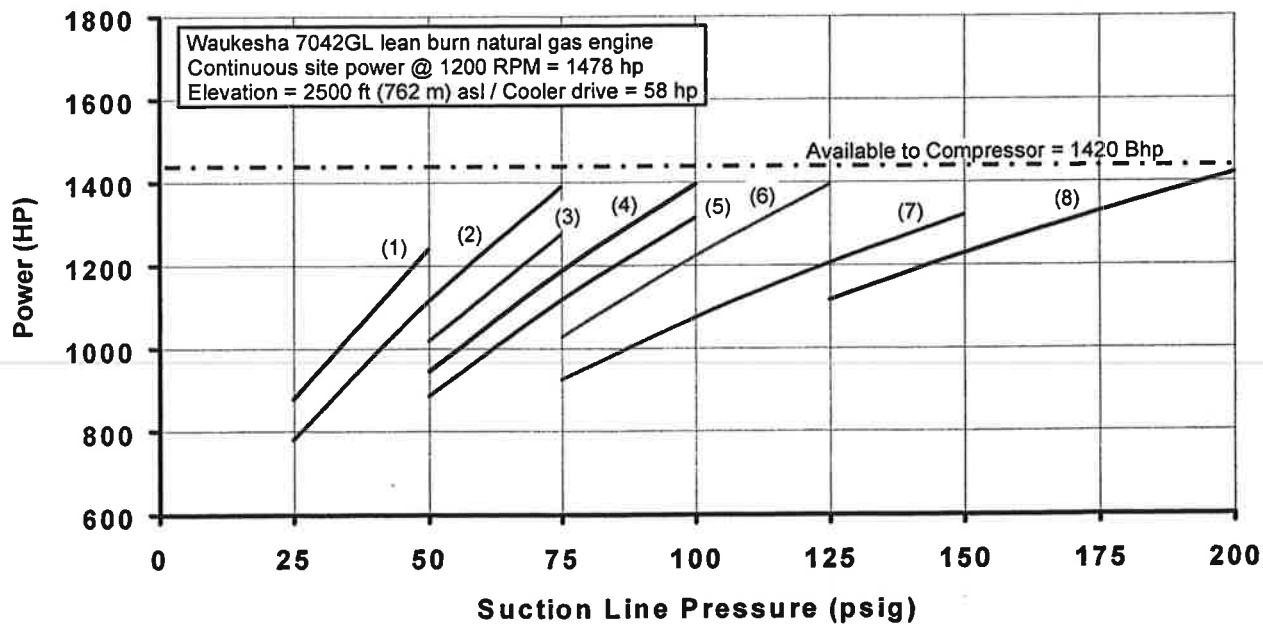
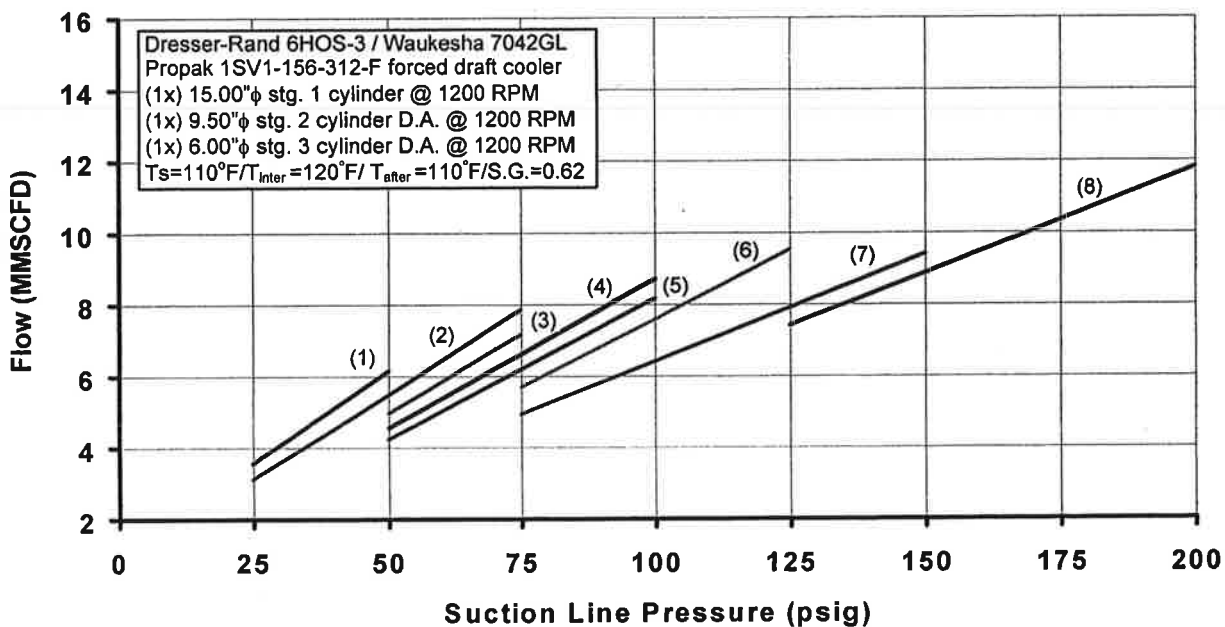
Pd (line) = 1200 psig  
Speed = 1200 rpm

c/o Optima Engineers & Constructors Inc.

Hamburg, Alberta

2-6 Compression Project, Optima #20690

**1478 hp Gas Compressor Performance Curves**



Calc. By: JWS  
Propak S.O. #99404 / 99420 (two compressor packages)





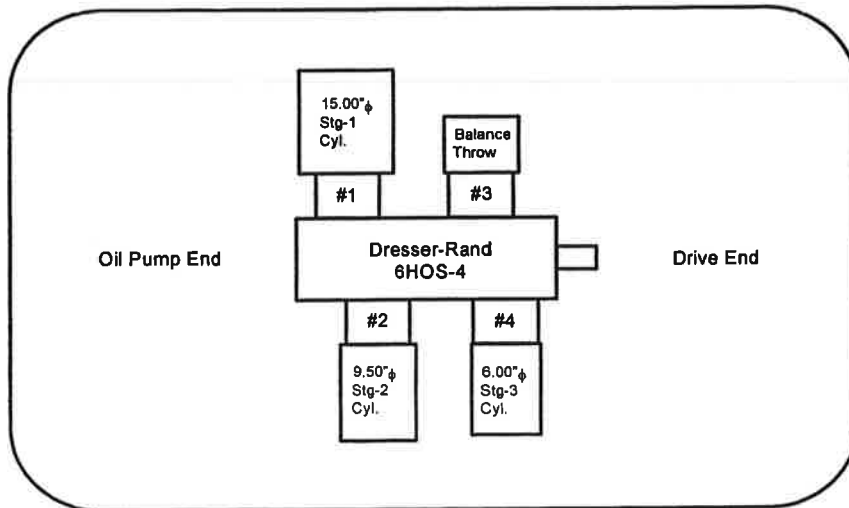
**Project**  
#99404 / 99420

**COMPRESSOR UNLOADING TABLE**

**Pd=1200 psig**

**Customer:** Apache Canada Ltd.  
**Location:** Hamburg, Alberta  
**L.S.D.:** 2-6-97-11 W6M

**Compressor:** Dresser-Rand 6HOS-4  
**Driver:** Waukesha 7042GL engine, 1478 Bhp @ 1200 RPM  
**Cooler:** Propak model 1SV1-156-312-F, engine jackshaft drive



Curve #	Stage 1				Stage 2		Stage 3	
	Throw #1 15.00"φ	VVCP % open	Throw #3 Balance	VVCP % open	Throw #2 9.50"φ	VVCP % open	Throw #4 6.00"φ	VVCP % open
1	D.A.	0%	-	-	D.A.	0%	D.A.	-
2	D.A.	25%	-	-	D.A.	0%	D.A.	-
3	D.A.	50%	-	-	D.A.	0%	D.A.	-
4	D.A.	75%	-	-	D.A.	0%	D.A.	-
5	D.A.	100%	-	-	D.A.	0%	D.A.	-
6	D.A.	100%	-	-	D.A.	25%	D.A.	-
7	S.A.C.E.	-	-	-	D.A.	0%	D.A.	-
8	S.A.C.E.	-	-	-	D.A.	100%	D.A.	-

D.A. = Cylinder is Double Acting    S.A.C.E. = Cylinder is Single Acting, Crank End    N.A. = Cylinder is non-acting

**CURVE NOTES:**

- (1) Curve information is calculated at 1200 RPM.
- (2) Horsepower and capacity vary linearly with speed within the operating range of 800-1200 RPM.
- (3) DO NOT OPERATE MACHINE OUTSIDE OF CURVE LIMITS. IF ADDITIONAL PERFORMANCE IS REQUIRED, CONTACT PROPAK COMPRESSION @ 1-800-408-4434 or (403) 912-7000.
- (4) Curve points are limited by available power, compressor rod load, cylinder volumetric efficiency and discharge temperature.

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION DATE: Oct 2, 2000  
 LOCATION: Hamburg (2-6), Alberta FILE: 9404-420.DAT " 8"  
 JOB/REF : Apache Canada / Optima Engineers CALC BY: J.Saxinger  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp.(F): 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 200 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 8
Avg. Temp. Expon. (K)		1.264	1.271	1.285	
Avg. Vol. Expon. (N)		1.262	1.273	1.308	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.975	0.956	0.922	
Z Discharge		0.974	0.957	0.929	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	196.00	382.15	693.64	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	389.20	704.41	1212.00	
Ratio of Compression		1.923	1.815	1.733	
Adiabatic Disch. Temp.	F	193.38	198.62	195.16	
Est. Actual Disch. Temp	F	224.77	212.70	204.35	
Stg. Piston Displ.	CFM	715.9	570.2	215.2	
Stg. Inlet Capacity	ACFM	619.8	326.7	175.9	
CAPACITY ACTUAL WET	MMSCFD	11.87	11.84	11.82	
CAPACITY ACTUAL DRY	MMSCFD	11.80	11.79	11.80	
TOTAL COMPRESSOR POWER	HP	1418.93			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./INSACE		0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	533.9	0.0	441.9	386.4
HE Disch. Vol. Eff.	%	0.00	0.00	19.39	54.47
CE Disch. Vol. Eff.	%	51.58	0.00	53.59	52.72
HE Inlet Vol. Eff.	%	0.00	0.00	30.97	82.95
CE Inlet Vol. Eff.	%	86.59	0.00	85.57	80.29
Avg. Inlet Vol. Eff.	%	43.29	0.00	58.27	81.62
HE Clearance Req'd.	%	14.50	0.00	109.30	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	0.00	0.00	100.00	0.00
HE Clearance Added	IN3	0.0	0.0	392.1	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	32230	0	19385	8707
Flange Gas Load - C	LBF	-962	0	-24718	-18061
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	51733	42942	27977	28943
Combined Rod Load - C	LBF	-36841	-29381	-36283	-31732
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	140.0	160.0	170.0	155.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp. (F): 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia (IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 7"

CALC BY: J.Saxinger

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 175 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 8
Avg. Temp. Expon. (K)		1.263	1.269	1.282	
Avg. Vol. Expon. (N)		1.260	1.270	1.302	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.978	0.960	0.928	
Z Discharge		0.977	0.961	0.935	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	171.50	343.40	634.44	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	349.76	644.31	1212.00	
Ratio of Compression		1.964	1.843	1.891	
Adiabatic Disch. Temp.	F	195.87	200.30	207.15	
Est. Actual Disch. Temp	F	227.72	214.77	216.75	
Stg. Piston Displ.	CFM	715.9	570.2	215.2	
Stg. Inlet Capacity	ACFM	616.3	318.4	169.1	
CAPACITY ACTUAL WET	MMSCFD	10.39	10.37	10.34	
CAPACITY ACTUAL DRY	MMSCFD	10.32	10.32	10.32	
TOTAL COMPRESSOR POWER	HP	1327.79			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia.	Act./INSACE/0.00	NA/0.00	DA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	482.1	0.0	397.8	391.1
HE Disch. Vol. Eff.	%	0.00	0.00	17.64	49.06
CE Disch. Vol. Eff.	%	50.39	0.00	52.61	47.09
HE Inlet Vol. Eff.	%	0.00	0.00	28.56	80.05
CE Inlet Vol. Eff.	%	86.09	0.00	85.15	76.83
Avg. Inlet Vol. Eff.	%	43.05	0.00	56.85	78.44
HE Clearance Req'd.	%	14.50	0.00	109.30	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	0.00	0.00	100.00	0.00
HE Clearance Added	IN3	0.0	0.0	392.1	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	29784	0	18166	10381
Flange Gas Load - C	LBF	-842	0	-23014	-19444
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	51853	42942	29680	27337
Combined Rod Load - C	LBF	-36302	-29381	-35818	-30476
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	145.0	160.0	175.0	160.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp. (F): 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 6"  
 CALC BY: J.Saxinger

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 150 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 8
Avg. Temp. Expon. (K)		1.261	1.267	1.278	
Avg. Vol. Expon. (N)		1.259	1.267	1.297	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.981	0.965	0.935	
Z Discharge		0.980	0.965	0.943	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	147.00	304.35	574.64	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	310.01	583.60	1212.00	
Ratio of Compression		2.016	1.879	2.084	
Adiabatic Disch. Temp.	F	198.98	202.41	220.42	
Est. Actual Disch. Temp	F	231.36	217.34	230.86	
Stg. Piston Displ.	CFM	715.9	570.2	215.2	
Stg. Inlet Capacity	ACFM	611.9	308.3	161.0	
CAPACITY ACTUAL WET	MMSCFD	8.92	8.90	8.88	
CAPACITY ACTUAL DRY	MMSCFD	8.85	8.85	8.85	
TOTAL COMPRESSOR POWER	HP	1227.68			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./INSACE		0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	429.6	0.0	352.9	388.4
HE Disch. Vol. Eff.	%	0.00	0.00	15.57	43.48
CE Disch. Vol. Eff.	%	48.97	0.00	51.45	41.27
HE Inlet Vol. Eff.	%	0.00	0.00	25.62	76.58
CE Inlet Vol. Eff.	%	85.48	0.00	84.62	72.70
Avg. Inlet Vol. Eff.	%	42.74	0.00	55.12	74.64
HE Clearance Req'd.	%	14.50	0.00	109.30	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	0.00	0.00	100.00	0.00
HE Clearance Added	IN3	0.0	0.0	392.1	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	27285	0	16929	12071
Flange Gas Load - C	LBF	-722	0	-21288	-20842
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	51973	42942	31407	25720
Combined Rod Load - C	LBF	-35761	-29381	-35351	-28909
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	155.0	160.0	170.0	155.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp.(F): 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 5"  
 CALC BY: J.Saxinger

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 125 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 8
Avg. Temp. Expon. (K)		1.259	1.265	1.274	
Avg. Vol. Expon. (N)		1.257	1.264	1.292	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.984	0.969	0.941	
Z Discharge		0.983	0.969	0.950	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	122.50	264.93	514.01	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	269.89	522.04	1212.00	
Ratio of Compression		2.084	1.924	2.323	
Adiabatic Disch. Temp.	F	203.01	205.11	235.36	
Est. Actual Disch. Temp	F	236.08	220.60	246.95	
Stg. Piston Displ.	CFM	715.9	570.2	215.2	
Stg. Inlet Capacity	ACFM	606.2	295.6	151.1	
CAPACITY ACTUAL WET	MMSCFD	7.47	7.44	7.42	
CAPACITY ACTUAL DRY	MMSCFD	7.40	7.40	7.40	
TOTAL COMPRESSOR POWER	HP	1115.63			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia.	Act./INSACE/0.00	NA/0.00	DA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	376.1	0.0	307.0	375.8
HE Disch. Vol. Eff.	%	0.00	0.00	13.08	37.67
CE Disch. Vol. Eff.	%	47.22	0.00	50.05	35.23
HE Inlet Vol. Eff.	%	0.00	0.00	21.95	72.36
CE Inlet Vol. Eff.	%	84.68	0.00	83.97	67.66
Avg. Inlet Vol. Eff.	%	42.34	0.00	52.96	70.01
HE Clearance Req'd.	%	14.50	0.00	109.30	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	0.00	0.00	100.00	0.00
HE Clearance Added	IN3	0.0	0.0	392.1	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	24720	0	15662	13786
Flange Gas Load - C	LBF	-601	0	-19525	-22258
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	52093	42942	33170	24083
Combined Rod Load - C	LBF	-35218	-29381	-34656	-26888
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	155.0	160.0	170.0	160.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp.(F) : 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 6"  
 CALC BY: J.Saxinger

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 150 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 7
Avg. Temp. Expon. (K)		1.264	1.260	1.279	
Avg. Vol. Expon. (N)		1.261	1.262	1.299	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.981	0.973	0.932	
Z Discharge		0.980	0.974	0.940	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	147.00	228.73	596.98	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	233.04	606.28	1212.00	
Ratio of Compression		1.536	2.559	2.008	
Adiabatic Disch. Temp.	F	163.51	243.93	215.31	
Est. Actual Disch. Temp	F	196.08	261.61	225.40	
Stg. Piston Displ.	CFM	715.9	570.2	215.2	
Stg. Inlet Capacity	ACFM	649.7	434.1	164.2	
CAPACITY ACTUAL WET	MMSCFD	9.47	9.46	9.42	
CAPACITY ACTUAL DRY	MMSCFD	9.40	9.40	9.39	
TOTAL COMPRESSOR POWER	HP	1320.22			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./INSACE/0.00		NA/0.00	DA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	314.7	0.0	558.3	390.5
HE Disch. Vol. Eff.	%	0.00	0.00	36.33	45.58
CE Disch. Vol. Eff.	%	64.56	0.00	35.96	43.46
HE Inlet Vol. Eff.	%	0.00	0.00	76.49	77.95
CE Inlet Vol. Eff.	%	90.76	0.00	75.72	74.33
Avg. Inlet Vol. Eff.	%	45.38	0.00	76.11	76.14
HE Clearance Req'd.	%	14.50	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	0.00	0.00	0.00	0.00
HE Clearance Added	IN3	0.0	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	14061	0	23786	11440
Flange Gas Load - C	LBF	-722	0	-27884	-20320
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	51973	42942	33622	26324
Combined Rod Load - C	LBF	-36028	-29381	-33529	-29674
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	175.0	160.0	175.0	155.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION DATE: Oct 2, 2000  
 LOCATION: Hamburg (2-6), Alberta FILE: 9404-420.DAT " 5"  
 JOB/REF : Apache Canada / Optima Engineers CALC BY: J.Saxinger  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA) : 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp. (F) : 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN) : 6.0 Rod Dia (IN) : 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 125 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 7
Avg. Temp. Expon. (K)		1.263	1.257	1.276	
Avg. Vol. Expon. (N)		1.260	1.259	1.294	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.984	0.977	0.939	
Z Discharge		0.983	0.978	0.947	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	122.50	195.07	535.03	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	198.78	543.38	1212.00	
Ratio of Compression		1.561	2.671	2.234	
Adiabatic Disch. Temp.	F	165.35	249.14	229.99	
Est. Actual Disch. Temp	F	198.35	267.68	241.14	
Stg. Piston Displ.	CFM	715.9	570.2	215.2	
Stg. Inlet Capacity	ACFM	647.2	425.7	154.8	
CAPACITY ACTUAL WET	MMSCFD	7.97	7.96	7.92	
CAPACITY ACTUAL DRY	MMSCFD	7.90	7.90	7.90	
TOTAL COMPRESSOR POWER	HP	1204.76			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./INSACE/0.00		NA/0.00	DA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	273.5	0.0	493.2	381.4
HE Disch. Vol. Eff.	%	0.00	0.00	34.40	39.70
CE Disch. Vol. Eff.	%	63.48	0.00	34.02	37.34
HE Inlet Vol. Eff.	%	0.00	0.00	75.06	73.92
CE Inlet Vol. Eff.	%	90.41	0.00	74.23	69.52
Avg. Inlet Vol. Eff.	%	45.21	0.00	74.65	71.72
HE Clearance Req'd.	%	14.50	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	0.00	0.00	0.00	0.00
HE Clearance Added	IN3	0.0	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	12504	0	22022	13191
Flange Gas Load - C	LBF	-601	0	-25647	-21767
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	52093	42942	33515	24650
Combined Rod Load - C	LBF	-35684	-29381	-32213	-27664
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	180.0	160.0	170.0	160.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA) : 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp. (F) : 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN) : 6.0 Rod Dia (IN) : 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP) : 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 4"  
 CALC BY: J.Saxinger

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 100 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 7
Avg. Temp. Expon. (K)		1.261	1.255	1.272	
Avg. Vol. Expon. (N)		1.259	1.256	1.288	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.987	0.981	0.946	
Z Discharge		0.986	0.982	0.955	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	98.00	161.21	471.99	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	164.33	479.38	1212.00	
Ratio of Compression		1.595	2.822	2.525	
Adiabatic Disch. Temp.	F	167.89	256.02	246.78	
Est. Actual Disch. Temp	F	201.47	275.63	259.45	
Stg. Piston Displ.	CFM	715.9	570.2	215.2	
Stg. Inlet Capacity	ACFM	643.8	414.6	143.0	
CAPACITY ACTUAL WET	MMSCFD	6.48	6.47	6.43	
CAPACITY ACTUAL DRY	MMSCFD	6.41	6.41	6.41	
TOTAL COMPRESSOR POWER	HP	1074.50			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./INSACE/0.00		NA/0.00	DA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	231.8	0.0	425.5	360.5
HE Disch. Vol. Eff.	%	0.00	0.00	32.03	33.56
CE Disch. Vol. Eff.	%	62.05	0.00	31.63	30.95
HE Inlet Vol. Eff.	%	0.00	0.00	73.14	68.87
CE Inlet Vol. Eff.	%	89.93	0.00	72.24	63.51
Avg. Inlet Vol. Eff.	%	44.96	0.00	72.69	66.19
HE Clearance Req'd.	%	14.50	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	0.00	0.00	0.00	0.00
HE Clearance Added	IN3	0.0	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	10914	0	20199	14974
Flange Gas Load - C	LBF	-481	0	-23343	-23240
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	52214	42942	33742	22949
Combined Rod Load - C	LBF	-35339	-29381	-30619	-25185
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	175.0	160.0	170.0	160.0



DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 Ref. Pressure ( PSIA) : 14.70  
 COMPRESSOR: Frame : 6 HOS 4  
 DRIVER: Type : Gas Engine  
 DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 3"  
 CALC BY: J.Saxinger  
 Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Temp. (F): 60.  
 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 Max RPM : 1200.0 Cooler (HP): 58.0  
 Avail (HP) : 1478.0 Model: 7042GL

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 75 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 7
Avg. Temp. Expon. (K)		1.260	1.252	1.267	
Avg. Vol. Expon. (N)		1.258	1.253	1.283	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.990	0.985	0.953	
Z Discharge		0.989	0.985	0.963	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	73.50	127.16	407.81	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	129.67	414.22	1212.00	
Ratio of Compression		1.646	3.042	2.909	
Adiabatic Disch. Temp.	F	171.66	265.34	266.34	
Est. Actual Disch. Temp	F	206.12	286.33	281.35	
Stg. Piston Displ.	CFM	715.9	570.2	215.2	
Stg. Inlet Capacity	ACFM	638.6	398.5	127.7	
CAPACITY ACTUAL WET	MMSCFD	5.00	4.99	4.95	
CAPACITY ACTUAL DRY	MMSCFD	4.93	4.93	4.93	
TOTAL COMPRESSOR POWER	HP	925.47			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia.	Act./INSACE	0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	189.4	0.0	354.2	325.1
HE Disch. Vol. Eff.	%	0.00	0.00	28.95	27.12
CE Disch. Vol. Eff.	%	60.01	0.00	28.54	24.24
HE Inlet Vol. Eff.	%	0.00	0.00	70.37	62.35
CE Inlet Vol. Eff.	%	89.20	0.00	69.37	55.73
Avg. Inlet Vol. Eff.	%	44.60	0.00	69.87	59.04
HE Clearance Req'd.	%	14.50	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	0.00	0.00	0.00	0.00
HE Clearance Added	IN3	0.0	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	9289	0	18314	16789
Flange Gas Load - C	LBF	-361	0	-20972	-24740
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	52334	42942	34304	21267
Combined Rod Load - C	LBF	-34994	-29381	-29164	-22666
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	175.0	160.0	155.0	145.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA) : 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp.(F) : 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN) : 6.0 Rod Dia(IN) : 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP) : 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 125 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 6
Avg. Temp. Expon. (K)		1.260	1.263	1.280	
Avg. Vol. Expon. (N)		1.258	1.264	1.299	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.984	0.970	0.932	
Z Discharge		0.983	0.971	0.939	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	122.50	258.60	601.95	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	263.44	611.32	1212.00	
Ratio of Compression		2.037	2.297	1.991	
Adiabatic Disch. Temp.	F	199.96	229.41	214.19	
Est. Actual Disch. Temp	F	221.46	246.28	224.22	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	779.9	389.6	164.9	
CAPACITY ACTUAL WET	MMSCFD	9.61	9.58	9.54	
CAPACITY ACTUAL DRY	MMSCFD	9.52	9.52	9.52	
TOTAL COMPRESSOR POWER	HP	1393.18			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./IN	DA/0.00	NA/0.00	DA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	446.2	0.0	499.5	390.8
HE Disch. Vol. Eff.	%	13.12	0.00	30.20	46.04
CE Disch. Vol. Eff.	%	48.38	0.00	40.98	43.95
HE Inlet Vol. Eff.	%	23.11	0.00	58.30	78.24
CE Inlet Vol. Eff.	%	85.18	0.00	79.10	74.67
Avg. Inlet Vol. Eff.	%	54.14	0.00	68.70	76.46
HE Clearance Req'd.	%	95.80	0.00	40.15	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	100.00	0.00	25.00	0.00
HE Clearance Added	IN3	862.0	0.0	98.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	23613	0	22001	11299
Flange Gas Load - C	LBF	-25508	0	-26271	-20204
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	27187	42942	27223	26458
Combined Rod Load - C	LBF	-35057	-29381	-34217	-29861
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	175.0	160.0	170.0	155.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp.(F): 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 4"  
 CALC BY: J.Saxinger

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 100 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 6
Avg. Temp. Expon. (K)		1.258	1.260	1.275	
Avg. Vol. Expon. (N)		1.256	1.261	1.292	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.987	0.975	0.941	
Z Discharge		0.986	0.976	0.949	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	98.00	212.59	521.93	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	216.61	530.08	1212.00	
Ratio of Compression		2.065	2.405	2.289	
Adiabatic Disch. Temp.	F	201.35	234.91	233.31	
Est. Actual Disch. Temp	F	223.63	252.71	244.73	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	762.1	376.2	152.5	
CAPACITY ACTUAL WET	MMSCFD	7.67	7.64	7.61	
CAPACITY ACTUAL DRY	MMSCFD	7.58	7.58	7.58	
TOTAL COMPRESSOR POWER	HP	1222.27			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./IN	DA/0.00	DA/0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	364.9	0.0	422.6	378.0
HE Disch. Vol. Eff.	%	11.84	0.00	27.48	38.44
CE Disch. Vol. Eff.	%	47.61	0.00	38.69	36.03
HE Inlet Vol. Eff.	%	21.08	0.00	55.13	72.96
CE Inlet Vol. Eff.	%	84.78	0.00	77.62	68.38
Avg. Inlet Vol. Eff.	%	52.93	0.00	66.37	70.67
HE Clearance Req'd.	%	95.80	0.00	40.15	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	100.00	0.00	25.00	0.00
HE Clearance Added	IN3	862.0	0.0	98.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FFM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	19897	0	19903	13562
Flange Gas Load - C	LBF	-21441	0	-23548	-22073
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	31253	42942	29220	24297
Combined Rod Load - C	LBF	-34446	-29381	-32897	-27149
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	180.0	160.0	165.0	160.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp.(F): 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 3"

CALC BY: J.Saxinger

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 75 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 6
Avg. Temp. Expon. (K)		1.257	1.256	1.269	
Avg. Vol. Expon. (N)		1.255	1.257	1.286	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.990	0.980	0.950	
Z Discharge		0.989	0.981	0.959	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	73.50	166.38	440.72	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	169.59	447.63	1212.00	
Ratio of Compression		2.106	2.564	2.698	
Adiabatic Disch. Temp.	F	203.54	242.83	255.95	
Est. Actual Disch. Temp	F	226.94	261.87	269.63	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	736.0	356.7	136.0	
CAPACITY ACTUAL WET	MMSCFD	5.76	5.73	5.70	
CAPACITY ACTUAL DRY	MMSCFD	5.68	5.68	5.68	
TOTAL COMPRESSOR POWER	HP	1027.68			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia.	Act./IN	DA/0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	283.4	0.0	342.3	345.2
HE Disch. Vol. Eff.	%	10.00	0.00	23.90	30.45
CE Disch. Vol. Eff.	%	46.52	0.00	35.68	27.71
HE Inlet Vol. Eff.	%	18.11	0.00	50.54	65.91
CE Inlet Vol. Eff.	%	84.18	0.00	75.47	59.97
Avg. Inlet Vol. Eff.	%	51.15	0.00	63.00	62.94
HE Clearance Req'd.	%	95.80	0.00	40.15	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	100.00	0.00	25.00	0.00
HE Clearance Added	IN3	862.0	0.0	98.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	16148	0	17738	15858
Flange Gas Load - C	LBF	-17341	0	-20752	-23971
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	35354	42942	31942	22125
Combined Rod Load - C	LBF	-33826	-29381	-31179	-23957
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	175.0	160.0	170.0	150.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION DATE: Oct 2, 2000  
 LOCATION: Hamburg (2-6), Alberta FILE: 9404-420.DAT " 4"  
 JOB/REF : Apache Canada / Optima Engineers CALC BY: J.Saxinger  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp.(F): 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 100 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 5
Avg. Temp. Expon. (K)		1.259	1.258	1.276	
Avg. Vol. Expon. (N)		1.257	1.260	1.294	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.987	0.976	0.938	
Z Discharge		0.986	0.977	0.946	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	98.00	201.29	546.54	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	205.11	555.07	1212.00	
Ratio of Compression		1.961	2.648	2.188	
Adiabatic Disch. Temp.	F	194.61	248.08	227.13	
Est. Actual Disch. Temp	F	216.79	266.45	238.06	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	821.2	427.4	156.7	
CAPACITY ACTUAL WET	MMSCFD	8.27	8.24	8.20	
CAPACITY ACTUAL DRY	MMSCFD	8.17	8.17	8.17	
TOTAL COMPRESSOR POWER	HP	1314.82			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./IN	DA/0.00	DA/0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	368.9	0.0	505.4	383.9
HE Disch. Vol. Eff.	%	16.40	0.00	34.78	40.81
CE Disch. Vol. Eff.	%	50.25	0.00	34.41	38.49
HE Inlet Vol. Eff.	%	28.03	0.00	75.35	74.73
CE Inlet Vol. Eff.	%	85.89	0.00	74.54	70.49
Avg. Inlet Vol. Eff.	%	56.96	0.00	74.94	72.61
HE Clearance Req'd.	%	95.80	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	100.00	0.00	0.00	0.00
HE Clearance Added	IN3	862.0	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	17922	0	22352	12866
Flange Gas Load - C	LBF	-19410	0	-26065	-21498
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	33285	42942	33531	24961
Combined Rod Load - C	LBF	-34440	-29381	-32509	-28118
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	180.0	160.0	170.0	155.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 Ref. Pressure ( PSIA) : 14.70  
 COMPRESSOR: Frame : 6 HOS 4  
 .....Calc RPM : 1200.0  
 DRIVER: Type : Gas Engine

DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 3"  
 CALC BY: J.Saxinger  
 Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Temp.(F): 60.  
 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 Max RPM : 1200.0 Cooler (HP): 58.0  
 Avail (HP) : 1478.0 Model: 7042GL

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 75 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 5
Avg. Temp. Expon. (K)		1.257	1.255	1.271	
Avg. Vol. Expon. (N)		1.256	1.256	1.287	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.990	0.981	0.947	
Z Discharge		0.989	0.982	0.956	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	73.50	156.39	462.94	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	159.41	470.19	1212.00	
Ratio of Compression		1.988	2.848	2.572	
Adiabatic Disch. Temp.	F	196.05	257.19	249.37	
Est. Actual Disch. Temp	F	219.27	276.98	262.31	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	802.8	412.7	141.0	
CAPACITY ACTUAL WET	MMSCFD	6.29	6.26	6.22	
CAPACITY ACTUAL DRY	MMSCFD	6.19	6.19	6.19	
TOTAL COMPRESSOR POWER	HP	1117.04			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./IN	DA/0.00	DA/0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	288.3	0.0	415.6	356.4
HE Disch. Vol. Eff.	%	15.02	0.00	31.64	32.67
CE Disch. Vol. Eff.	%	49.42	0.00	31.24	30.01
HE Inlet Vol. Eff.	%	25.97	0.00	72.81	68.05
CE Inlet Vol. Eff.	%	85.44	0.00	71.90	62.53
Avg. Inlet Vol. Eff.	%	55.70	0.00	72.35	65.29
HE Clearance Req'd.	%	95.80	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	100.00	0.00	0.00	0.00
HE Clearance Added	IN3	862.0	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FFM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	14400	0	19935	15230
Flange Gas Load - C	LBF	-15543	0	-23011	-23452
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	37152	42942	33796	22705
Combined Rod Load - C	LBF	-33831	-29381	-30394	-24829
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	175.0	160.0	170.0	160.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp.(F): 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 2"  
 CALC BY: J.Saxinger

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 50 psig Pd (line)= 1200 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 5
Avg. Temp. Expon. (K)		1.255	1.251	1.265	
Avg. Vol. Expon. (N)		1.254	1.252	1.280	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.993	0.986	0.957	
Z Discharge		0.992	0.987	0.967	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	49.00	111.25	377.61	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	113.47	383.56	1212.00	
Ratio of Compression		2.033	3.184	3.134	
Adiabatic Disch. Temp.	F	198.48	271.59	276.64	
Est. Actual Disch. Temp	F	223.40	293.51	293.20	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	772.8	388.4	119.0	
CAPACITY ACTUAL WET	MMSCFD	4.33	4.30	4.26	
CAPACITY ACTUAL DRY	MMSCFD	4.24	4.24	4.24	
TOTAL COMPRESSOR POWER	HP	886.50			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia.	Act./IN	DA/0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	207.3	0.0	319.7	302.8
HE Disch. Vol. Eff.	%	12.85	0.00	27.21	24.02
CE Disch. Vol. Eff.	%	48.10	0.00	26.79	21.01
HE Inlet Vol. Eff.	%	22.62	0.00	68.63	58.62
CE Inlet Vol. Eff.	%	84.68	0.00	67.57	51.27
Avg. Inlet Vol. Eff.	%	53.65	0.00	68.10	54.95
HE Clearance Req'd.	%	95.80	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	100.00	0.00	0.00	0.00
HE Clearance Added	IN3	862.0	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	10835	0	17419	17643
Flange Gas Load - C	LBF	-11633	0	-19848	-25446
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	41062	42942	34716	20480
Combined Rod Load - C	LBF	-33222	-29381	-28595	-21482
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	175.0	160.0	150.0	140.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA) : 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp.(F) : 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN) : 6.0 Rod Dia (IN) : 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP) : 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

DATE: Oct 2, 2000

FILE: 9404-420.DAT " 4"

CALC BY: J.Saxinger

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 100 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 4
Avg. Temp. Expon. (K)		1.258	1.259	1.278	
Avg. Vol. Expon. (N)		1.256	1.261	1.296	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.987	0.975	0.935	
Z Discharge		0.986	0.976	0.943	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	98.00	213.41	568.91	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	217.45	577.78	1212.00	
Ratio of Compression		2.072	2.606	2.104	
Adiabatic Disch. Temp.	F	201.83	246.15	221.76	
Est. Actual Disch. Temp	F	224.41	264.20	232.29	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	875.4	430.5	160.1	
CAPACITY ACTUAL WET	MMSCFD	8.81	8.78	8.74	
CAPACITY ACTUAL DRY	MMSCFD	8.71	8.71	8.71	
TOTAL COMPRESSOR POWER	HP	1395.38			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./IN	DA/0.00	DA/0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	422.1	0.0	528.9	387.6
HE Disch. Vol. Eff.	%	20.46	0.00	35.49	42.94
CE Disch. Vol. Eff.	%	47.43	0.00	35.12	40.71
HE Inlet Vol. Eff.	%	36.55	0.00	75.88	76.22
CE Inlet Vol. Eff.	%	84.70	0.00	75.09	72.27
Avg. Inlet Vol. Eff.	%	60.62	0.00	75.49	74.24
HE Clearance Req'd.	%	75.48	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	75.00	0.00	0.00	0.00
HE Clearance Added	IN3	646.5	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	20041	0	22991	12234
Flange Gas Load - C	LBF	-21589	0	-26875	-20976
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	31106	42942	33567	25565
Combined Rod Load - C	LBF	-34658	-29381	-33087	-28821
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	180.0	160.0	170.0	155.0



DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp. (F) : 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN) : 6.0 Rod Dia (IN) : 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP) : 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 3"  
 CALC BY: J.Saxinger

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 75 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 4
Avg. Temp. Expon. (K)		1.257	1.255	1.272	
Avg. Vol. Expon. (N)		1.255	1.257	1.289	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.990	0.980	0.945	
Z Discharge		0.989	0.981	0.954	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	73.50	166.15	481.24	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	169.35	488.77	1212.00	
Ratio of Compression		2.103	2.797	2.477	
Adiabatic Disch. Temp.	F	203.37	254.89	244.18	
Est. Actual Disch. Temp	F	226.97	274.32	256.59	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	858.4	416.4	144.9	
CAPACITY ACTUAL WET	MMSCFD	6.72	6.69	6.64	
CAPACITY ACTUAL DRY	MMSCFD	6.62	6.62	6.62	
TOTAL COMPRESSOR POWER	HP	1187.29			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./IN	DA/0.00	NA/0.00	DA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	330.6	0.0	435.6	364.3
HE Disch. Vol. Eff.	%	19.20	0.00	32.41	34.47
CE Disch. Vol. Eff.	%	46.58	0.00	32.02	31.90
HE Inlet Vol. Eff.	%	34.71	0.00	73.46	69.69
CE Inlet Vol. Eff.	%	84.21	0.00	72.57	64.48
Avg. Inlet Vol. Eff.	%	59.46	0.00	73.01	67.08
HE Clearance Req'd.	%	75.48	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	75.00	0.00	0.00	0.00
HE Clearance Added	IN3	646.5	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	16107	0	20469	14712
Flange Gas Load - C	LBF	-17299	0	-23683	-23024
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	35395	42942	33688	23199
Combined Rod Load - C	LBF	-34001	-29381	-30850	-25548
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	175.0	160.0	170.0	160.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp. (F): 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia (IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 2"  
 CALC BY: J.Saxinger

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 50 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 4
Avg. Temp. Expon. (K)		1.255	1.252	1.266	
Avg. Vol. Expon. (N)		1.254	1.253	1.281	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.993	0.986	0.955	
Z Discharge		0.992	0.986	0.965	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	49.00	118.65	391.75	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	121.01	397.92	1212.00	
Ratio of Compression		2.154	3.115	3.024	
Adiabatic Disch. Temp.	F	206.23	268.91	271.72	
Est. Actual Disch. Temp	F	231.54	290.44	287.50	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	830.6	393.5	123.2	
CAPACITY ACTUAL WET	MMSCFD	4.66	4.62	4.58	
CAPACITY ACTUAL DRY	MMSCFD	4.56	4.56	4.56	
TOTAL COMPRESSOR POWER	HP	945.49			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./IN	DA/0.00	DA/0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	238.9	0.0	336.1	313.7
HE Disch. Vol. Eff.	%	17.21	0.00	28.07	25.48
CE Disch. Vol. Eff.	%	45.24	0.00	27.66	22.53
HE Inlet Vol. Eff.	%	31.72	0.00	69.51	60.43
CE Inlet Vol. Eff.	%	83.40	0.00	68.48	53.44
Avg. Inlet Vol. Eff.	%	57.56	0.00	68.99	56.93
HE Clearance Req'd.	%	75.48	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	75.00	0.00	0.00	0.00
HE Clearance Added	IN3	646.5	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	12131	0	17842	17243
Flange Gas Load - C	LBF	-12965	0	-20378	-25115
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	39730	42942	34525	20849
Combined Rod Load - C	LBF	-33050	-29381	-28865	-22036
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	170.0	160.0	155.0	140.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp. (F): 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 75 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 3
Avg. Temp. Expon. (K)		1.256	1.256	1.274	
Avg. Vol. Expon. (N)		1.255	1.258	1.291	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.990	0.979	0.943	
Z Discharge		0.989	0.980	0.951	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	73.50	178.37	503.99	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	181.79	511.87	1212.00	
Ratio of Compression		2.246	2.739	2.368	
Adiabatic Disch. Temp.	F	212.04	252.28	237.99	
Est. Actual Disch. Temp	F	236.11	271.32	249.82	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	927.9	420.7	149.3	
CAPACITY ACTUAL WET	MMSCFD	7.26	7.22	7.18	
CAPACITY ACTUAL DRY	MMSCFD	7.16	7.16	7.16	
TOTAL COMPRESSOR POWER	HP	1275.85			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia.	Act./IN	DA/0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	386.4	0.0	460.1	372.6
HE Disch. Vol. Eff.	%	23.93	0.00	33.30	36.70
CE Disch. Vol. Eff.	%	43.40	0.00	32.91	34.22
HE Inlet Vol. Eff.	%	45.61	0.00	74.19	71.58
CE Inlet Vol. Eff.	%	82.70	0.00	73.33	66.73
Avg. Inlet Vol. Eff.	%	64.16	0.00	73.76	69.15
HE Clearance Req'd.	%	55.15	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	50.00	0.00	0.00	0.00
HE Clearance Added	IN3	431.0	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	18244	0	21127	14069
Flange Gas Load - C	LBF	-19497	0	-24515	-22492
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	33198	42942	33558	23813
Combined Rod Load - C	LBF	-33418	-29381	-31423	-26474
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	175.0	160.0	165.0	160.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION DATE: Oct 2, 2000  
 LOCATION: Hamburg (2-6), Alberta FILE: 9404-420.DAT " 2"  
 JOB/REF : Apache Canada / Optima Engineers CALC BY: J.Saxinger  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp.(F) : 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 50 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 3
Avg. Temp. Expon. (K)		1.254	1.252	1.267	
Avg. Vol. Expon. (N)		1.253	1.253	1.283	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.993	0.985	0.953	
Z Discharge		0.992	0.985	0.963	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	49.00	127.87	409.20	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	130.38	415.64	1212.00	
Ratio of Compression		2.304	3.037	2.900	
Adiabatic Disch. Temp.	F	214.98	265.40	265.89	
Est. Actual Disch. Temp	F	240.71	286.40	280.83	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	902.7	399.0	128.1	
CAPACITY ACTUAL WET	MMSCFD	5.06	5.02	4.98	
CAPACITY ACTUAL DRY	MMSCFD	4.96	4.96	4.96	
TOTAL COMPRESSOR POWER	HP	1019.06			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./IN	DA/0.00	NA/0.00	DA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	280.3	0.0	355.9	326.1
HE Disch. Vol. Eff.	%	22.12	0.00	29.04	27.26
CE Disch. Vol. Eff.	%	42.03	0.00	28.63	24.39
HE Inlet Vol. Eff.	%	43.06	0.00	70.45	62.51
CE Inlet Vol. Eff.	%	81.81	0.00	69.45	55.92
Avg. Inlet Vol. Eff.	%	62.44	0.00	69.95	59.22
HE Clearance Req'd.	%	55.15	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	50.00	0.00	0.00	0.00
HE Clearance Added	IN3	431.0	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	13742	0	18357	16749
Flange Gas Load - C	LBF	-14622	0	-21025	-24707
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	38073	42942	34287	21304
Combined Rod Load - C	LBF	-32552	-29381	-29195	-22720
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	175.0	160.0	155.0	145.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp.(F) : 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 3"  
 CALC BY: J.Saxinger

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 75 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 2
Avg. Temp. Expon. (K)		1.254	1.257	1.276	
Avg. Vol. Expon. (N)		1.253	1.259	1.293	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.990	0.977	0.939	
Z Discharge		0.989	0.978	0.948	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	73.50	193.93	532.92	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	197.62	541.24	1212.00	
Ratio of Compression		2.428	2.675	2.243	
Adiabatic Disch. Temp.	F	222.29	249.34	230.52	
Est. Actual Disch. Temp	F	246.79	267.91	241.71	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	1017.0	425.4	154.4	
CAPACITY ACTUAL WET	MMSCFD	7.96	7.91	7.87	
CAPACITY ACTUAL DRY	MMSCFD	7.85	7.85	7.85	
TOTAL COMPRESSOR POWER	HP	1389.79			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./IN	DA/0.00	DA/0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	461.3	0.0	490.9	380.8
HE Disch. Vol. Eff.	%	29.35	0.00	34.33	39.50
CE Disch. Vol. Eff.	%	39.82	0.00	33.95	37.13
HE Inlet Vol. Eff.	%	59.57	0.00	75.00	73.77
CE Inlet Vol. Eff.	%	80.80	0.00	74.17	69.34
Avg. Inlet Vol. Eff.	%	70.19	0.00	74.59	71.56
HE Clearance Req'd.	%	34.83	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	25.00	0.00	0.00	0.00
HE Clearance Added	IN3	215.5	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	20964	0	21961	13251
Flange Gas Load - C	LBF	-22295	0	-25570	-21817
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	30779	42942	33512	24593
Combined Rod Load - C	LBF	-33391	-29381	-32159	-27581
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	170.0	160.0	170.0	160.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA) : 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp.(F) : 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN) : 6.0 Rod Dia(IN) : 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP) : 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 2"

CALC BY: J.Saxinger

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 50 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 2
Avg. Temp. Expon. (K)		1.253	1.253	1.269	
Avg. Vol. Expon. (N)		1.252	1.254	1.285	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.993	0.983	0.951	
Z Discharge		0.992	0.984	0.960	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	49.00	139.66	431.41	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	142.39	438.19	1212.00	
Ratio of Compression		2.496	2.950	2.755	
Adiabatic Disch. Temp.	F	225.64	261.67	258.81	
Est. Actual Disch. Temp	F	251.85	282.12	272.83	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	995.7	405.3	133.8	
CAPACITY ACTUAL WET	MMSCFD	5.58	5.53	5.49	
CAPACITY ACTUAL DRY	MMSCFD	5.47	5.47	5.47	
TOTAL COMPRESSOR POWER	HP	1114.25			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./IN	DA/0.00	NA/0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	336.6	0.0	380.9	339.9
HE Disch. Vol. Eff.	%	27.76	0.00	30.20	29.52
CE Disch. Vol. Eff.	%	38.45	0.00	29.79	26.73
HE Inlet Vol. Eff.	%	57.63	0.00	71.53	64.95
CE Inlet Vol. Eff.	%	79.82	0.00	70.57	58.83
Avg. Inlet Vol. Eff.	%	68.73	0.00	71.05	61.89
HE Clearance Req'd.	%	34.83	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	25.00	0.00	0.00	0.00
HE Clearance Added	IN3	215.5	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	15805	0	19009	16121
Flange Gas Load - C	LBF	-16744	0	-21846	-24188
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	35951	42942	33995	21883
Combined Rod Load - C	LBF	-32173	-29381	-29627	-23592
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	170.0	160.0	170.0	145.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION DATE: Oct 2, 2000  
 LOCATION: Hamburg (2-6), Alberta FILE: 9404-420.DAT " 1"  
 JOB/REF : Apache Canada / Optima Engineers CALC BY: J.Saxinger  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp.(F): 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 25 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 2
Avg. Temp. Expon. (K)		1.251	1.248	1.261	
Avg. Vol. Expon. (N)		1.251	1.249	1.276	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.996	0.989	0.962	
Z Discharge		0.995	0.990	0.974	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	24.50	84.81	326.86	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	86.56	332.04	1212.00	
Ratio of Compression		2.637	3.517	3.601	
Adiabatic Disch. Temp.	F	232.43	284.76	296.19	
Est. Actual Disch. Temp	F	262.11	308.69	316.61	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	951.2	365.0	101.2	
CAPACITY ACTUAL WET	MMSCFD	3.23	3.18	3.14	
CAPACITY ACTUAL DRY	MMSCFD	3.12	3.12	3.12	
TOTAL COMPRESSOR POWER	HP	781.38			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./IN	DA/0.00	DA/0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	210.2	0.0	258.8	255.7
HE Disch. Vol. Eff.	%	24.69	0.00	23.61	18.70
CE Disch. Vol. Eff.	%	35.81	0.00	23.17	15.47
HE Inlet Vol. Eff.	%	53.60	0.00	64.60	51.04
CE Inlet Vol. Eff.	%	77.75	0.00	63.38	42.22
Avg. Inlet Vol. Eff.	%	65.67	0.00	63.99	46.63
HE Clearance Req'd.	%	34.83	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	25.00	0.00	0.00	0.00
HE Clearance Added	IN3	215.5	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	10542	0	15894	19077
Flange Gas Load - C	LBF	-11088	0	-17940	-26631
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	41607	42942	35663	19161
Combined Rod Load - C	LBF	-31193	-29381	-27830	-19554
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	165.0	160.0	155.0	140.0

DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION  
 LOCATION: Hamburg (2-6), Alberta  
 JOB/REF : Apache Canada / Optima Engineers  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp. (F) : 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia (IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

DATE: Oct 2, 2000  
 FILE: 9404-420.DAT " 2"  
 CALC BY: J.Saxinger

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 50 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 1
Avg. Temp. Expon. (K)		1.252	1.255	1.271	
Avg. Vol. Expon. (N)		1.251	1.256	1.287	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.993	0.982	0.947	
Z Discharge		0.993	0.982	0.956	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	49.00	155.24	460.77	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	158.24	467.99	1212.00	
Ratio of Compression		2.750	2.854	2.584	
Adiabatic Disch. Temp.	F	238.63	257.48	250.00	
Est. Actual Disch. Temp	F	265.00	277.31	263.01	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	1118.9	412.2	140.6	
CAPACITY ACTUAL WET	MMSCFD	6.27	6.21	6.17	
CAPACITY ACTUAL DRY	MMSCFD	6.14	6.14	6.14	
TOTAL COMPRESSOR POWER	HP	1240.35			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./IN	DA/0.00	DA/0.00	NA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	414.9	0.0	413.3	355.4
HE Disch. Vol. Eff.	%	34.25	0.00	31.55	32.45
CE Disch. Vol. Eff.	%	34.41	0.00	31.15	29.79
HE Inlet Vol. Eff.	%	76.87	0.00	72.73	67.85
CE Inlet Vol. Eff.	%	77.24	0.00	71.81	62.29
Avg. Inlet Vol. Eff.	%	77.05	0.00	72.27	65.07
HE Clearance Req'd.	%	14.50	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	0.00	0.00	0.00	0.00
HE Clearance Added	IN3	0.0	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	18528	0	19871	15291
Flange Gas Load - C	LBF	-19545	0	-22930	-23502
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	36993	42942	33809	22648
Combined Rod Load - C	LBF	-31749	-29381	-30340	-24744
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	170.0	160.0	170.0	155.0



DRESSER-RAND GAS FIELD COMPRESSOR PERFORMANCE (DRSIZE copyright 1996-2000 V1.3a)

PACKAGER: PROPAK COMPRESSION DATE: Oct 2, 2000  
 LOCATION: Hamburg (2-6), Alberta FILE: 9404-420.DAT " 1"  
 JOB/REF : Apache Canada / Optima Engineers CALC BY: J.Saxinger  
 JOBSITE : Amb T (F) : 90. Alt. (FT) : 2500. Atm ( PSIA): 13.42  
 Ref. Pressure ( PSIA) : 14.70 Ref. Temp.(F): 60.  
 COMPRESSOR: Frame : 6 HOS 4 Stroke (IN): 6.0 Rod Dia(IN): 2.500  
 .....Calc RPM : 1200.0 Max RPM : 1200.0 Cooler (HP): 58.0  
 DRIVER: Type : Gas Engine Avail (HP) : 1478.0 Model: 7042GL

Stage Number		1	2	3	
Gas		Natural	Natural	Natural	Ps (line)= 25 psig
Dry Gas Mol. Weight		17.958	17.958	17.958	Pd (line)= 1200 psig
Dry Gas Spec. Gravity		0.620	0.620	0.620	
Cp/Cv @ 14.7/60		1.287	1.287	1.287	Curve 1
Avg. Temp. Expon. (K)		1.250	1.249	1.263	
Avg. Vol. Expon. (N)		1.250	1.251	1.278	
Gas Crit. Temperature	R	371.286	371.286	371.286	
Gas Crit. Pressure	PSIA	672.998	672.998	672.998	
Z Standard		0.998	0.998	0.998	
Z Suction		0.996	0.988	0.960	
Z Discharge		0.996	0.989	0.971	
Inlet Temperature	F	110.00	120.00	120.00	
Inlet Press. @ Cyl Flg	PSIG	24.50	95.21	346.85	
Interstage Press. Drop	%	1.75	1.50	1.00	
Disch. Press. @ Cyl Flg	PSIG	97.14	352.34	1212.00	
Ratio of Compression		2.916	3.367	3.401	
Adiabatic Disch. Temp.	F	245.92	278.96	288.26	
Est. Actual Disch. Temp	F	275.80	302.00	306.93	
Stg. Piston Displ.	CFM	1452.2	570.2	215.2	
Stg. Inlet Capacity	ACFM	1085.2	375.5	108.8	
CAPACITY ACTUAL WET	MMSCFD	3.68	3.62	3.58	
CAPACITY ACTUAL DRY	MMSCFD	3.56	3.56	3.56	
TOTAL COMPRESSOR POWER	HP	878.36			

Stage number at (HE/CE)		1/1	0/0	2/2	3/3
Frame Ext/Cyl. Bore	#/IN	1/15.000	3/10.000	2/ 9.500	4/ 6.000
Cylinder Pattern		G12203	BALANCE	G12199	G12196
RDP	PSIG	450.0	0.0	1150.0	1750.0
MAWP	PSIG	495.0	0.0	1265.0	1925.0
Cyl. Action/HE Rod Dia. Act./IN	DA/0.00	NA/0.00	DA/0.00	DA/0.00	DA/0.00
Brake power / Cylinder	HP	262.4	0.0	283.3	275.9
HE Disch. Vol. Eff.	%	31.65	0.00	25.15	20.82
CE Disch. Vol. Eff.	%	31.82	0.00	24.72	17.68
HE Inlet Vol. Eff.	%	74.53	0.00	66.41	54.27
CE Inlet Vol. Eff.	%	74.94	0.00	65.26	46.08
Avg. Inlet Vol. Eff.	%	74.73	0.00	65.83	50.17
HE Clearance Req'd.	%	14.50	0.00	17.10	24.80
HE Clearance Min.	%	14.50	0.00	17.10	24.80
HE Pocket Open	%	0.00	0.00	0.00	0.00
HE Clearance Added	IN3	0.0	0.0	0.0	0.0
CE Clearance Req'd.	%	14.20	0.00	17.80	29.90
CE Clearance Min.	%	14.20	0.00	17.80	29.90
CE Clearance Added	IN3	0.0	0.0	0.0	0.0
Valve Model - HE		PF67	XXXX	PF48	PF48
Valve Model - CE		PF67	XXXX	PF48	PF48
Valves / Corner (HE/CE)		2/2	0/0	2/2	1/1
Valve Lift - HE	IN	0.080	0.000	0.080	0.080
Valve Lift - CE	IN	0.080	0.000	0.080	0.080
Valve Lift Area - HE	SQIN	10.420	0.000	5.640	5.640
Valve Lift Area - CE	SQIN	10.420	0.000	5.640	5.640
API Inlet Vlv Vel Avg.	FPM	10034.2	0.0	7279.6	5493.6
Flange Gas Load - T	LBF	12360	0	16497	18512
Flange Gas Load - C	LBF	-12957	0	-18693	-26164
Max. Allow. Gas Load	LBF	60000	60000	60000	60000
Combined Rod Load - T	LBF	40269	42942	35243	19683
Combined Rod Load - C	LBF	-30517	-29381	-28095	-20302
Max Allow Rod Load	LBF	60000	60000	60000	60000
Recip. Weight @ XHD Pin	LB	362.0	295.0	362.0	295.0
Reversal @ XHD Pin	DEG	160.0	160.0	155.0	140.0



**APACHE CANADA LIMITED**  
**EQUIPMENT LIST - PROPAK SO# 99404**  
**HAMBURG 2 - 6 COMPRESSOR STATION**  
**LSD: 02-06-097-11 W6M**

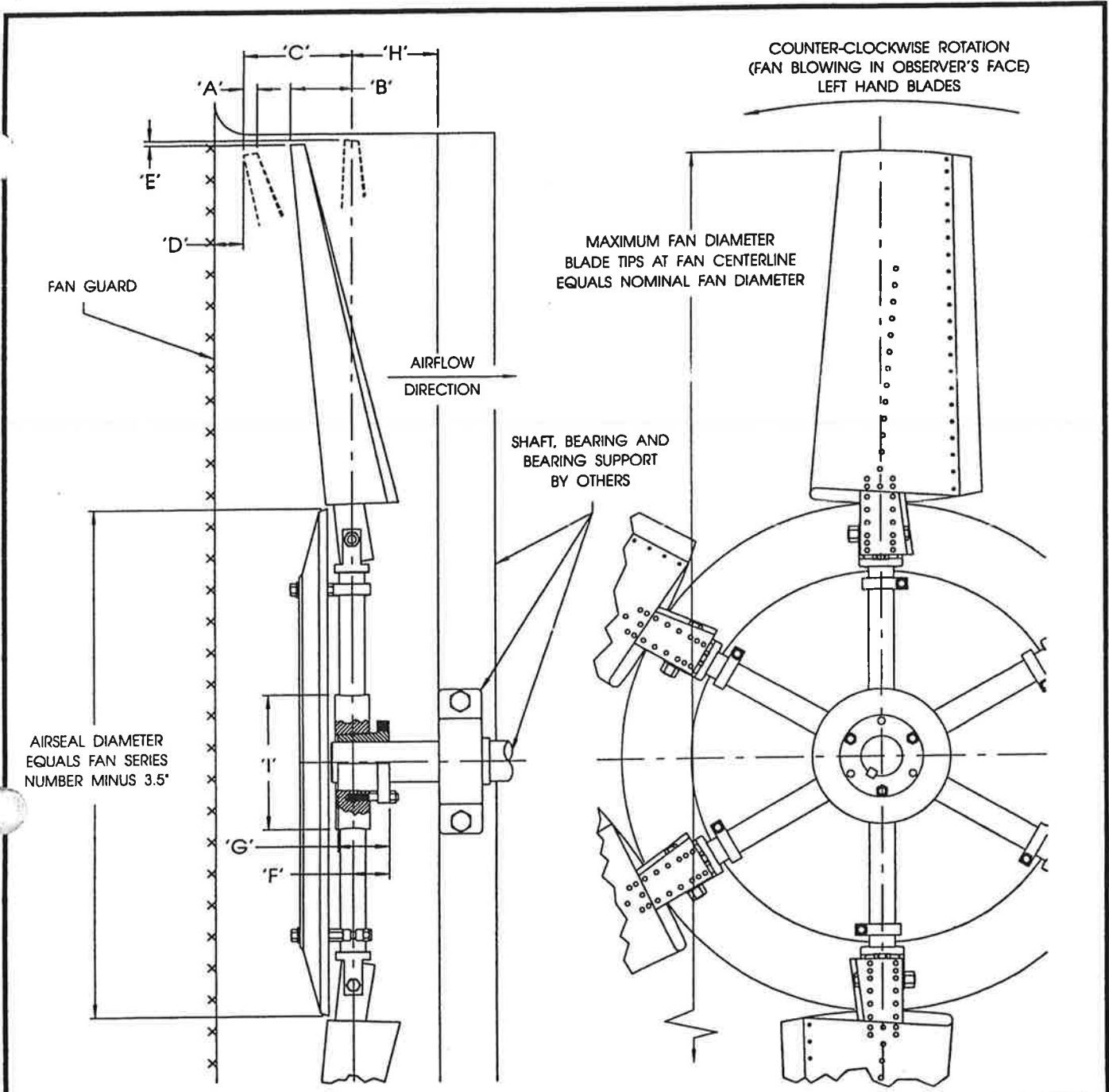
DATE	0	1	2	3	4											
REV #	MFS #	SKID #	QUOTE TAG #	DESCRIPTION	SIZE (MODEL)	MAKE	DUTY KW	POWER HP	DESIGN kPaq	DESIGN T (°C)	REMARKS (e.g. SHELLSIDE MAWF)					
				<b>PROCESS</b>												
1	4		V-100	1ST STAGE SUCTION SCRUBBER	813 mm OD x 1930 mm S/S	PROPAK			4516	-28/149						
0	4		V-110	2ND STAGE SUCTION SCRUBBER	660 mm OD x 1626 mm S/S	PROPAK			4516	-28/149						
1	4		V-120	3RD STAGE SUCTION SCRUBBER	508 mm OD x 1473 mm S/S	PROPAK			9067	-28/149						
1	4		V-121	1ST STAGE SUCTION BOTTLE	610 mm OD x 1778 mm S/S	PROPAK			4516	-28/149						
1	4		V-122	1ST STAGE DISCHARGE BOTTLE	457 mm OD x 2235 mm S/S	PROPAK			4447	-28/176						
1	4		V-123	2ND STAGE SUCTION BOTTLE	457 mm OD x 914 mm S/S	PROPAK			4516	-28/149						
1	4		V-124	2ND STAGE DISCHARGE BOTTLE	406 mm OD x 1016 mm S/S	PROPAK			8908	-28/176						
1	4		V-125	3RD STAGE SUCTION BOTTLE	406 mm OD x 914 mm S/S	PROPAK			9067	-28/149						
1	4		V-126	3RD STAGE DISCHARGE BOTTLE	356 mm OD x 1016 mm S/S	PROPAK			11377	-28/176						
0	4		KC-200A/B	1ST STAGE COMPRESSOR CYLINDER	381 MM DIAMETER	DRESSER RAND			3413	-28/149						
0	4		KC-202	2ND STAGE COMPRESSOR CYLINDER	241 MM DIAMETER	DRESSER RAND			8722	-28/149						
0	4		KC-203	3RD STAGE COMPRESSOR CYLINDER	152 MM DIAMETER	DRESSER RAND			13273	-28/149						
1	4		AC-210	1ST STAGE INTERCOOLER		PROPAK	277		4447	-28/149	COMMON AIR COOLER					
1	4		AC-211	2ND STAGE INTERCOOLER		PROPAK	376		8908	-28/149	COMMON AIR COOLER					
1	4		AC-212	3RD STAGE AFTERCOOLER		PROPAK	316		11377	-28/149	COMMON AIR COOLER					
				<b>ENGINE FUEL AND START GAS SYSTEM</b>												
0	5		F-220	FUEL GAS FILTER	385AP, C/W 70-C ELEMENT	HEADLINE										
1	5		P-228/M-226	ENGINE PRELUBE PUMP	C/W ENGINE	WAUKESHA										
1	5		KD-200	COMPRESSOR DRIVER	L7042GL	WAUKESHA		1478			1478 BHP @ 1200 RPM					
1	5		STR-227	ENGINE STARTER	T112-80001-B1R	TDI										
1	5		KS-225	COMPRESSOR SILENCER	JAT-14-SO12	SILEX										
				<b>GLYCOL COOLING SYSTEM</b>												
0	6		AC-220	JACKET WATER COOLER		PROPAK	117.4		ATM	-28/149	COMMON AIR COOLER					
0	6		AC-230	AUXILIARY WATER COOLER		PROPAK	22.7		ATM	-28/149	COMMON AIR COOLER					
0	6		E-241	ENGINE OIL COOLER	SUPPLIED WITH ENGINE	WAUKESHA										
0	6		T-235A/B	JACKET/AUXILIARY WATER SURGE TANK	160 / 74 LITER CAPACITY	PROPAK				ATM	-28/100					
				<b>ENGINE LUBE OIL</b>												
0	7		F-253	ENGINE OIL FILTER	SUPPLIED WITH ENGINE	WAUKESHA										
0	7		E-241	ENGINE OIL COOLER	SUPPLIED WITH ENGINE	WAUKESHA										
1	7		KD-200	COMPRESSOR DRIVER	L7042GL	WAUKESHA		1478			1478 BHP @ 1200 RPM					
0	7		P-250	ENGINE OIL PUMP	C/W ENGINE	WAUKESHA										
0	7		F-256	ENGINE OIL STRAINER	C/W ENGINE	WAUKESHA										
0	7		T-260	LUBE OIL SUPPLY TANK	425 LITER CAPACITY	PROPAK				ATM	-28/100	RHS CRANE RAIL				
0	7		F-261	LUBE OIL SUPPLY FILTER	BF-914 HOUSING	BALDWIN						C/W BALDWIN BF-915 ELEMENT				
1	7		P-260	PNEUMATIC DIAPHRAGM PUMP	T2, M/N:AAAB/BN/BN/ABN	WILDEN						CRANE RAIL FILL PUMP				
				<b>COMPRESSOR LUBE OIL &amp; GLYCOL</b>												
0	8		P-276	COMPRESSOR PRE-LUBE PUMP	T2, M/N:AAAB/BN/BN/ABN	WILDEN										
0	8		F-250	COMPRESSOR LUBE OIL FILTER	C/W COMPRESSOR	DRESSER RAND										
0	8		E-277	COMPRESSOR LUBE OIL COOLER	C/W COMPRESSOR	DRESSER RAND										
0	8		F-270	COMPRESSOR OIL SUPPLY FILTER	BF-914 HOUSING	BALDWIN						C/W BALDWIN BF-915 ELEMENT				
1	8		K-200	COMPRESSOR	6 HOS - 3	DRESSER RAND										

**APACHE CANADA LIMITED**  
**EQUIPMENT LIST - PROPAK SO# 99404**  
**HAMBURG 2 - 6 COMPRESSOR STATION**  
**LSD: 02-06-097-11 W6M**

DATE	0	1	2	3	4						
12/27	10/19										
REV #	MFS #	SKID #	QUOTE TAG #	DESCRIPTION	SIZE (MODEL)	MAKE	DUTY KW	POWER HP	DESIGN kPag	DESIGN T (°C)	REMARKS (e.g. SHELLSIDE MAWP)
1	8		P-270	PNEUMATIC DIAPHRAGM PUMP	T2, M/N:AAAB/BN/BN/ABN	WILDEN					CRANE RAIL FILL PUMP
0	8		T-270	COMPRESSOR LUBE OIL SUPPLY	425 LITER CAPACITY	PROPAK			ATM	-28/100	
0	8		T-284	WASTE OIL TANK	800 LITER CAPACITY	PROPAK			ATM	-28/100	
				<b>CYLINDER &amp; PACKING LUBRICATION</b>							
0	9		V-130	PACKING VENT AND DRAIN SEAL POT	273 mm OD x 813 mm S/S	PROPAK			ATM	-28/100	
				<b>BUILDING UTILITIES</b>							
1	11		EF-241A/B	EXHAUST FAN	ET 12-2	ENERTECH					C/W XP MOTOR, BIRD SCREEN & HOOD
1	11		H-240A/B	BUILDING HEATERS	XL 416-575360-15 KW	RUFFNECK	15				



CLASS 5000 SERIES 60



**NOTES**  
 THE MOORE COMPANY JOB NO. 60447-E  
 PROPAK SYSTEMS LTD. P.O. NO. 108732  
 PROPAK SYSTEMS LTD. JOB NO. 99404-238

- A = BLADE TIP THICKNESS - 10° CLEVIS ANGLE
- B = RUNNING POSITION OF BLADES
- C = STOPPED POSITION OF BLADES
- D = MINIMUM OBSTACLE CLEARANCE AT INLET
- E = DECREASE OF MAXIMUM POSSIBLE RADIUS AT RUNNING POSITION
- H = MINIMUM OBSTACLE CLEARANCE AT OUTLET

DIA.	A	BLADE LOAD		C	D	E	H	BUSHING	F	G	MAX BORE
		100%	75%					E	J	I	MAX BLD
10"	3.9"	4.4"	3.4"	6.5"	2.0"	0.34"	7.0"		2.8"	2.7"	2.875"
11"	3.4"	5.2"	3.9"	7.5"	2.0"	0.40"	7.0"	9.0"		8	E
12"	3.1"	6.1"	4.5"	8.5"	2.0"	0.48"	7.0"			12	E OR J
13"	2.8"	6.9"	5.4"	9.0"	2.0"	0.56"	7.0"				
14"	2.4"	7.9"	6.1"	10.0"	2.0"	0.66"	7.0"				

**SERIES 60 ENGINE DRIVE FAN**

CLASS 5000



LEFT HAND  
ROTATION



CERT. NO. 950 99 0534

# Moore

## ENGINE DRIVE FANS OWNER'S MANUAL

### INSTALLATION

### MAINTENANCE

### OPERATION

#### ABOUT THIS MANUAL .....

The Moore Company is as interested as are its customers that Moore fans operate at top efficiency for many, many years. This manual has been written to achieve that result and is based on more than 50 years of experience as a manufacturer of axial flow fans.

Moore fans represent the highest degree of axial fan development and are in all respects, regardless of price, the finest obtainable for their intended purpose. As for any fine equipment, certain precautions are necessary and certain abuses must be avoided in order to insure the best performance over the longest period of time.

If you have any questions regarding the installation or operation of your Moore fan(s), please contact the Company for assistance.

#### INSPECTION

All Moore units are carefully balanced, inspected and

packed at the factory. If any damage is evident before or after unpacking, the delivering carrier should be promptly notified so that an inspection may be made by the claims adjustor. It is the responsibility of the consignee to file damage claims with the carrier. Although The Moore Company will not be responsible for shipping damage, it is requested that any damage, even of a minor nature, be reported to the factory at once.

#### IDENTIFY YOUR FAN'S FEATURES

Section 1 consisting of your unit's specifications will be found in the pocket on the inside of this cover. Section 2 Getting Started should be read carefully before installation begins. Moore fans have several unique features. Those unfamiliar with these units should read the short summary of these important features set out on the back cover.

**PLEASE COMPLETE AND RETURN THE OWNER'S REGISTRATION CARD ON THE BACK COVER**

THE MOORE COMPANY MARCELINE, MO 64658 PHONE (660) 376-3575 FAX (660) 376-2909

## **1.0 ORDER INFORMATION**

**1.1 Fan Specifications**

**1.2 Dimensional Drawing(s)**

**1.3 Fan Curve(s) (if supplied)**

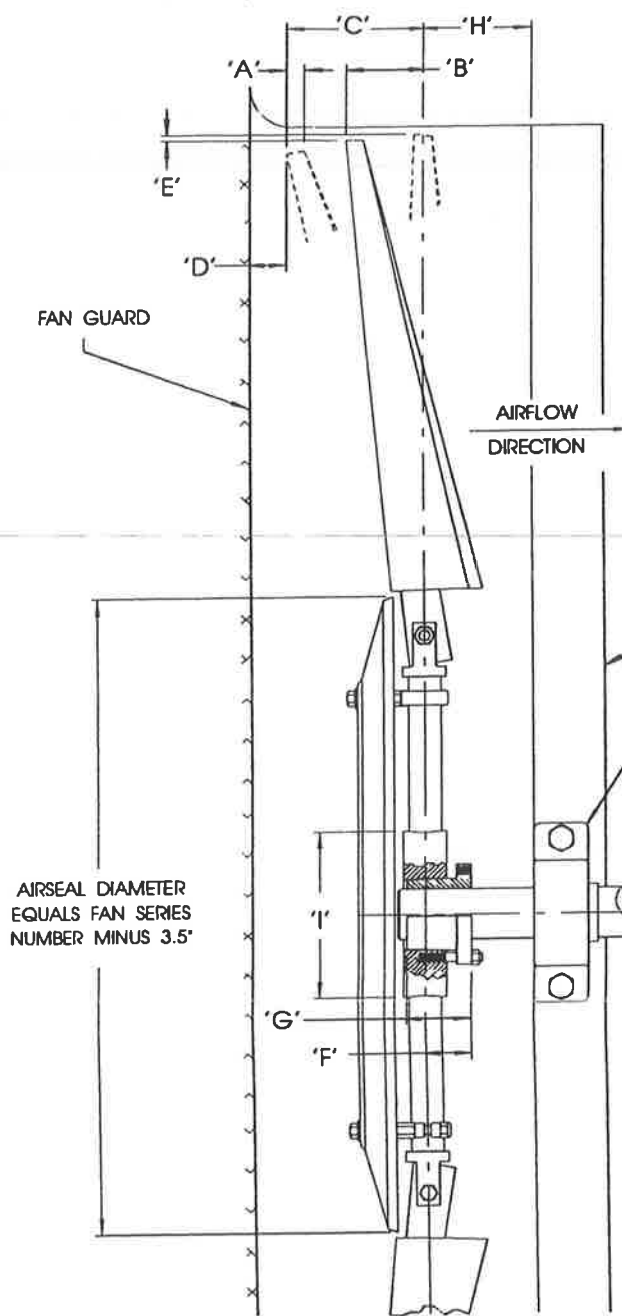
**1.4 Noise Data (if supplied)**

**The papers contained in this envelope provide information about your fan(s) that should be kept as a permanent record. This information will be essential in future years for the proper operation and maintenance of these units.**



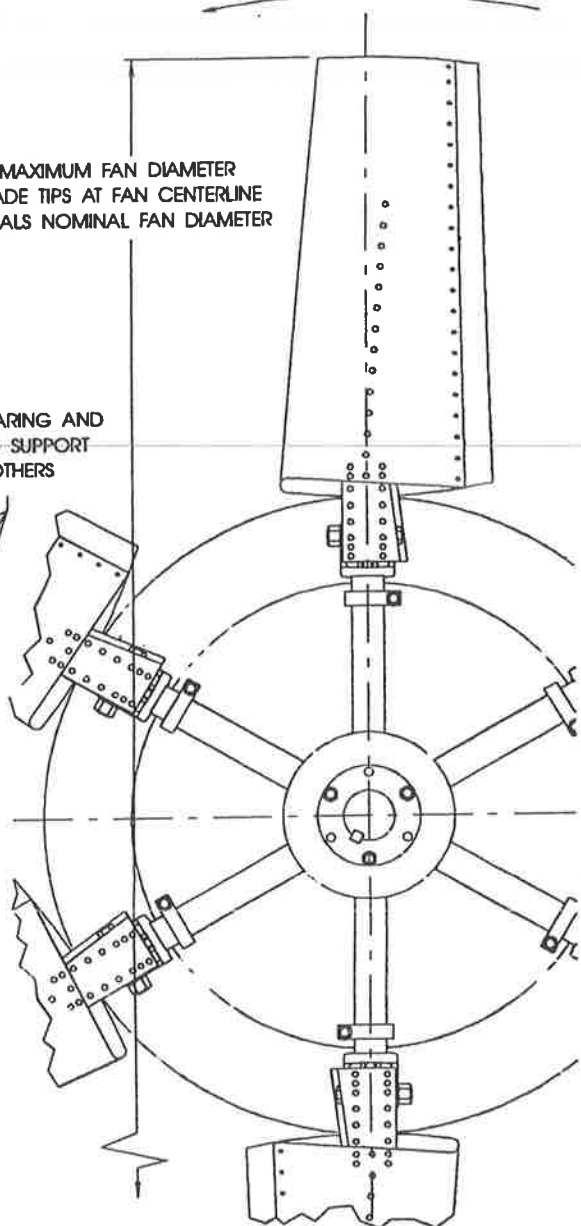
CLASS 5000 SERIES 49

COUNTER-CLOCKWISE ROTATION  
(FAN BLOWING IN OBSERVER'S FACE)  
LEFT HAND BLADES



MAXIMUM FAN DIAMETER  
BLADE TIPS AT FAN CENTERLINE  
EQUALS NOMINAL FAN DIAMETER

SHAFT, BEARING AND  
BEARING SUPPORT  
BY OTHERS



NOTES

THE MOORE COMPANY JOB NO. 61724-F  
PROPAK SYSTEMS LTD. P.O. NO. 111862  
PROPAK SYSTEMS LTD. JOB NO. 00136-138

- A = BLADE TIP THICKNESS - 10° CLEVIS ANGLE
- B = RUNNING POSITION OF BLADES
- C = STOPPED POSITION OF BLADES
- D = MINIMUM OBSTACLE CLEARANCE AT INLET
- E = DECREASE OF MAXIMUM POSSIBLE RADIUS AT RUNNING POSITION
- H = MINIMUM OBSTACLE CLEARANCE AT OUTLET

DIA.	A	BLADE LOAD		C	D	E	H	BUSHING	F	G	MAX BORE
		100%	75%					E	MAX BLDS	BUSHING	
9'	3.8"	3.8"	2.9"	6.0"	2.0"	0.24"	7.0"	E	2.8"	2.7"	2.875"
10'	3.4"	4.4"	3.3"	6.5"	2.0"	0.29"	7.0"	J	3.2"	4.6"	3.750"
11'	3.2"	5.0"	3.8"	7.0"	2.0"	0.33"	7.0"	12.0"	10	10	E OR J
12'	2.7"	5.7"	4.5"	8.0"	2.0"	0.39"	7.0"				

SERIES 49 ENGINE DRIVE FAN

CLASS 5000



LEFT HAND  
ROTATION



# THE MOORE COMPANY

800 S. MISSOURI AVENUE  
 MARCELINE, MO 64658 USA  
 TELEPHONE: (660) 376-3575  
 FACSIMILE: (660) 376-2511

## INSTALLATION MANUAL

JOB NO.: 61724 -E

SOLD TO PROPAK SYSTEMS LTD.  
 POSTAL BAG NO. 2  
 AIRDRIE AB T4B 2C3  
 CANADA

INVOICE DATE:  
 MODEL NO.: 5449/12B-ED-9-A-7  
 PURCHASE ORDER NO: 111862  
 CUSTOMER JOB NO: 00136-138  
 SHIP REQUIRED: 29-Jun-2000  
 PAYMENT TERMS: NET 30 DAYS  
 ROUTING: AMERICAN  
 F.O.B. POINT: MARCELINE, MO.  
 FREIGHT: COLLECT  
 CRATING: STANDARD DOMESTIC

SHIP TO PROPAK SYSTEMS LTD.  
 404 EAST LAKE ROAD  
 AIRDRIE AB T4B 2C3  
 CANADA

QTY	DESCRIPTION
2	5449/12B-ED-9-A-7
Serial Nos.: F93624 - F93625	
CLASS 5000	ASSEMBLY DATA MATERIAL: ALUMINUM
SERIES: 49 BLADES: 7 ARRANGEMENT: 12B CLEVIS ANGLE: 9.1° Engine Drive Left Hand HUB LENGTH C/L TO BASE: 3.2	DIA.: 9.00 TYPE: MANUAL MOUNTS: 3 In WEIGHT: 4 INCH HOLE IN AIR SEAL: NO
BUSHING: J KEYWAY: 0.750" X 0.375" STD. BORE TOL.: +.001" - .000" AIR OFF: STOP DROOP: 6.0 CH TO TIP: 34.00 BALANCE WT.:	
H DIM.: 3.264" BORE: 2.938" HUB TRAVEL: ° CUT DROOP: 0.0 COLOR CODE:	
AIR PERFORMANCE DATA	
ELEVATION: 530 Ft. AIR TEMPERATURE: 117 ° ACFM/FAN: 100006 RPM: 293 PHUD: 1.58 DENSITY RATIO: 0.901 STATIC PRESSURE: 0.700" WG VELOCITY PRESSURE: 0.199" WG INLET CORRECTION: 1.3 VELOCITY THROUGH FAN: 1888 FPM TIP CLEARANCE: 0.27" TOTAL PRESSURE: 0.899" WG BHP REQUIRED: 18.6 *MOTOR HP: 25.0 *MAXIMUM APPLIED TORQUE: 896 FT.LBS. THEORETICAL NO. OF BLADES: 6.7 BLADE LOAD FACTOR: 0.95	
CAUTION: * MAXIMUM APPLIED TORQUE USING FACTOR OF NOMINAL TIMES 2.00 (FACTORY SHOULD BE NOTIFIED IF MAX. APPLIED TORQUE OR MOTOR HP IS GREATER THAN THE VALUE SHOWN.)	
ADDITIONAL NOTES:	MARKS: P.O. NO. 111862 JOB NO. 00136-138

# CONTENTS

## 1.0 ORDER INFORMATION

- 1.1 Fan Specifications
- 1.2 Dimensional Drawing(s)
- 1.3 Fan Curve(s) (If Supplied)
- 1.4 Noise Data (If Supplied)

## 2.0 INSTALLATION

- 2.1 Getting Started
  - 2.1.1 Fan Identification
  - 2.1.2 Planning the Installation
- 2.2 Install Hub and Air Seal
- 2.3 Install and Adjust Blades
  - 2.3.1 Install Blades
  - 2.3.2 Adjust Blade Angle
- 2.4 Start-up Procedures

## 3.0 MAINTENANCE

- 3.1 Periodic Inspection
  - 3.1.1 Purpose
  - 3.1.2 Frequency of Inspection
  - 3.1.3 Check Blade Position & Angle
  - 3.1.4 Check for Wear on Clevises
  - 3.1.5 Cracks, Dents and Corrosion
  - 3.1.6 Hub Inspection

- 3.2 Annual Inspection
  - 3.2.1 Clean Blades if indicated
  - 3.2.2 Check System Pressure
  - 3.2.3 Close Inspection

- 3.3 Vibration and Unbalance
  - 3.3.1 General
  - 3.3.2 Fan Unbalance
  - 3.3.3 Belt Drive Units
  - 3.3.4 Rough Gears
  - 3.3.5 Throat Flutter
  - 3.3.6 Field Balancing

## 3.4 WARRANTY

## 3.5 DRAWING AND PARTS LIST

## 4.0 OPERATING CONDITIONS

- 4.1 Aerodynamic Abuse
  - 4.1.1 About This Section
  - 4.1.2 Normal Operating Conditions
  - 4.1.3 Abnormal Conditions
- 4.2 Blade Overload
- 4.3 Causes of Improper Blade Load
  - 4.3.1 Variation From Predicted Conditions
  - 4.3.2 Excessive Tip Clearance
  - 4.3.3 Poor Entrance Conditions
  - 4.3.4 Excessive Deflection
- 4.4 Checking Blade Load
- 4.5 Damaging Operating Conditions
  - 4.5.1 General
  - 4.5.2 Wind
  - 4.5.3 Obstructions
  - 4.5.4 Uneven Tip Clearance

# 2.0 INSTALLATION

## 2.1 GETTING STARTED

### 2.1.1 FAN IDENTIFICATION

Every fan, or group of identical fans, is assigned a Job Number. This number will be found on Section 1.1 Fan Specifications inserted in the envelope on the inside cover of this manual. If non-identical fans are shipped together, a Job Number is assigned to each fan or group and a set of Order Information Sheets will be included for each Job Number.

The Job Number is written in semi-permanent ink on each blade, hub and air seal. All fan parts bearing the same Job Number are entirely interchangeable. (Blades of the same Series and Diameter are also interchangeable between Job Numbers.)

Fan components covered by more than one Job Number may be crated together. The Job Number that is written on each part, however, will make sorting simple.

Each individual fan produced by The Moore Company is assigned a Serial Number. This Serial Number is embossed on a permanent metal tag and attached to each fan hub. It will be found on the side of the hub between two of the hub tubes. The Fan Specification Sheet provided for each Job Number lists all of the

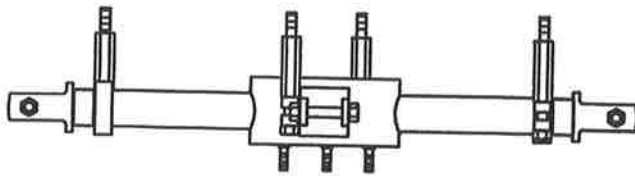
individual Serial Numbers of the identical fans covered by that Job Number so that, in future years, reference to the Fan Specification Sheets provided will identify the characteristics of each individual fan.

The Moore Company keeps records indexed by serial and job numbers of all fans produced for at least forty years in order to provide proper maintenance advice and information on spare parts and replacements.

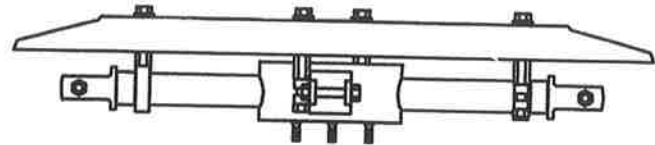
### 2.1.2 PLANNING THE INSTALLATION

The sequence given for the installation may be changed if the conditions warrant. For example, the air seal may be installed on the hub before the hub is installed on the drive shaft. (In fact, for inverted fans, it is necessary to install the air seal first.) The installation should be planned before beginning so that the steps required are taken in the most convenient order. If you need information not found here, please contact The Moore Company.

## 2.2 INSTALL HUB AND AIR SEAL

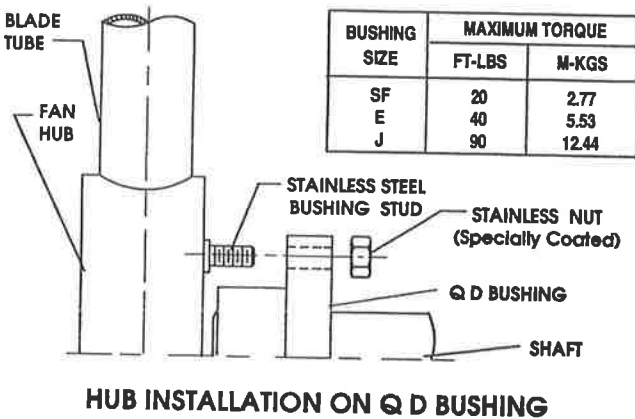


Hub Only Without Air Seal



Air Seal Installed on Hub

On orders consisting of more than a small number of fans, the air seals are crated separately and must be installed in the field. When field installed, the air seal may be installed on the fan hub before the hub is installed on the bushing if it is more convenient to do so. **The air seal, however, must not be used to lift the hub.**



HUB INSTALLATION ON Q D BUSHING

### To install the hub:

If the (3) stainless steel bushing studs are not already installed in the fan hub, install them at this time. Hand-tighten only.

Slip the bushing onto the shaft and check the key for proper fit. Be sure the shaft is completely through the bushing.

Carefully clean the bore of the hub and the outside of the bushing with a clean, dry cloth. **Use no lubricants in this installation.** Use of lubricants can cause hub breakage.

**Do not clean or alter the lubricant coating on the hex nuts.**

Lift the hub by grasping the clevises or hub tubes. Do not lift the hub by grasping the air seal.

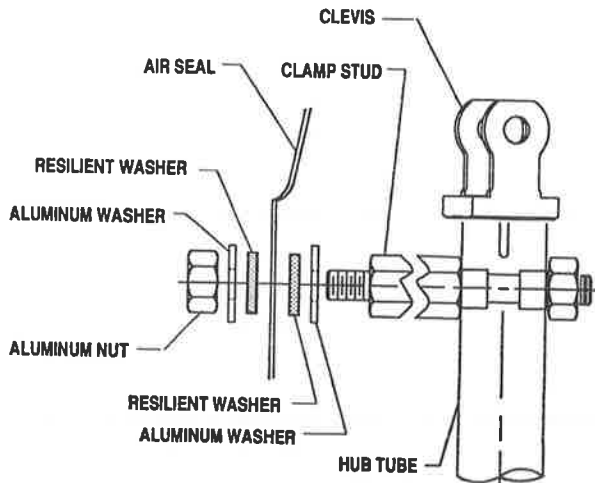
Install the fan hub on the bushing with the studs extending through the bushing flange. Place the stud nuts on the studs and tighten the nuts alternately, keeping the pull on all of them as nearly equal as possible while drawing the hub onto the bushing until the bushing tightly grips the shaft. **Caution should be used to prevent the hub from cocking on the bushing.**

Tighten the nuts to the torque shown in the table at left. **Do not over-torque.** Excessive torque can cause hub or bushing breakage.

### To install the airseal:

Locate the air seal installation hardware in the plastic bag taped to one of the hub tubes. Remove the protective plastic caps from the bolts or studs. Place one aluminum washer and one resilient washer on each bolt or stud as shown in the drawings at left. Place the air seal onto the bolts or studs and install the remaining hardware, following the sequence shown in the drawings. Do not lubricate this end of the bolts or studs.

Note that the diameter of the resilient washers, before they are compressed, is slightly less than the diameter of the aluminum washers. Tighten each nut until the resilient washer's diameter is the same as the aluminum washer. Do not overtighten. Overtightness exists when the resilient washer has expanded in diameter larger than the diameter of the aluminum washer.

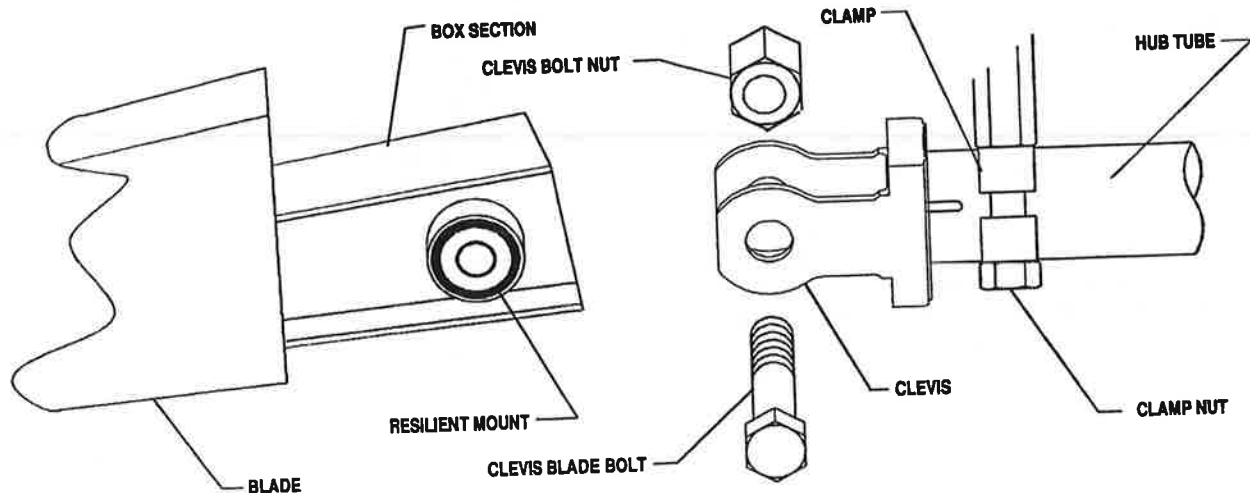


AIR SEAL INSTALLATION ON HUB

Note: Some air seals are provided with more mounting holes than may be required. This is done intentionally to make the air seals more interchangeable between units. For example, an air seal with 8 mounting holes can be used with either a 4-blade or an 8-blade unit.

## 2.3 INSTALL AND ADJUST BLADES

### 2.3.1 INSTALL BLADES ON ENGINE DRIVE FANS



#### BEFORE INSTALLING BLADES. . .

Check to see that the hub is level. If the drive shaft is not truly horizontal, causing the hub to be cocked, it will be difficult to adjust blade angles accurately. Eccentric rotation of the fan can also cause serious vibration problems.

If misalignment, vibration or unbalance in the system is present, it will be more easily identified and corrected at this time.

Moore fan blades are carefully balanced to the same moment at the factory. Any blade of the same series and diameter may be installed on any hub furnished on the job. They are completely interchangeable.

Moore fans designed for engine drive have been modified for the more severe requirements of this service. Proper installation, with particular attention to tightening nuts to the specified torque, is essential to maintain the design integrity of these units.

To install, remove the clevis bolt and nut from the clevis ears. Clean any grease or dirt from inside the clevis ears and inspect the blade resilient mount faces. Note that these mounts are 3" long and have a rough, high-friction layer on the faces. Other mounts should not be used on Engine Drive Fans.

Align the mount hole with the holes in the clevis ears and insert the clevis bolt. Screw the nut onto the projecting bolt threads loosely. When shipped from the factory, the nut threads and the washer face of the nut are coated with a low-friction grease. It is essential that sufficient grease for proper lubrication is retained on the nut face.

Complete the installation of one blade by holding the blade so that the blade extends straight out from the hub tube and clevis. Holding the blade in this position, tighten the nut using a torque wrench set to 100 ft-lb (14 m-kg).

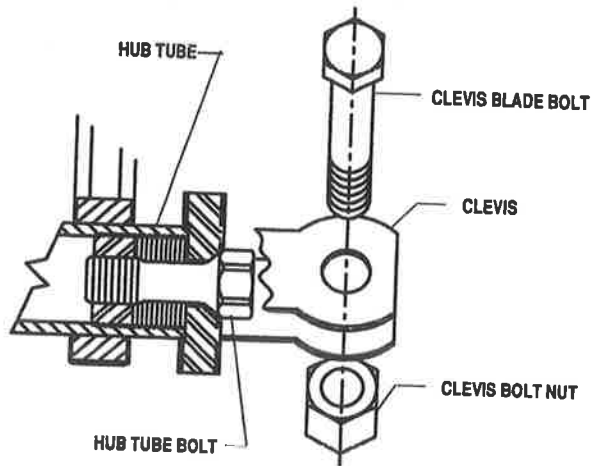
After installing the first blade, manually rotate the fan while moving the blade tip in and out to be sure the blade clears the ring or throat at all points. When the blade is held in alignment with the blade tube (that is, straight outward from the hub), it should clear the fan ring by a distance adequate to provide for any relative motion between the fan wheel and the ring. Excess clearance between the blade tips and the ring, however, should be avoided to prevent backflow which seriously reduces fan efficiency.

Install the rest of the blades so that they are identical with the first blade. Torque all clevis nuts to 100 ft-lbs (14 m-kg). If blades are installed properly, they will return to their undisturbed position if the tips are pressed in the axial direction with moderate force (10 to 20 lb).

## 2.3.2 ADJUST BLADE ANGLE

Hubs are shipped from the factory with the clevises set for the blade angle indicated by the design performance. A change in blade angle is sometimes necessary, however, to adjust to actual site conditions. Failure to adjust the blade angle when required may result in blade overload. The causes of improper blade loading are explained in Section 4.3 of this manual. Section 4.4 "Checking Blade Load" provides a simple method of determining the maximum blade angle allowable in terms of static pressure vs blade angle. Please refer to these sections before increasing blade angle.

**WARNING:** The fan is designed to consume the horsepower stated on the Fan Specification Sheet. The engine drive typically produces far more power than the fan can absorb. Too great an increase in blade angle can cause serious blade overload which will stall the blades. In this condition, the fan will actually deliver less air and blade life may be shortened. Blade load considerations are discussed in Section 4.0 Operation in this manual.

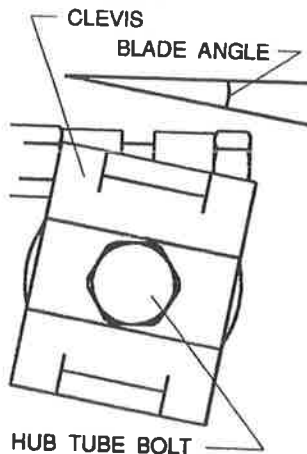


tration at right. (This is the point of measurement of the blade angle stated on 1.1 Fan Specifications.) Make a permanent record of the final clevis angle selected and take care that all blades on the fan are set at the same angle. A typical adjustment may be +/- 3°. The maximum recommended clevis angle is 15°.

Remove each blade from the fan before beginning blade angle adjustment by removing the clevis blade bolt and nut.

Manually rotate the fan until one of the hub tubes is in a horizontal position. Use a level to be sure the tube is held or locked in this position. If the tube is not horizontal, the blade angle will not be correctly measured during adjustment.

Loosen the Hub Tube Bolt just enough to allow the clevis to be turned. Place a protractor level on the flat upper or lower surface of the clevis as shown in the illus-



**NOTE:** Some recent fan models are furnished with a scale marked in degrees attached to the hub tube and an arrow machined on the clevis. In this case, blade angle is set by simply aligning the arrow with the mark for the desired angle. The hub tube may be in any position.

**Retighten the Hub Tube Bolt to 150 ft-lb (21 m-kg).**  
**NOTE: It is essential that bolts are properly tightened for engine drive operation. Recheck the blade angle after tightening.**  
 Reinstall the blades following the instructions under Section 2.3.1 on the preceding page. Be sure that sufficient grease remains on the clevis bolt nut faces and that they are tightened to the proper torque of 100 ft-lbs (14 m-kg).

## 2.4 START-UP PROCEDURES

Before starting the fan, manually check all bolts or nuts to see if they are tightened. Take care not to exceed the stated torque limits.

Manually rotate the fan while checking each blade for proper clearance.

Start the fan and watch it in operation. All blades should move to the same operating position, indicating that the blade angles are properly set and that all blades are equally loaded. If vibration or unbalance is evident, see Section 3.3.

After the fan has been operating for several minutes, stop

the fan and observe the blades as the fan comes to rest. All of the blades should return to their original position at the same rate.

Inspect the inner surface of the fan ring and the blade tips for any indication of scoring.

The horsepower given on the Fan Specifications is the calculated horsepower (at the fan shaft) that is required for the specified performance. Consult the factory or the fan curve before increasing the blade angle for the fan to consume more than the specified horsepower.



## 3.0 MAINTENANCE

### 3.1 PERIODIC INSPECTION

#### 3.1.1 PURPOSE

Fan failure is most likely the result of destructive repetitive stress acting over a period of time. These stresses may be caused by mechanical abuse, e.g. rough gears or drive shaft imbalance, or by aerodynamic abuse such as blade overload or abnormal flow conditions. Fortunately, these stresses manifest themselves in typical ways that may easily be detected on inspection if one knows what to look for. The purpose of this section of this manual is to describe the symptoms of potentially damaging mechanical problems and how they can be corrected. Aerodynamic abuses are covered in Section 4.0 Operation.

#### 3.1.2 FREQUENCY OF INSPECTION

The frequency of inspection varies widely in accordance with the severity of service and a suitable inspection schedule should be developed with experience over time. During the first week of operation, at least one inspection should be made. At these initial inspections, in addition to the items listed below, check all nuts for tightness to make certain that all were tightened properly at installation. Take care not to exceed the stated torque limits. Following the first week, it is probable that inspections of the fan need be made no more frequently than inspection of the drive.

#### 3.1.3 CHECK BLADE ANGLE AND RUNNING POSITION

Turn off the unit and watch the blade tips. A looseness in the hub tube bolt will permit a blade to flatten in angle. This usually can be detected by looking at the tips of the blades while the fan is slowing down. At the same time, before the unit comes to a complete stop, watch the track of the blade tips to see that all blades move to the same operating position. If one or more blades is at a substantially different position than the other blades, or if all of the blades are at a different position than at the last inspection, investigate further. This condition may be caused by:

1. A damaged resilient mount that requires replacement
2. Wear at the end of the box section against the clevis, indicating that the box section has been riding against the clevis during operation. If only one blade is affected, that blade is set at a steeper angle than the other blades. This should be checked and corrected.

#### 3.1.4 CHECK FOR WEAR ON CLEVISES

Clevises should be examined at each inspection for possible wear against the end of the box section. Since contact between the box section and the face of the clevis provides a stop to prevent excessive droop when the fan is shut down, there will undoubtedly be a mark on the face of the clevis at the point of contact. There should, however, be no evidence of wear which would indicate repetitive

contact between the two parts during operation. If wear at this point is indicated, a check should be made of blade loading as set out under Section 4.4 Checking Blade Load. If blade overload is not responsible, the end of the box section can be dressed off with a file to permit greater blade droop when the fan is not operating so long as the greater droop will not cause the blade to hit an obstruction. If the fan has been operating for a considerable length of time and previous inspections have not disclosed wear at this point, it is possible that a recent unusually high wind condition might have disturbed the blades sufficiently to cause them to temporarily make repetitive contact with the clevis while in operation.

#### 3.1.5 CRACKS, DENTS AND CORROSION

Skin cracking may be caused by the tips dragging on the fan ring, or it may be the result of long-term fatigue due to continued operation under conditions of vibration or unbalance as discussed in Section 3.3 which follows. Skin cracking can also be caused by continued operation under overload conditions as discussed in Section 4.3 Causes of Blade Overload.

Cracking in air seals can occur if the airseal has been improperly installed. See Section 2.2. Check to be sure the resilient washers are present and the nuts properly tightened.

The fatigue strength of materials, whether metal or plastic, may be lowered by long-term exposure to water.

Dents in blades are caused by objects falling into the fan or the fan striking some obstacle. Minor dents may sometimes be repaired by drilling a small hole in the center of the dent and pulling outward on the blade skin. Blades may be ordered from the factory for replacement. If there is any evidence of this type of damage, the hub should be carefully inspected as discussed in Section 3.1.6 which follows.

The Type 5052 aluminum, a marine alloy, used as the blade material on Moore fans works well with either fresh or sea water. Waters that are acid, alkaline, or contain copper salts, however, should be avoided for all aluminum alloys. If you have questions regarding the suitability of the fan materials under certain water conditions, please contact the factory.

#### 3.1.6 HUB INSPECTION

If damage to the fan has occurred, the hub should be carefully inspected since subtle damage may have been caused that is not readily apparent. Check the hub for any sign of bending or twisting of the hub tubes. Hub tubes cannot be replaced in the field on manual fans and a new hub should be ordered.

Bushings are frequently cracked during a fan wreck and should be carefully inspected. Damage may occur to the stainless steel studs that attach the hub to the bushing. It is a good idea to replace the studs when replacing a damaged fan blade.

## 3.2 ANNUAL INSPECTION

### 3.2.1 CLEAN BLADES IF INDICATED

A smooth blade surface is essential for efficient fan performance. If an incrustation forms on the blades it should be removed. Use steel wool as an abrasive along with a mild detergent or a very mild form of solvent. Lye must not be used because it attacks aluminum readily.

### 3.2.2 CHECK SYSTEM PRESSURE

Radiator sections may be effected by the accumulation of dust and dirt in some atmospheres. (Cottonwood seeds are particularly troubling.) These accumulations may significantly increase the static pressure. Adjust the blade angle if necessary as described in Section 4.4 Checking Blade Load.

### 3.2.3 CLOSE INSPECTION

The yearly inspection should be a very thorough one. All nuts and bolts should be checked and careful scrutiny given to all highly stressed areas.

Inspect the resilient mounts as follows: With the fan turned off, grasp each blade and feel for looseness at the mount. If in doubt, the blade should be removed and the mount assembly visually inspected. Wear is indicated by a fretting effect and the resilient mount material will show signs of extruding from the cavity. If these indications are not apparent, replace the blade and continue normal operations.

Inspect the blade tips for any signs of cracking and the fan ring for any scoring that might indicate that the blades have been striking or rubbing against the fan ring.

## 3.3 VIBRATION AND UNBALANCE

### 3.3.1 GENERAL

No piece of rotating equipment is perfectly balanced. It is always possible that the minute unbalances of the various components may combine to provide a noticeable lack of balance. This rarely occurs, since it is unlikely that all unbalanced components will become assembled with their heavy sides in the same direction. Nevertheless, if unbalance is noted, the various components should be rotated into different positions to see if this might cure the unbalanced condition.

If vibration or unbalance occur, either at the time of installation or later during the operation of the unit, its cause may be determined by following the directions below.

### 3.3.2 FAN UNBALANCE

Vibration is most likely to be caused by the fan if the blades are not set at the same angle. If the blades are properly set, the fan is the least likely cause of vibration. All fan components are balanced to within +/- .02 ft-lbs.

If the fan is in an unbalanced condition, the frequency of vibration of the structure will be that of the RPM of the fan and is quite low. In the case of large fans, the frequency is often low enough to be mentally counted along with the rotation of the fan. A vibration of 500 RPM or less will be felt as a weave in the structure rather than a vibration. Below 400 RPM, the vibration may be mentally counted and above that point may be read with a frequency meter.

Before assuming fan unbalance, check for loose bearing seats or bearings journaling the shaft on which the fan is mounted. This condition will cause the shaft to rotate eccentrically, throwing the weight of the fan off-center, resulting in unbalance of the frequency of the fan RPM.

After all checks have been made and the fan is still determined to be unbalanced, field balancing may be accomplished as described below in Section 3.3.6.

It should be noted that the loads imposed on the drive shaft and its supporting bearings by fan unbalance are negligible. A rotating centrifugal load of 100 pounds, due to unbal-

ance, would be extremely objectionable and possibly even damage the structure on which the drive was mounted. By contrast, it would be unlikely that the drive shaft of a fan, of perhaps 25 HP, would be supported on bearings rated less than 2000 or 3000 pounds radial load. For higher horsepower, the bearing capacity would be correspondingly increased. From this it is evident that speed reducer or drive shaft bearing failure could never be caused by moderate or even objectionable fan unbalance.

### 3.3.3 BELT DRIVE UNITS

The more common causes of vibration in belt drive units are not the drives themselves but the result of shafts that are too flexible or non-rigid supporting members. Vibration can be caused by misalignment of the sheaves or poorly adjusted belt tension. Consult the manufacturer of the drives for information. The quickest way to identify the cause of vibration in belt drive units is to operate the fan with the blades removed.

### 3.3.4 ROUGH GEARS

Continued operation on rough gears and bearings is almost certain to develop cracks in the blade skins. Rough gears may be of two types:

1. Rough or failed bearings in the drives or gears will result in a high frequency vibration being transmitted into the fan where some areas of the skin will respond to the frequencies applied. Cracks will appear in the blade skin and eventually, in some areas, the skin may actually fall away.

2. The other type of rough gear occurs when the output shaft accelerates and decelerates with each pinion tooth engagement. With a six tooth pinion and a motor speed of 1800 RPM, or 30 cycles per second, this gear misalignment impresses upon the fan a vibrating frequency of  $30 \times 6 = 180$  cycles per second. If the engagement of teeth is also included, the frequency is 360 cycles per second. This type of high frequency vibration is at least as serious as that caused by bad bearings.



**3.3.5 THROAT FLUTTER**

Any fan that is effectively moving air at the tips of the blades will develop a reduced pressure area (or suction) on the fan throat or ring at the tip of the blade. This suction tends to draw the throat toward the tip of each blade, which means that a four blade fan would tend to draw the throat into something approaching a square while a six blade fan would draw it into something resembling a hexagon, etc. Since the fan is rotating, the effect on the throat is that of continually drawing it into a rotating polygon. The resulting throat flutter is frequently mistaken for fan unbalance.

A substantial throat or ring will be sufficiently rigid that flutter will not exist. A weak or flexible throat, particularly when used with a fan of a low number of blades, will be greatly affected by this type of vibration. Throat flutter is easily detected due to the fact that it is invariably of a frequency of the fan RPM times the number of blades on the fan.

Throat flutter will cause no damage to the fan so long as the throat does not disintegrate and fall into the fan blades. It may be eliminated by stiffening or bracing the throat.

If in doubt that throat flutter is the cause of vibration, reduce the angle of the blades until the fan is doing little or no work. If the vibration ceases under this condition, it is certain that throat flutter is present when the blades are loaded.

**3.3.6 FIELD BALANCING**

Unbalance in older fans may develop because of some structural change or by installing one new blade on an old fan where the existing blades had changed in weight in the course of operation.

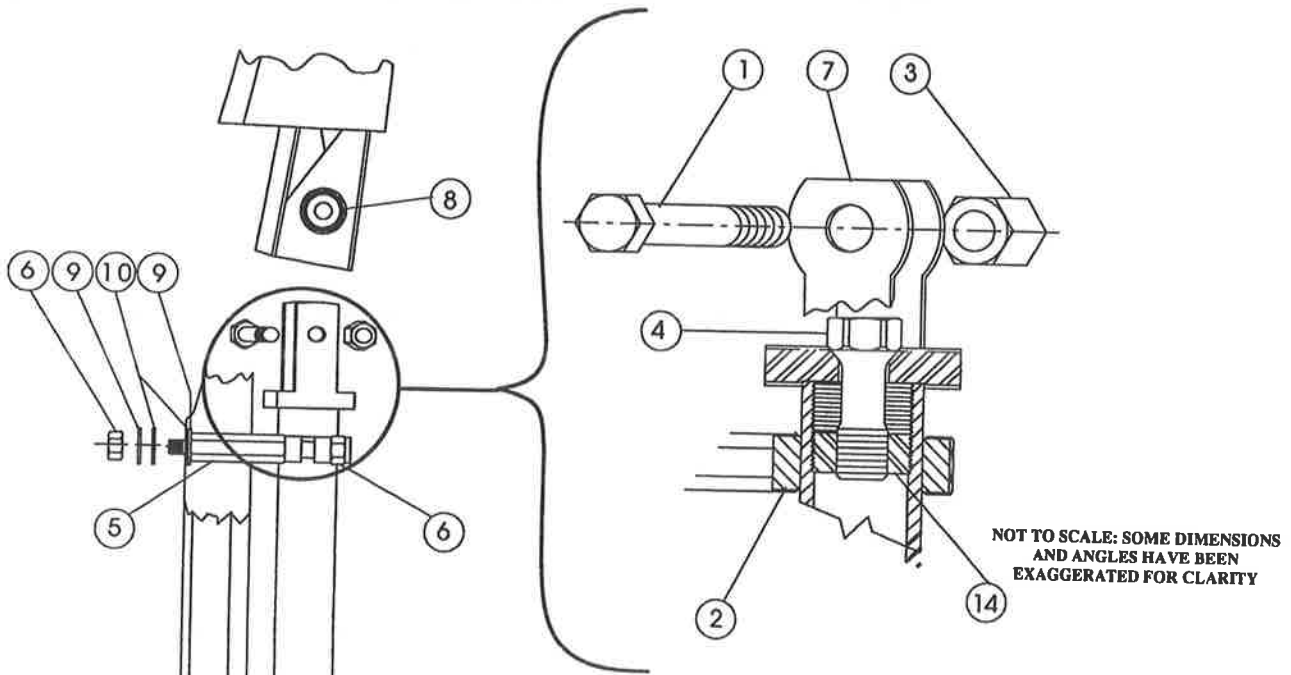
Use wire to attach a small weight in succession to each of the clamp studs until the best location for the weight is found. The weight should then be increased or decreased until the best balance is achieved. The permanent weight may then be secured to the clamp stud, clevis, or hub tube, whichever is the most convenient for the type and shape of weight to be used. One or more pieces of metal shaped like a washer could be placed over the clamp stud, on the hub tube, behind the clamp stud, or over the threaded portion of the clevis. Aluminum or stainless weights should be used and weights should not be attached to the blade skin.

**3.4 WARRANTY**

The Moore Company (the Seller) warrants only to Buyer, as its purchaser for resale, that the fans manufactured and sold by Seller to Buyer under this Agreement will be free from all defects in material and workmanship under ordinary use for a period of two (2) years from the date of shipment or one (1) year from the date the fan is installed on a customer's premises, whichever occurs first. This warranty period shall apply only if Seller receives written notice of any defect within the warranty period. Upon receipt of such notice, Seller, at its option, may require Buyer to return the fan at Buyer's cost to Seller for inspection by Seller. If the fan is found to be defective on inspection by Seller, as a sole and exclusive remedy, Seller will, at its option, either repair or replace the fan. This warranty shall not apply to damage on account of misuse,

neglect or accident or shipping damage, or if repairs or part replacements have been made or attempted without Seller's prior written authorization. SELLER SHALL NOT BE LIABLE IN ANY EVENT FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES FOR BREACH OF THIS OR ANY WARRANTY. THIS WARRANTY IS IN LIEU OF ALL OTHER GUARANTEES OR EXPRESSED WARRANTIES AND ALL IMPLIED WARRANTIES, INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY AND OF FITNESS FOR A PARTICULAR PURPOSE. DUE TO THE VARIETY OF CONDITIONS UNDER WHICH THE FANS MAY BE USED, RISKS OF RESULTS OBTAINED FROM USE OF THE FANS, WHETHER USED ALONE OR IN COMBINATION WITH OTHER PRODUCTS, IS ENTIRELY BUYER'S. THE ABOVE LIMITATIONS ON DAMAGE AND EXCLUSION OR LIMITATION OF IMPLIED WARRANTIES ARE NOT APPLICABLE TO THE EXTENT PROHIBITED BY STATE LAW.

# 3.5 PARTS LIST



DWG. NO.	SHOP PART NO.	DESCRIPTION
1	913	22 MM ALUMINUM CLEVIS/BLADE BOLT
2	644	SMALL CLEVIS CLAMP
3	914	22 MM ALUMINUM CLEVIS/BLADE BOLT NUT
4	912	HUB TUBE BOLT
5	608	CLAMP STUD
6	169	16 MM ALUMINUM NUT
7	931	CLEVIS
8	939	LARGE MOUNT (3" LONG)
9	151	5/8" ALUMINUM FLAT WASHER
10	52	5/8" RESILIENT WASHER
11	1345	10MM STAINLESS STEEL STUD FOR QDSF BUSHING (3)
	1347	12 MM STAINLESS STEEL STUD FOR QDE BUSHING (3)
	1558	16 MM STAINLESS STEEL STUD FOR QDJ BUSHING (3)
12		QDSF, QDE OR QDJ TYPE BUSHING
13	1346	10MM STAINLESS STEEL NUT FOR QDSF BUSHING (3)
	1348	12 MM STAINLESS STEEL NUT FOR QDE BUSHING (3)
	1559	16 MM STAINLESS STEEL NUT FOR QDJ BUSHING (3)
14	911	ANCHOR PLUG

## 4.0 OPERATION

### 4.1 AERODYNAMIC ABUSE

#### 4.1.1 ABOUT THIS SECTION . . .

It is widely acknowledged that the kinds of mechanical abuse described on the preceding pages are destructive for all types of operating equipment. It is less well recognized that — for fans — aerodynamic stresses are an even more serious hazard. This section deals with the causes of destructive aerodynamic stresses and how they can be avoided.

Although this information is given primarily for the benefit of operators of Moore equipment, it may be applied to fans of any manufacture.

Unlike smaller fans, which are typically furnished complete with their surroundings, the large fan wheel is supplied as an unprotected component of the system and is installed in innumerable types of surroundings. Not only do the types and conditions of the drives for these fan wheels vary widely, but the entrance and exit conditions and the enclosure for the wheel assume a myriad of possible combinations. In designing his product, the manufacturer of fan wheels must anticipate the operating conditions based upon his knowledge of what is reasonable and customary for the industry. He may over-design for abnormal stresses only until the practical limit is reached to avoid excessive weight, cost and inefficiency.

#### 4.1.2 NORMAL OPERATING CONDITIONS

The fan manufacturer assumes a fairly reasonable atmosphere for the operation of his product, including the following:

- The fan selection will be reasonably in line with the performance the unit is expected to maintain, with an adequate blade area for the pressure required at the given RPM. Blades will not be loaded beyond their capacity to maintain air flow.
- A fan ring will be provided that is round, rigid and of a depth at least sufficient to cover the tips of the blades. Tip clearances will be uniform and controlled.
- The approach air will represent a relatively uniform and axial flow with, of course, some unavoidable turbulence expected. Adequate open area will be provided at the inlet of the fan.
- Major obstructions will not be present at either the inlet or discharge of the fan.
- The RPM of the fan will be within the design limits.
- The relative direction and velocity of approaching air to the blades will be fairly constant and protection will be provided from extreme wind conditions.

Under such conditions, the unit stresses in the blades would not be expected to vary more than plus or minus 50%. Fan design based on such assumptions is entirely reasonable and, with proper drives and installation conditions, has proven highly successful.

#### 4.1.3 ABNORMAL CONDITIONS

Abnormal operating conditions result in destructive repetitive stresses that can seriously shorten fan life. The aerodynamic abuses discussed in this section can cause repeated flexing of the fan blades and hub. Violent displacement of the resiliently mounted Moore fan blades may occur — a greater displacement than would occur in rigidly mounted blades. The resilient mounting, of course, minimizes the structural unit stresses which would be transmitted to the root of the blade and into the hub and drive. Although Moore units may be expected to resist greater stress than units of conventional design, such repetitive stresses may exceed the capability of the resilient mounts to absorb them. If so, fatigue of the mounts and metal may develop, adjusting linkages may wear, and ultimate failure becomes a possibility.

Some of the abuses set out in the following text are far less important than others. All of them may occur in varying degrees.

Specifically, abuse due to serious repetitive stresses can lead to mount failure and, if carried to extremes, can cause clevis breakage and failure in the box section due to the end of the box section repeatedly striking the clevis as the blades are violently displaced. In units of other manufacture with rigidly mounted blades, repetitive stresses of this type may lead to blade breakage, probably near the root or at the point of attachment to the hub where stresses are highest, or may lead to failure of the hub itself. The resilient mount design, unique with Moore fans, dampens these vibrational forces and results in a fan that is far less vulnerable to failure from these conditions than other units with rigidly mounted blades. Even so, extreme conditions can cause damage.

A well-designed fan can be expected to operate for many years without trouble under normal operation as described above. The extreme repetitive stresses described below, however, will certainly reduce the life of the fan, causing failure many years sooner than would occur if the fan were operated as intended. Fortunately, these destructive conditions are readily observable to someone who is knowledgeable about them, and they can be corrected with reasonable effort and expense once they are observed.

## 4.2 BLADE OVERLOAD

Of all the aerodynamic abuses to be avoided in the operation of a fan, the most important is that of overloading the fan blades. Blade overload occurs because of insufficient blade area: In other words, when there is an inadequacy in the number of blades on the fan selected.

The Moore system of rating is based upon the pressure that each blade will produce at a given RPM with good efficiency. This pressure is called 100% blade load. When blade load exceeds 110%, the fan will not only operate at lower efficiency, it may be subject to structural damage as well.

In selecting a fan, the total pressure divided by the pressure to be produced by one blade determines the number of blades required for the anticipated performance. Whenever information is available, The Moore Company checks the selection. Even so, underestimation of the pressure requirements by the system designer, or changes in the operating conditions over time, may result in overload conditions.

Why is a blade overload condition of such concern? We are all aware of the fact that an airplane traveling at a given speed can carry only a certain load. If the speed of the airplane is decreased or the load increased, stalling flow over the wing will occur. In the case of an airplane, approximately two-thirds of the lift provided by the wing is the result of the air flow over the top or convex portion of the wing. Lift is provided as a reaction to the flow of air being accelerated and deflected downward as it passes over the wing. A negative pressure area is thus formed on the top surface of the wing which tends to lift it upward.

So long as air flow over the wing is smooth and clings to the surface of the wing, little turbulence is present. When the load is increased, or the speed decreased, the angle of the wing to the air stream must be increased to a point where the air flow breaks away from the upper surface of the wing. This is known as stalling or burbling flow, since the air, instead of clinging to the wing, breaks away near the leading edge and leaves what might be called a turbulent void above the upper wing surface, nullifying the accelerated flow which was responsible for the greater part of the lift of the wing.

When this occurs, the wing loses a large portion of its lift. Flow, however, will re-establish briefly and break again, the cycle being repeated continuously, resulting in a severe

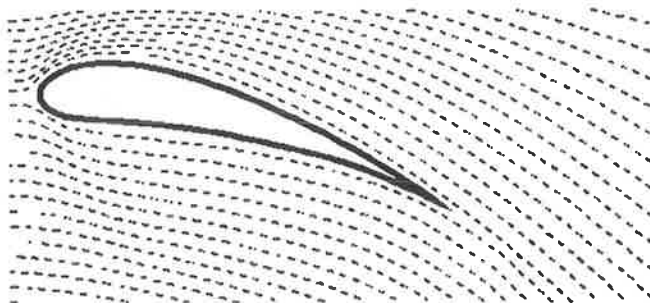
vibration throughout the aircraft as the flow alternately makes and breaks. Anyone who has experienced a stall in an airplane will be familiar with this violent phenomenon.

A fan blade is no different than an airplane wing except that the air usually is being deflected upward rather than downward, the convex side of the blade being the lower surface rather than the upper surface as in the case of an airplane. The result of blade overload is identical: When blade load exceeds that allowable, a violent vibration will take place in the blade as the laminar, or uniform, flow makes and breaks perhaps many times a second.

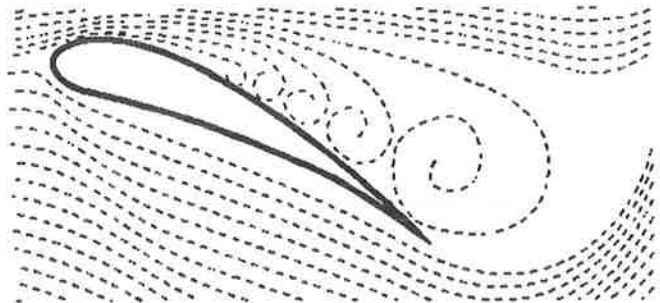
Another way of looking at this problem is to consider that the available number of blades are set at too steep an angle to be able to move air at the axial velocity which is necessary to maintain a smooth flow over the convex surface. In other words, to move air at the velocity necessary for this blade angle, plus overcoming the static resistance of the system, the total pressure which would have to be maintained for an air flow corresponding to this angle is greater than the total pressure capability of the given number of blades at this RPM. Such a condition can only be corrected by decreasing the blade angle until smooth flow is obtained or by increasing the number of blades and the total pressure potential of the fan until the fan's pressure potential equals the pressure necessary to move the specified quantity of air through the system.

Continued operation under conditions of stalling flow, or blade overload, will significantly shorten the life of the fan. Operation under these conditions will also reduce efficiency to a ridiculously low figure. See the chart under Section 4.4 Checking Blade Load which follows. Note that although air flow remains constant or decreases, horsepower continues to increase with increased blade angle.

In conclusion, if a given fan, in a given installation, can only absorb forty horsepower, for example, the blades may be pitched up to consume fifty horsepower without any increase in air delivery, and possibly with a decrease. As a result, the extra ten horsepower is totally wasted--perhaps worse than wasted. It is good practice to select a sufficient number of blades so that blade load will amount to slightly less than 100% of full blade load when consuming 100% of the rated fan horsepower. There are a number of reasons for allowing this safety factor which are set out in detail below.



**AIRFLOW IN NORMAL FLOW**  
Downward flow provides lift to the wing



**AIRFLOW IN STALLING FLOW**  
Note lack of air deflection downward.

## 4.3 CAUSES OF IMPROPER BLADE LOADING

### 4.3.1 VARIATION FROM PREDICTED CONDITIONS

Although those who design air coolers and cooling towers undoubtedly do their best to accurately state the calculated static resistance of the system, a number of factors may cause the actual conditions to vary from the design conditions. When a variation occurs, it may be found, upon testing, that the static pressure for a given volume through the system is higher than anticipated. In this case, the number of blades provided may be inadequate to meet the performance. On the other hand, the static pressure may have been overestimated and excess blade area provided, resulting in a fan with unutilized capacity operating at low efficiency.

**Inadequate Blade Area:** The blade angle is selected to move the anticipated volume of air and the number of blades is selected to maintain the total anticipated pressure required to move this volume at a given RPM. If the static pressure turns out to be higher than predicted, the fan may then be operating in an overload condition. If the RPM cannot be increased, the only solution to this condition is to reduce the blade angle until the fan can carry the then reduced volume at the originally anticipated pressure. Since reducing the volume, while holding the total pressure as originally anticipated, can only reduce the horsepower, it is then impossible to consume the horsepower originally intended without overloading the fan. This is one of a number of reasons for providing some safety factor in blade loading at the time of original fan selection.

**Excessive Blade Area:** Occasionally, an excessive number of blades may be specified in the interest of making a conservative selection. If the static pressure has been overstated, the theoretical number of blades will be greater than needed. This theoretical number of blades is usually a fractional number and the actual number of blades used must, of course, be the next larger integer, resulting in some "safety factor" in the selection. If, in addition, a blade or two is added as a "safety factor" or in anticipation of increased future requirements, it may be impossible to meet the original performance requirement efficiently. The only way to provide the original performance and draw no more than the original horsepower is to flatten the blade angle. There is a limit, however, in how far the blade angle may be reduced before further reduction will decrease airflow without a further reduction in horsepower. For belt drive units, the most practical solution to this problem is to reduce the RPM of the fan.

### 4.3.2 EXCESSIVE TIP CLEARANCE

Unless the fan ring is very close to the tip of the blade, air from the high pressure surface of the blade will flow around the tip and nullify the negative pressure on the underside of the blade for some distance in from the tip. For a fan of, say, 12-ft diameter, the last 12 to 18 inches of the blade could be producing no pressure what-

ever and performing no useful function. The balance of the fan blade toward the hub then must produce a higher pressure to compensate for the portion near the tip.

Excessive tip clearance also leaves an unswept area between the tip of the blade and the fan ring. Air that has been pumped by the fan will return downward through this unswept area at a velocity greater than that at which it passed through the fan in the desired direction. This condition adds even further to the requirements of the portion of the blade which is doing the work and efficiency will be greatly reduced.

With the loss of a foot at the tips of the blades, plus the back flow between the tips and the ring, the 12-ft fan in this example might be considered an effective 10-ft fan. It would have to deliver sufficient air to satisfy the performance requirements of the installation, plus the amount of air which is returning in the void between the tips and the throat. Under such circumstances, excessive blade loading could occur even though the required system pressure is not achieved.

### 4.3.3 POOR ENTRANCE CONDITIONS

Air will approach the fan from all possible directions, increasing in velocity as it nears the opening, then accelerating rapidly as it enters. The air approaching from the side must be turned through 90° to enter a ring whose entrance terminates in a flat plate. If the inlet end of the ring projects some distance out, with approach possible from all directions, a portion of the air must be turned through 180°. The inertia of the approaching air prevents it from turning sharply and advancing parallel to the desired flow. It consequently swoops toward the center, leaving the outer area of the fan with reduced flow or even reverse flow near the ring.

The effect of poor entrance conditions is similar to that previously described for excessive tip clearance in that the effective diameter has been reduced and excessive blade loading could occur even though the required system pressure is not achieved. Efficiency will be greatly reduced.

### 4.3.4 EXCESSIVE DEFLECTION

The pressure which the fan can achieve is dependent upon the square of the velocity of the blades relative to the air. If the air could be moved into the fan in an axial direction and passed through the fan into the discharge without changing direction, the relative velocity of the blades to the air stream would be the true velocity of the blades at any point. This, of course, is not the case. For the blades to accomplish work upon the air, they must also deflect the air in the direction of rotation of the fan. The air when rotated with the fan is moving with a certain velocity in the same direction as the rotation of the fan, which reduces the relative velocity between the fan blades and the air by some portion of this rotational velocity.

Moore fans are designed in contemplation of a maximum deflection of 50° at the hub, decreasing to a very small value at the tip. This deflection is considered in the determination of the pressure which may be provided by each blade over its full length. If fans are selected, or if conditions exist, which cause the deflection to exceed 50° at the hub, the velocity of the blades relative to the air is less than anticipated and the blades will not provide the rated pressure. The test below, however, will show the full allowable pressure capability of the fan, even though it does not reach the full rated pressure.

## 4.4 CHECKING BLADE LOAD

One method of checking blade load is to run a complete field test on the fan. Although laborious, this method will provide ample proof so long as neither excessive tip clearance nor poor entrance conditions are present. If either are present, however, the conditions set out above under Section 4.3.3 would apply and the fan could be overloaded even though the total pressure indicated by the test was within the allowable blade loading.

A better, more convenient and simpler method of detecting blade overload, or determining maximum allowable blade angle, is set out below. The equipment needed is a wrench, a torque wrench, a protractor and a draft gauge (or manometer).

All fans are shipped with the blade angle set for the anticipated performance requirements furnished to The Moore Company by the purchaser. This blade angle is called out on Section 1.1 Fan Specifications. This angle refers to the angle of the top or bottom of the clevis with the horizontal. Hubs are shipped with the clevises set at this angle.

To start the test, adjust the blades to an angle of approximately half that called out on the specifications or measured on the units. Connect the draft gauge to as quiescent a spot in the plenum as possible, preferably in the corner of the plenum and either ahead of or following the fan, depending upon whether the application is induced or forced draft. Since the figures obtained are purely relative, it is not necessary that accurate static pressure readings be obtained, but rather that the readings taken represent a consistent series of pressures at the point of reading chosen.

Start the fan and record on the chart provided the blade angle and the static pressure indicated. Advance the blade angle by one or two degrees and repeat the performance, recording again these readings. Keep increasing

## 4.3.5 CONCLUSION

As can be seen by the various points discussed in this section, there are a number of complex factors which tend to cause fans to be operated in a condition of improper blade loading which can shorten fan life or lower efficiency. When blade angles are set to consume the specified horsepower (at the fan shaft), the resulting performance should be very close to the specified performance. If this is not the case and the problem cannot be identified or corrected, please contact The Moore Company for assistance.

the angle and following this procedure until the motor is fully loaded, in which case the fan is able to consume full rated fan horsepower without overload OR until the curve which will have started on a definite slope begins to approach the horizontal. It will be noted that the static pressure will be consistently increasing with increased blade angle until the blade loading reaches maximum, at which point it will level off.

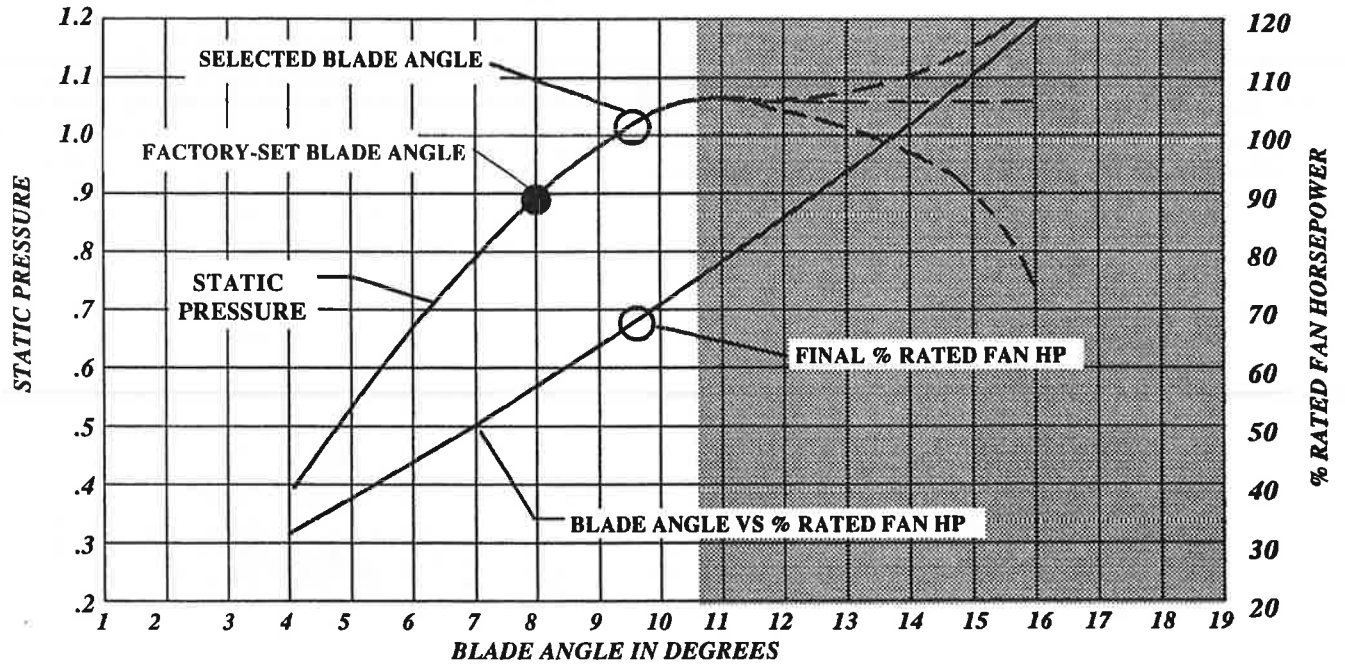
Subsequent increases in blade angle may have quite different effects, depending on the individual installation. The static pressure curve may merely stay level or may drop off sharply. In rare cases, it may level off and again start rising as the fan begins operating as a centrifugal blower.

Typical examples are shown in dotted lines on the chart opposite. Operation beyond the first point of leveling, or in the area of the dotted lines, is indicative of blade overload. Note that power consumption load will continue to increase even though the fan has passed into overload condition. The maximum blade angle allowable is that which produces a static pressure about 5% below the point where the curve becomes level. This represents a safe loading, and the blades may be set and left at this angle regardless of the location on the chart, assuming the motor is not overloaded.

The point so selected will also approximate the point of the most efficient operation of the fan. Due to possible error in static pressure predictions, or in readings which are intended only to be relative, as well as other variables, the final blade setting chosen may fall below or above the specified static pressure.

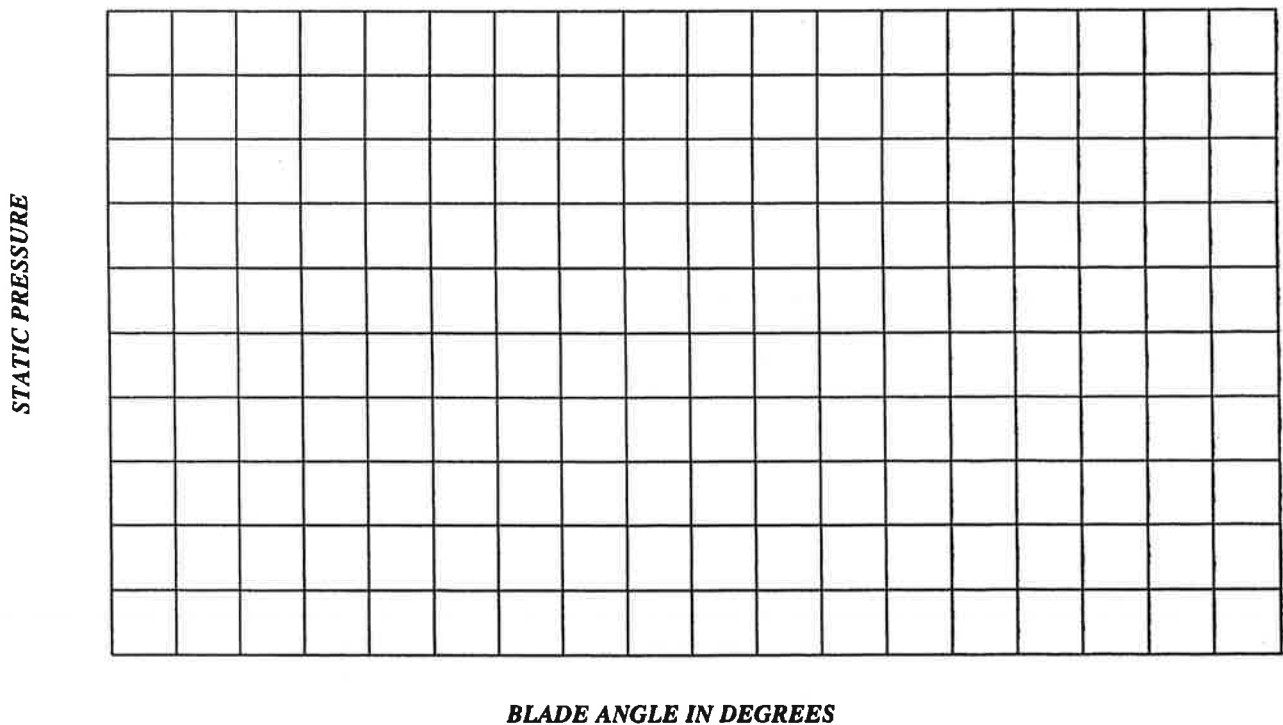
A typical performance chart is shown opposite for a fan capable of a higher blade loading than originally specified. A blank chart is also provided for your use.





Note in the chart above that static pressure (and air flow) has reached its maximum at an 11 degree blade setting and blade overload is beginning. With further increase in blade angle, anything may happen, as indicated by the dotted extensions into the shaded overload area. Note

that the final selected blade angle is 5% below the point where the static pressure curve becomes level. The horsepower curve has been added to illustrate the point that in an overload condition, horsepower will increase without increased performance.



BLANK CHART FOR CUSTOMER USE

## 4.5 DAMAGING OPERATING CONDITIONS

### 4.5.1 GENERAL

Any condition which causes repeated blade loading and unloading is detrimental to fan performance, both in terms of efficiency and structural durability. Normal obstructions, of course, must be expected in the air stream. There are certain conditions, however, which may be avoided by reasonable attention to the points briefly discussed in this section. Additional information on the importance of inlet and discharge conditions can be found in The Moore Company's General Catalog.

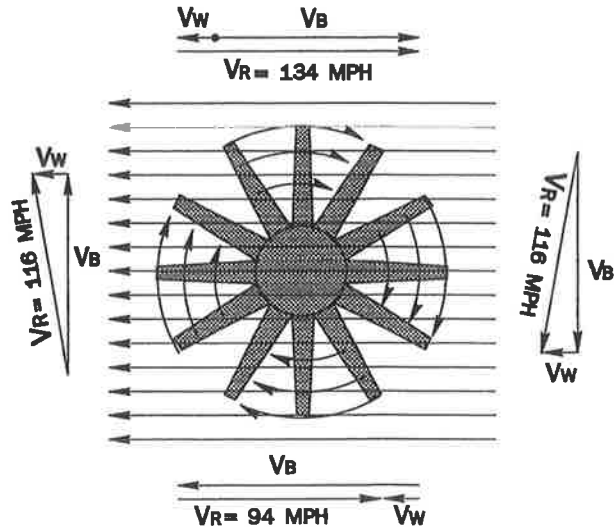
Ideally, air should approach a fan in an axial direction and at a uniform velocity over the area of the fan. Air approaching a fan at an angle tends to increase the relative velocity of the blades to the air on one side of the fan and decrease the relative velocity on the other side. This means that the fan blade during one-half of its revolution is picking up a heavier air load due to the higher relative velocity and, through the other half of its revolution, a lower air load as it goes "down wind". The net result is a repetitive loading and unloading of the blades at each revolution of the fan. This condition can be quite serious if the velocities are high and the angle of approach deviates considerably from axial.

### 4.5.2 WIND

With a vertically mounted fan blowing outward into the wind and surrounded by a short fan ring or stack, high winds may cause some concern. The farther the ring extends beyond the fan, the less effect would be expected from wind. It is a fact, however, that wind across the face of the ring will affect the direction of air flow well down into the ring. In the case of a fan installed near the outlet of the ring, the direction from axial of the fan discharge may be increased by as much as 45° under high wind conditions.

In the case of a fan blowing inward in a short ring, the condition is even more critical. In such an installation, the air on the inlet side of the fan has a horizontal velocity which may be quite high. It is necessary for the fan to pick up this air and direct it inward. In a strong wind, the angle of air moving through the fan may be increased more than 45°.

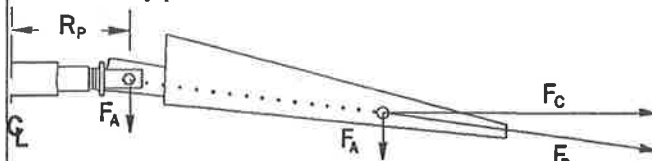
The illustration above assumes a fan operating with a tip speed ( $V_B$ ) of 10,000 feet per minute (114 miles per hour) with



a horizontal component of wind velocity ( $V_W$ ) of 20 miles per hour. Note that the velocity ( $V_R$ ) of the fan blade relative to the air varies by a factor of 1.43. The blade load varies as the square of this velocity, or 2.05.

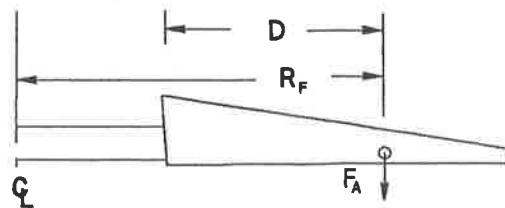
### THE EFFECT OF AIR LOAD ON HUB AND DRIVE

Moore fan blades are attached to the hub by a pivot. As the fan rotates, centrifugal force causes the blades to rise (as do the blades of a helicopter). The air load ( $F_A$ ) is uniform over the blade, but there is a point (shown on the blade in the drawing below) where, if the total load were applied at that point, the effect would be the same. The resultant of the air load ( $F_A$ ), assumed in this example to be downward, and the horizontal centrifugal force ( $F_C$ ) is the force on the blade ( $F_B$ ). The blade automatically positions itself in the direction of this force with



the result that the force is translated inward to the pivot point, as illustrated by the dotted line. The effect of this arrangement is exactly as if the total air load ( $F_A$ ) were applied at the pivot point rather than at the point outward on the blade. The maximum bending moment applied to the shaft by the air load is equal to the load ( $F_A$ ) multiplied by the distance from the fan centerline to the pivot point ( $R_p$ ).

In conventional fans with rigidly attached blades, the bending moment at the shaft due to the air load is equal to the load ( $F_A$ ) multiplied by the distance from the fan centerline to the point of application of the force on the blade ( $R_f$ ). This moment will be from 2 to 4 times as great as that produced by the Moore fan under the same conditions.



Also of concern with the conventional fan is the bending moment due to the air load at the point of attachment of the blades to the hub since this is usually the structurally weakest area of the fan. The moment due to the air load at this point is the load ( $F_A$ ) times the distance ( $D$ ). For the Moore fan, this moment is zero since the blades are attached at the pivot point.

A more complete discussion of the Moore fan design can be found in The Moore Company's General Catalog.



In this rather common wind condition, then, it can be seen that the blade load on the side where the blade is going against the wind will be double the load on the side where the blade is going with the wind. In a 40 mile per hour wind, the blade load would vary by a factor greater than 4. In a 60 mile per hour wind, the load would vary by a factor of more than 10! It is obvious that operation under such conditions will impose tremendous repetitive loadings on the fan blades.

In areas of unusually high wind velocities, it may be advisable to shield the fan in some manner.

#### 4.5.3 OBSTRUCTIONS

Obstructions of one type or another in the air stream, ahead of or behind the fan, are to be expected. In fact, it would be virtually impossible to eliminate all obstructions. Structural supporting members, foundations and the like, need not be of serious concern although all obstructions, even small ones, will increase the static pressure and must be taken into consideration by the system designer in specifying the fan performance.

The total free area from which the fan can draw air should be twice the net area of the fan (fan area minus hub area). In other words, the air approaching the inlet of the fan should have no more than half the velocity of the air passing through the fan. This area

should be distributed reasonably uniformly. It would be unwise to attempt to operate a fan with one-half or one-third of the fan area completely blanked off. Such a condition would cause stalling of the fan blade through one-half the revolution but create a condition of overload in the half which was not blocked off. Excessive vibration would result. Any condition which forces the air to approach the fan in a non-axial direction should be avoided.

#### 4.5.4 UNEVEN TIP CLEARANCE

Where fan rings are out of round or not centered with the fan, the tip clearance of each blade will vary as it makes a revolution. If tip clearance is tight at one point and excessive at another, proper flow will establish itself at the tight point, loading the blade to the very tip, while at the loose point the air will flow from the high pressure side of the blade through the opening between the blade tip and the ring and nullify the negative pressure on the under side of the blade. This will unload the blade near the tip within the area of excessive tip clearance. Under this condition, the blade will load and unload near the tip one or more times per revolution, resulting in an undesirable repetitive vibration. Every effort should be made to keep the tip clearance to a minimum and to have this clearance as constant as possible around the entire ring.



**IMPORTANT . . .**

Moore fans are frequently sold to original equipment manufacturers who sell their products, including the fan, to their customers who are usually unknown to The Moore Company. This makes it difficult for Moore to give prompt assistance to the owner in later years when more information or parts are required. By returning the Owner Registration card below, you will assure that The Moore Company will have accurate and detailed information about your fans in their permanent records, indexed by your company name, which will be readily accessible in the future. Owner registration will also make it possible for Moore to keep you informed about fan developments and new publications which may be of interest to you.

## OWNER REGISTRATION

**PLEASE  
TAKE A  
MOMENT TO  
COMPLETE  
AND  
RETURN  
THIS CARD  
NOW!**

**OWNER AND ULTIMATE USER:**

COMPANY NAME: \_\_\_\_\_

MAILING ADDRESS: \_\_\_\_\_  
\_\_\_\_\_

OWNER'S ADDRESS AT SITE:  
\_\_\_\_\_

**OWNER'S REPRESENTATIVE AT SITE:**

NAME: \_\_\_\_\_

TITLE: \_\_\_\_\_

PHONE: \_\_\_\_\_

FAX: \_\_\_\_\_

**MOORE JOB NO(S):** \_\_\_\_\_

**SERIAL NO(S):** (IF JOB NO. IS UNKNOWN)  
\_\_\_\_\_

**OWNER'S REFERENCE NUMBER(S):** \_\_\_\_\_

**INSTALLATION DATE:** \_\_\_\_\_

**TYPE OF INSTALLATION**  
\_\_\_\_\_

# For new users of Moore fans .....

Moore fans have a number of unique features. Some of these features are summarized here so that our new customers will understand their important advantages. If you would like to have more information about Moore fan design, please request a copy of The Moore Company's Engineering Catalog.

## Resilient Blade Mounting

Like the blades of a helicopter, Moore fan blades are attached to the hub by a pivot. In operation, centrifugal force causes the blades to rise to their working position. The pivot itself is surrounded by a vibration-absorbing resilient material. There are two major advantages to this design:

1. Compared to fans with rigidly mounted blades, only 1/4 to 1/2 of the stresses caused by the air load are transmitted to the hub and drive, substantially increasing the life of the fan driving mechanism.

2. Moore fans are ideally suited for operation by variable speed motors — the most efficient method for varying air flow — since resonant frequencies are eliminated and there are no critical speeds to be avoided.

## Low Inertia

Fan blades are jig-formed to the complex shape required for high aerodynamic efficiency. This method provides a blade that is rigid, yet lighter weight than possible with other forming methods. This lighter weight results in low blade inertia and lowers the possibility of fan damage in case of sudden emergency stops typical of engine drive operation.

## Odd or Even Numbers of Blades

Moore fans do not require an even number of blades since all blades are balanced to a standard moment. Because of the importance of avoiding either excess or insufficient blade area for efficient performance, it is an advantage to

be able to select any number of blades up to the physical limitation of the unit.

## Two Hubs

The ideal size of a fan hub from an aerodynamic point of view is much larger than the ideal size from a structural point of view. If the fan hub is too small, the blades do not terminate at the point where they become inefficient. Air flow will deteriorate or even reverse near the hub, resulting in wasted power. Yet, a hub of the size required by these aerodynamic considerations would be an extremely heavy and expensive structural member.

Moore avoids compromising on hub size by providing two hubs — a structural hub and an aerodynamic hub — each properly proportioned for its function. The aerodynamic hub is referred to as the air seal.

## Uniform Velocity from Hub to Tip

Uniform velocity over the entire blade area is the most important criteria of efficient axial flow fan design. To produce a uniform velocity throughout its length, a fan blade must vary from a thin, narrow tip to a thick, cambered root. Each point on the blade must have the proper combination of chord (blade width) and angle. This results in a great deal of twist in a properly designed blade.

Moore fan blades are jig-formed to provide the complex contour needed for high aerodynamic efficiency. Extruded blades (which must be of uniform width) cannot match the efficiency of blades that are properly proportioned.



NO POSTAGE  
NECESSARY  
IF MAILED  
IN THE  
UNITED STATES

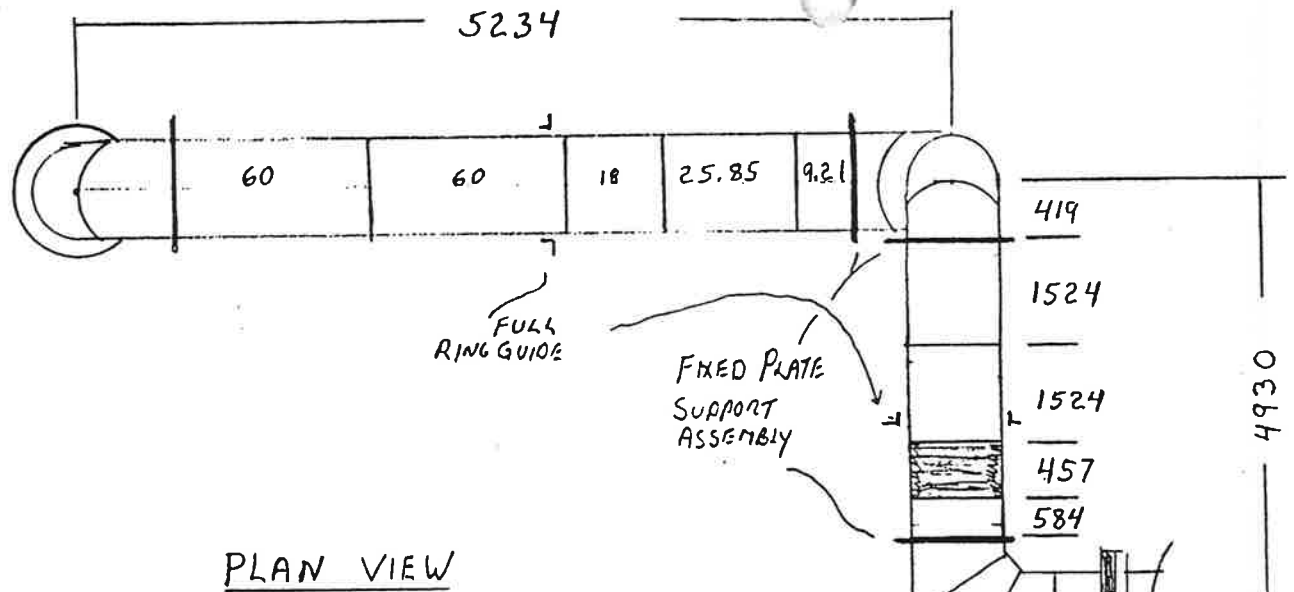


**BUSINESS REPLY CARD**  
FIRST CLASS PERMIT NO. 4 MARCELINE, MO.

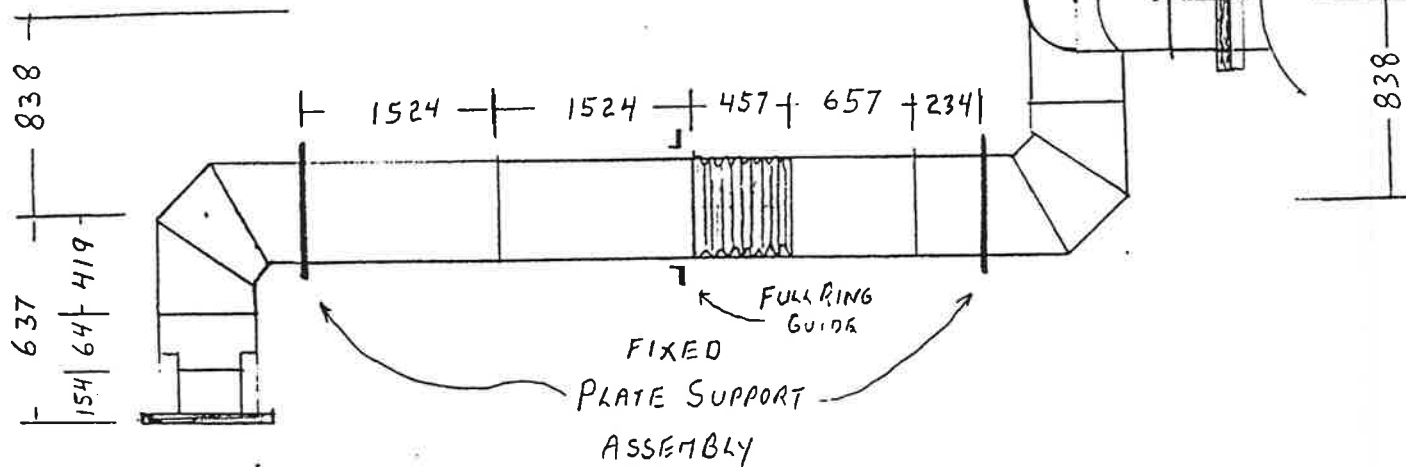
POSTAGE WILL BE PAID BY ADDRESSEE:

**THE MOORE COMPANY**  
**800 S MISSOURI AVENUE**  
**MARCELINE MO 64658-9985**





PLAN VIEW

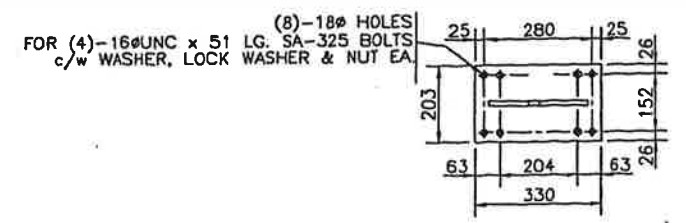
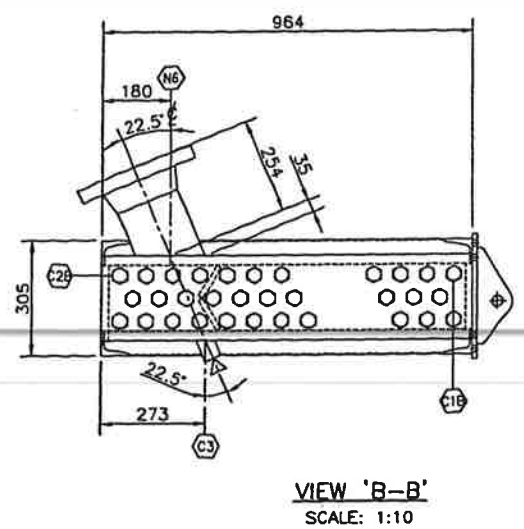
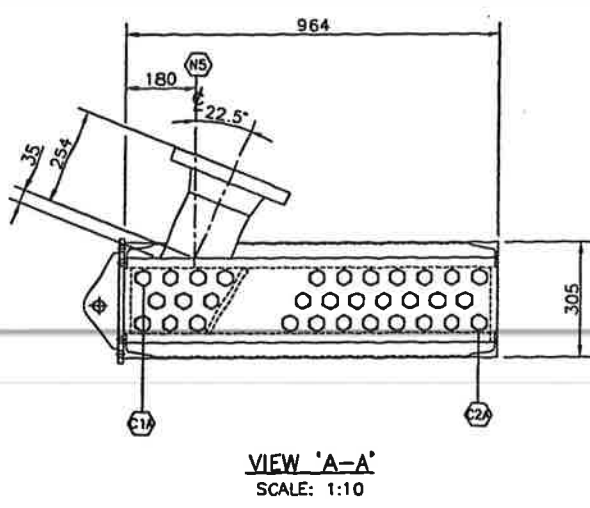
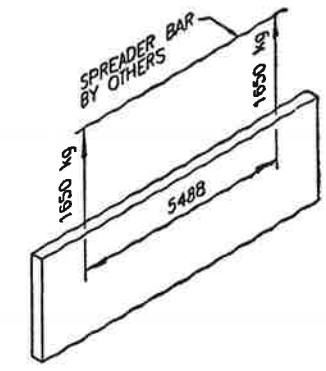
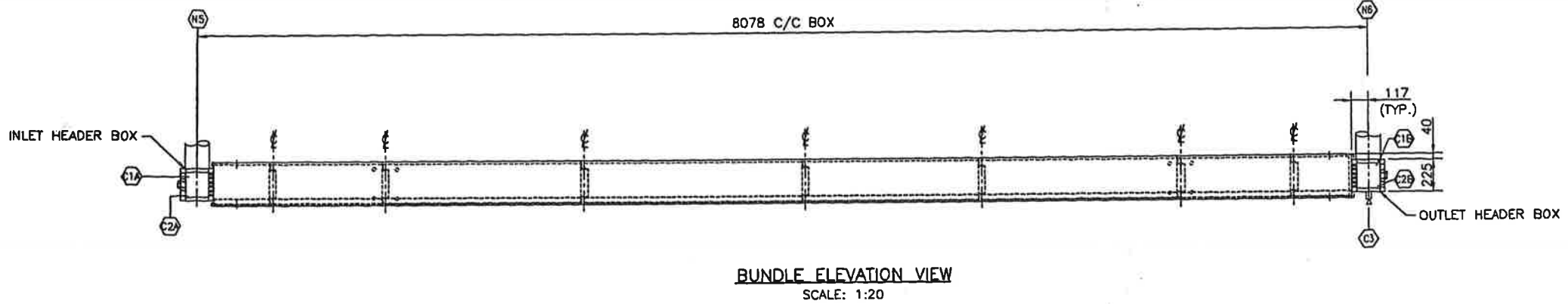
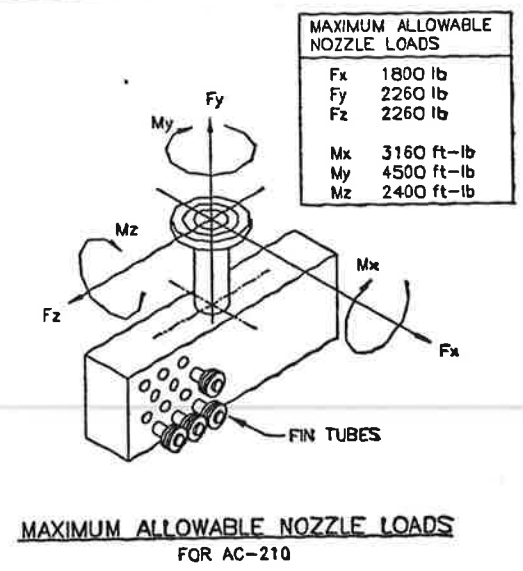
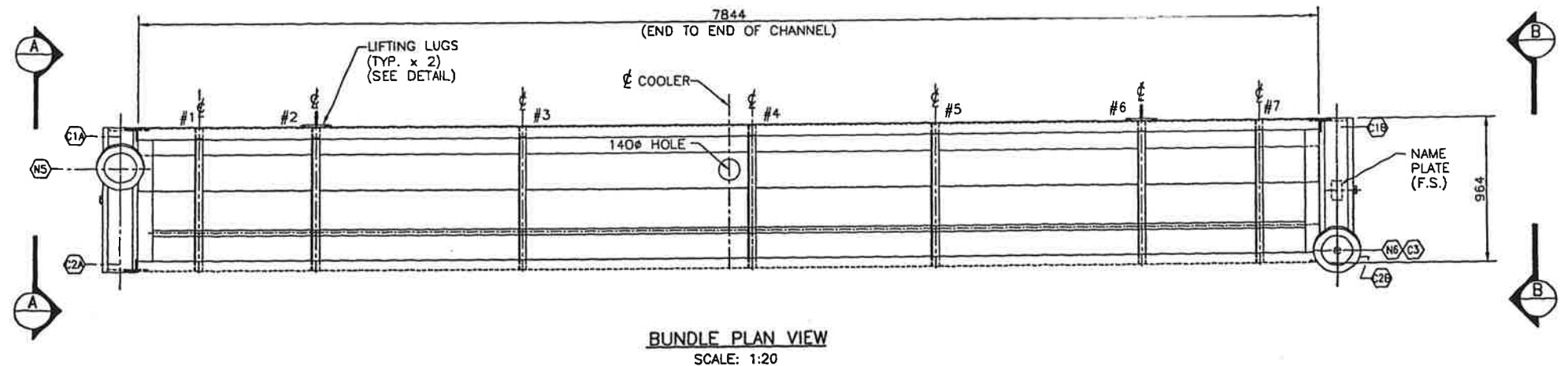


FRONT ELEVATION

PROPAK REV. 2
PROJECT 99404-352
P.O. 115520
S.E. LKIRK EXHAUST SYS
AIR CHECK OCT 19, 2000

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NOZZLE SCHEDULE									
MK	SIZE	RATING	FACING	SCH	SERVICE	EXT. PROJ	WELD		
N5	16B	300#	RFWN	160	INLET	254	-		
N6	16B	300#	RFWN	160	OUTLET	254	-		
A/B	C1	41	SLDR PLUG	12UN	-	VENT w/ PLUG	-		
A/B	C2	41	SLDR PLUG	12UN	-	DRAIN w/ PLUG	-		
A/B	C3	27	600	NPT	-	TC c/w PLUG	-		



- NOTES:**
- Holes spaced 204 apart are for 305 deep side channel holes 280 apart are for 381 side channel.
  - Shackle hole is designed so that the bottom of the suspended bundle will "kick out" slightly to aid in placement.
  - Lug should be permanently marked "2000 KG CAPACITY, (3000 KG DYNAMIC LOADING)".
  - Always use 2 lugs for lifting.
  - A spreader bar is req'd. to ensure straight up lift.
  - All materials SA-36.

**NOTE:**  
WEIGHTS SHOWN IN DIAGRAM INCLUDE 50% EXCESS FOR DYNAMIC LOADING  
LIFTING DIAGRAM WEIGHT w/o IMPACT LOAD: 2200 KG.

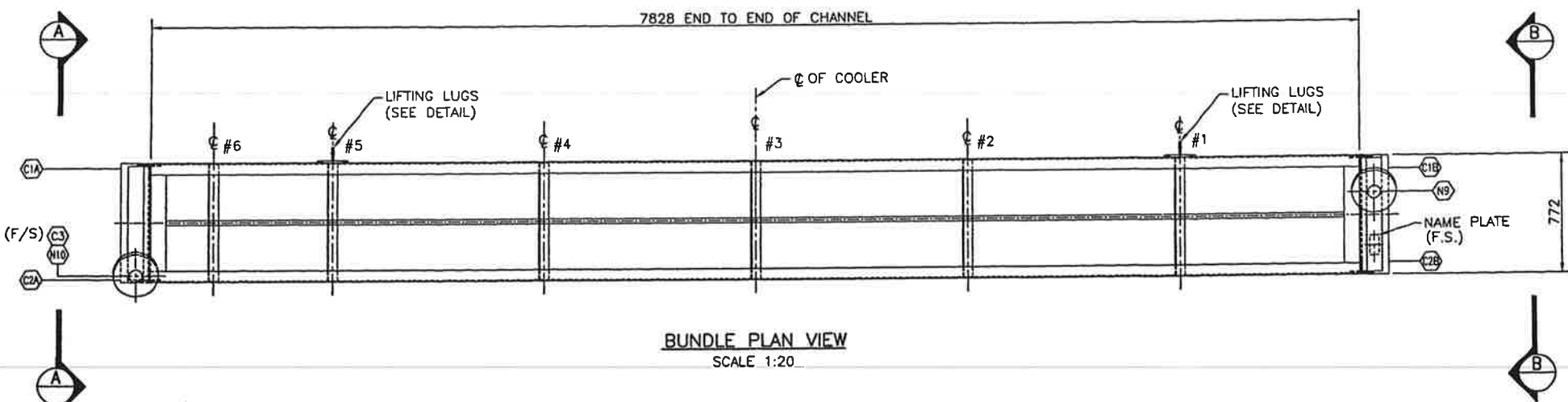
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WEIGHT EMPTY:	2200	kg	LSD NO.:		
WEIGHT FULL OF WATER:	2490	kg	CODE:	ASME SECT VIII DIV I, '98, ADDENDA '99	
SURFACE PREPARATION:			MAX. DES. PRES.:	4447	kPag
PRIMER:			DESIGN TEMP:	176	°C
FINISH PAINT:	PNT 12		CORR. ALLOW:	3.18	mm
INSULATION:	NONE		HYDROTEST:	6670	kPag
PROD. IMPACT TEST REQ'D:	NO		MDMT:	-28	°C
MECH. LOADS GOV. PER UG22:	NO			4447	kPag
IMPACT TEST:	NO-PER UG20(f) UCS-66(a); UCS-66(c)		MATERIAL: HDR BOXES:	SA-516-70N	
SHIP LOOSE:	NO		TUBES:	(SMLS) SA-179	
SERVICE:	NATURAL GAS		RADIOGRAPHY:	N/A	
			P.W.H.T.:	YES	
			MINIMUM TEMP:	594	°C
			FOR TIME:	1hr	
			<b>"SOUR SERVICE"</b>		
			TAG NO:	AC-210	

APPROVED		DRAWN		APACHE CANADA LIMITED		440 East Lake Road, Postal Bag #2 Airdrie, Alberta Canada T4B 2C3	
MECH/STRUCT.	BY	BY	CHECKED	1478 HP HAMBURG COMPRESSOR PACKAGE 1st STAGE INTERCOOLER AC-210			
DATE	DATE	DATE	DATE	DWO. No.: D-BDL-99404-233-SKT SHT. 1 OF 1 REV SKT			
ELECTRICAL	BY	BY	DATE				
PROJECT	DATE	DATE	SCALE	AS NOTED			
DATE	DATE	DATE	SCALE				
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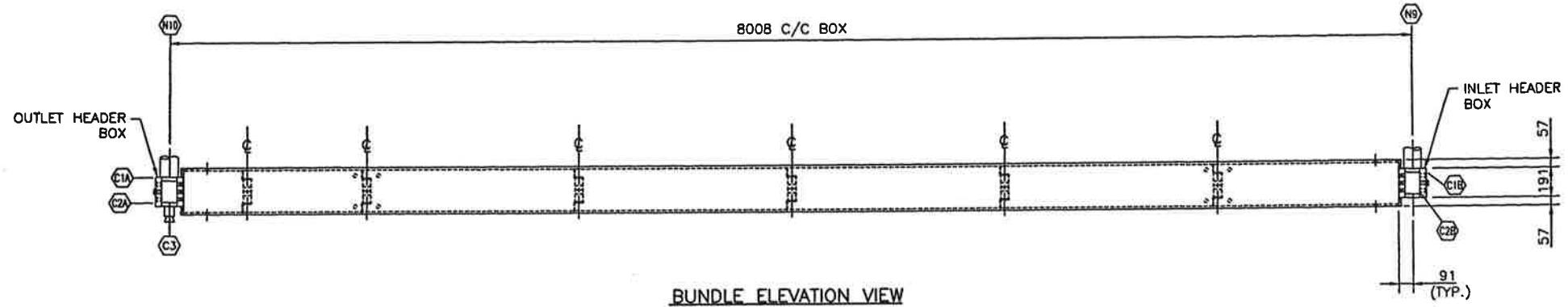




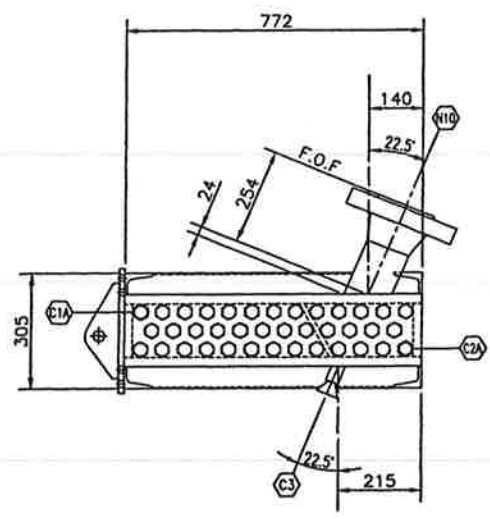
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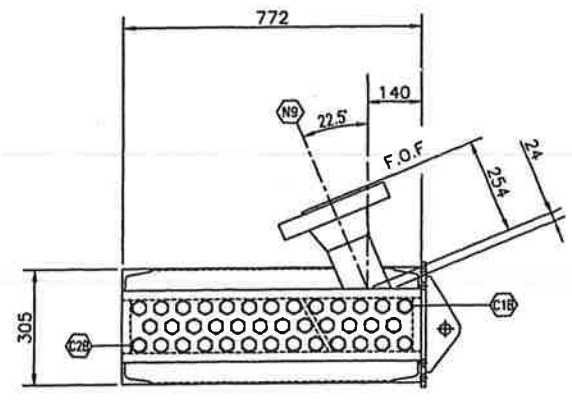
**BUNDLE PLAN VIEW**  
SCALE 1:20



**BUNDLE ELEVATION VIEW**  
SCALE 1:20

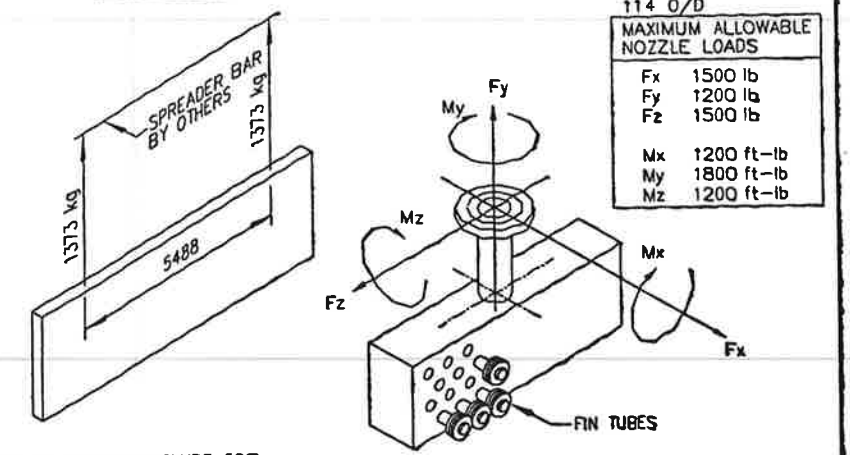


**VIEW 'A-A'**  
SCALE 1:10



**VIEW 'B-B'**  
SCALE 1:10

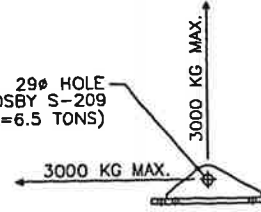
NOZZLE SCHEDULE									
MK	SIZE	RATING	FACING	SCH	SERVICE	PROJ	WELD		
N9	114	900#	RFWN	XXH	INLET	254	-		
N10	114	900#	RFWN	XXH	OUTLET	254	-		
A/B	C1	29	SHDR PLUG	12UNF	VENT	-	-		
A/B	C2	29	SHDR PLUG	12UNF	DRAIN	-	-		
A/B	C3	27	8000#	NPT	TC w/PLUG	-	-		



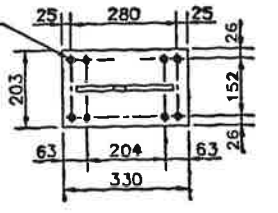
NOTE:  
WEIGHTS SHOWN IN DIAGRAM INCLUDE 50% EXCESS FOR DYNAMIC LOADING  
LIFTING DIAGRAM WEIGHT w/o IMPACT LOAD: 1830 KG

**LIFTING DIAGRAM**  
FOR AC-212

29# HOLE FOR CROSBY S-209 SHACKLE (WLL=6.5 TONS)



(B)-18# HOLES FOR (4)-16#UNC x 51 LG. SA-325 BOLTS, c/w WASHER, LOCK WASHER & NUT EA.



**REMOVABLE LIFTING LUG DETAIL**  
(2)-REQ'D. (REUSEABLE)  
SCALE: 1:10

- NOTES:**
- Holes spaced 204 apart are for 305 deep side channel. Holes 280 apart are for 381 side channel.
  - Shackle hole is designed so that the bottom of the suspended bundle will "kick out" slightly to aid in placement.
  - Lug should be permanently marked "2000 KG CAPACITY. (3000 KG DYNAMIC LOADING)".
  - ALWAYS USE 2 LUGS FOR LIFTING.
  - A SPREADER BAR IS REQ'D. TO ENSURE STRAIGHT UP LIFT.
  - ALL MATERIALS SA-36.

CAPACITY:	0.123	m <sup>3</sup>
SURFACE AREA OF TUBES INCLUDING FIN:	508.36	m <sup>2</sup>
WEIGHT EMPTY:	1830	kg
WEIGHT FULL OF WATER:	1953	kg
SURFACE PREPARATION:		
PRIMER:		
FINISH PAINT:	PNT 12	
INSULATION:	NONE	
PRODUCTION IMPACT TEST REQ'D:	NO	
MECH LOADINGS GOVERN PER UG 22:	NO	
IMPACT TEST: NO- PER UG20(f):UCS-66(a)		
	UCS-66(c)	
SHIP LOOSE:	NO	
SERVICE:	NATURAL GAS	

SERIAL NO:	99404-231	CRN:	
YEAR BUILT:	2000		
LSD NO.:			
CODE:			
ASME SECT VIII DIV I, '98, ADDENDA '99			
MAX. DESIGN PRESSURE:	11377	kPag	
DESIGN TEMP:	177	°C	
CORR. ALLOW:	3.18	mm	
HYDROTEST:	17065	kPag	
MINM DESIGN METAL TEMP:	-28	°C	
	11377	kPag	
MATERIAL: HEADERS:	SA-516-70N		
TUBES:	(SMLS) SA-179		
RADIOGRAPHY:	N/A		
EXCEPT FULL ON FLG/PIPE WELDS OF NOZZLE			
P.W.H.T.:	YES		
	MINIMUM TEMP: 593 °C		
	FOR TIME: 1 Hr		
TAG NO:	AC-212		

**"SOUR SERVICE"**

GENERAL NOTES		GENERAL NOTES		SKT	ISSUED FOR DOCUMENTATION	H. LE	00/09/15	VK	SW
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APPROVED		DRAWN	
MECH/STRUCT.	BY	DATE	DATE
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PROJECT	BY	DATE	DATE
DATE	BY	DATE	DATE
SCALE	AS NOTED		

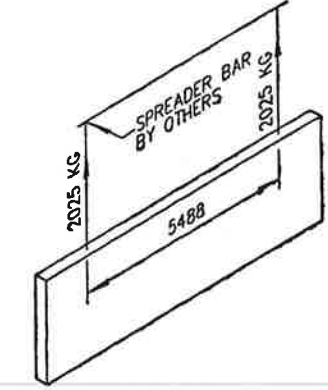
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1478 HP HAMBURG COMPRESSOR PACKAGE	
3rd STAGE GAS AFTERCOOLER	
AC-212	
DWG. No.:	D-BDL-99404-231-SKT SHT. 1 OF 1
REV. SKT	

**PROPAC**  
440 East Lake Road,  
Postal Bag #2  
Airdrie, Alberta  
Canada T4B 2C3



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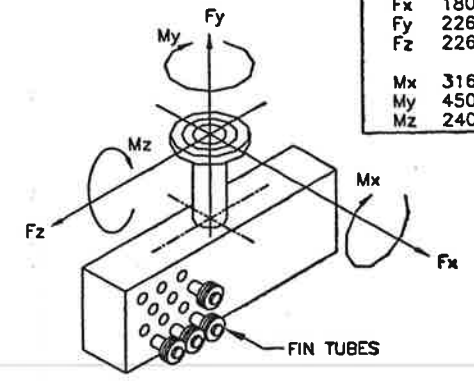
NOZZLE SCHEDULE							EXT. PROJ	WELD
MK	SIZE	RATING	FACING	SCH	SERVICE			
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N2	168	150	RFWN	80	EJW OUTLET (AC-220)	-	-	
A/B	C1	22	SLDR PLUG	14 UNF	VENT	-	-	
A/B	C2	22	SLDR PLUG	14 UNF	DRAIN	-	-	



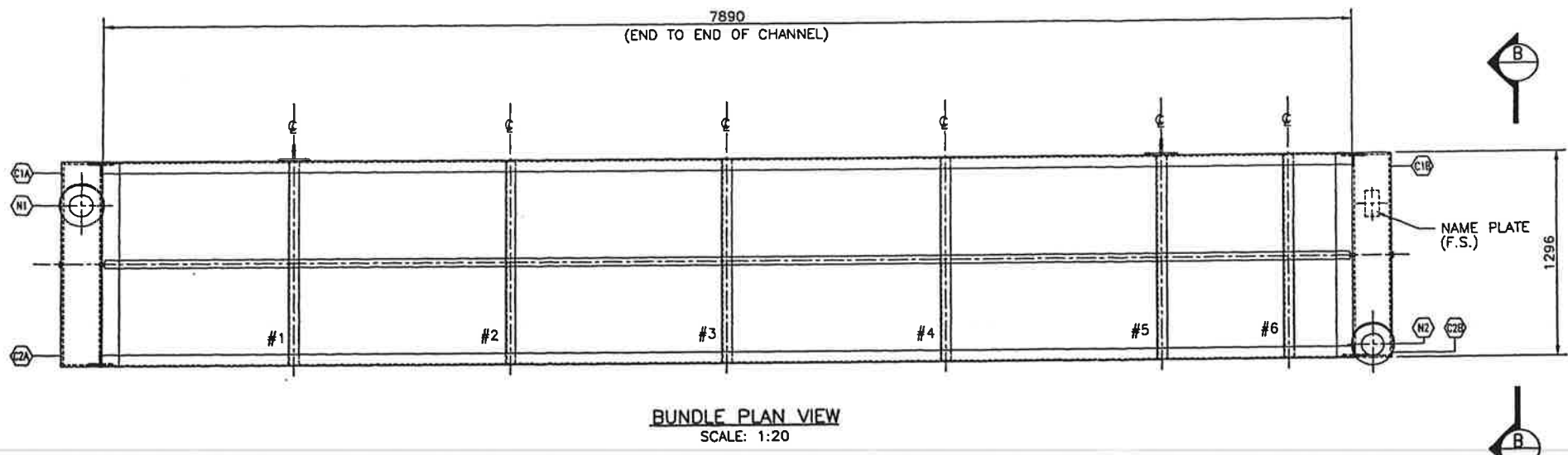
**LIFTING DIAGRAM**  
FOR AC-220

**NOTE:**  
WEIGHTS SHOWN IN DIAGRAM INCLUDE 50% EXCESS FOR DYNAMIC LOADING  
LIFTING DIAGRAM WEIGHT w/o IMPACT LOAD: 2700 KG.

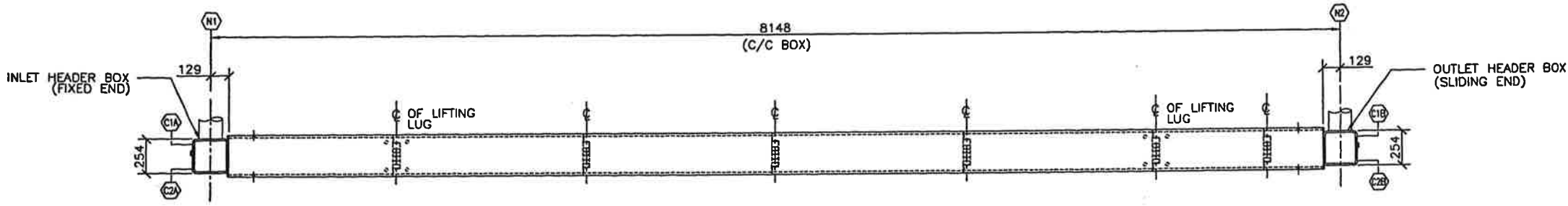
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F <sub>x</sub>	1800 lb
F <sub>y</sub>	2260 lb
F <sub>z</sub>	2260 lb
M <sub>x</sub>	3160 ft-lb
M <sub>y</sub>	4500 ft-lb
M <sub>z</sub>	2400 ft-lb



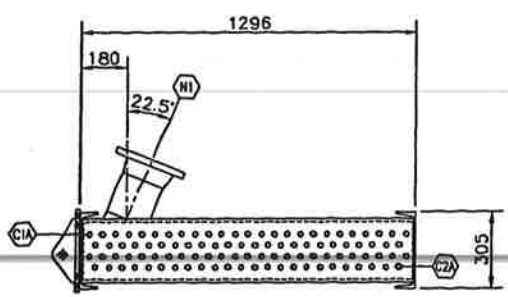
**MAXIMUM ALLOWABLE NOZZLE LOADS**  
FOR AC-220



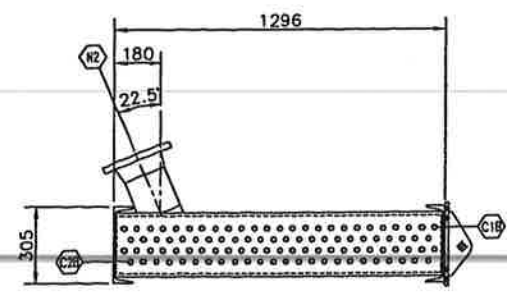
**BUNDLE PLAN VIEW**  
SCALE: 1:20



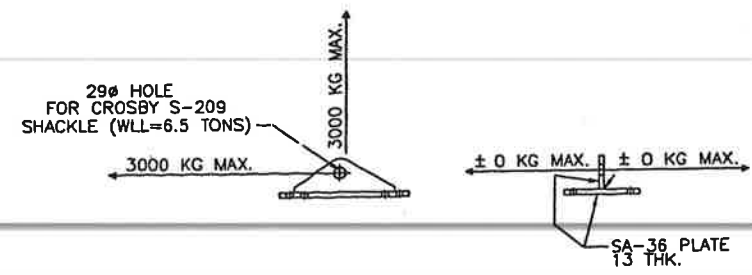
**BUNDLE ELEVATION VIEW**  
SCALE: 1:20



**VIEW 'A-A'**  
SCALE: 1:15



**VIEW 'B-B'**  
SCALE: 1:15



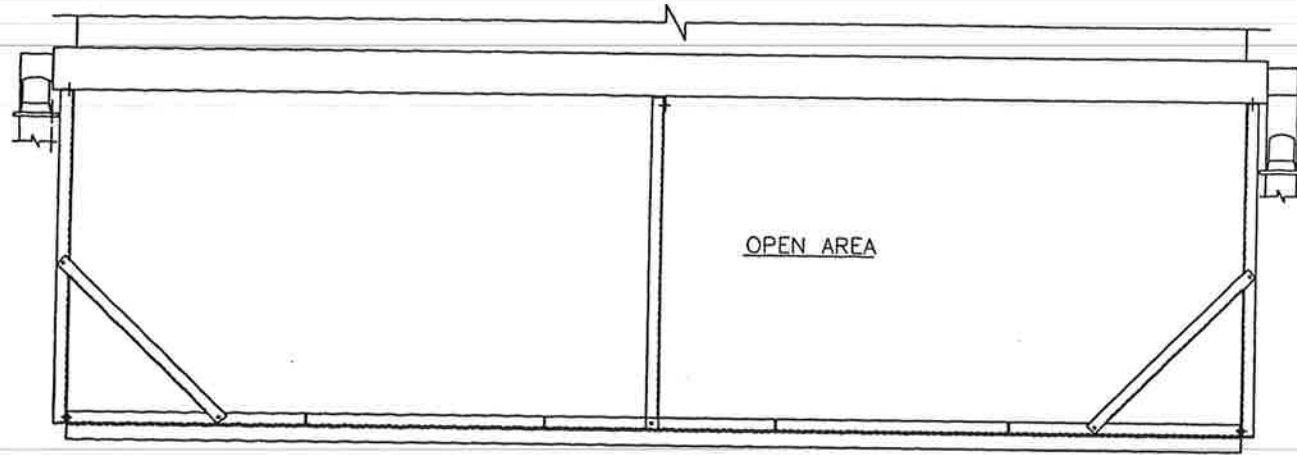
**REMOVABLE LIFTING LUG DETAIL**  
(REUSABLE)  
(2)-REQ'D.  
SCALE: 1:10

CAPACITY:	0.285 m <sup>3</sup>	SERIAL NO:	99404-235 CRN:
SURFACE AREA OF TUBES INCLUDING FINNS:	1114.34 m <sup>2</sup>	YEAR BUILT:	2000
WEIGHT EMPTY:	2700 kg	LSD NO.:	-
WEIGHT FULL OF WATER:	2985 kg	CODE:	NON-CODE
SURFACE PREPARATION:	PNT 11	MAX. DES. PRES.:	97 kPag
PRIMER:	-	DESIGN TEMP.:	149 °C
FINISH PAINT:	-	CORR. ALLOW.:	0 mm
INSULATION:	NONE	HYDROTEST:	518 kPag
PRODUCTION IMPACT TEST REQ'D:	NO	MDMT:	-28 °C
MECH LOADINGS GOVERN PER UG 22:	NO		97 kPag
IMPACT TEST:	NO	MATERIAL:	HDR BOXES: G40.21M-350(A-500C)/SA-516-70
SHIP LOOSE:	NO		TUBES: (WELDED) SA-214ERW
SERVICE:	60% EG/H2O	RADIOGRAPHY:	N/A
		P.W.H.T.:	NO
		MINIMUM TEMP.:	°C
		FOR TIME:	hr
		TAG NO:	AC-220

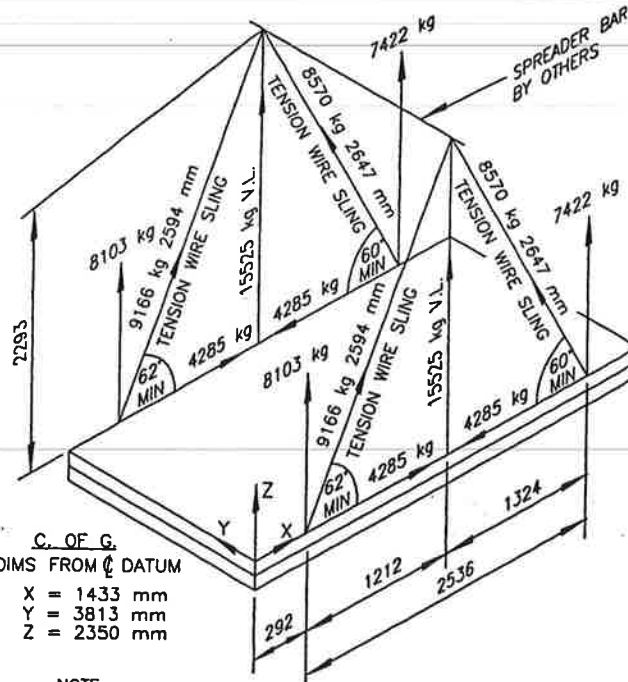
APPROVED		DRAWN		APACHE CANADA LIMITED		440 East Lake Road, Postal Bag #2 Airdrie, Alberta Canada T4B 2C3	
MECH/STRUCT.	BY	DATE	DATE	1478 HP HAMBURG COMPRESSOR PACKAGE		DWG. No.: D-BDL-99404-235-SKT SHT. 1 OF 1	
ELECTRICAL	BY	DATE	DATE	ENGINE JACKET WATER		REV. SKT	
PROJECT	BY	DATE	DATE	AC-220			
DATE	BY	DATE	DATE	SCALE AS NOTED			
GENERAL NOTES		GENERAL NOTES		APACHE CANADA LIMITED		440 East Lake Road, Postal Bag #2 Airdrie, Alberta Canada T4B 2C3	
DATE: 2000.09.25 4:23pm	FILE NAME: J:\jobs99\DWG\99404\Comp\Misc\BDL-99404-235-SKT-01.dwg	SKT No.	ISSUED FOR DOCUMENTATION	J. JUA	00/09/15	VK	SW
			REVISION				ENG



THE DESIGN IT COVERS ARE CONFIDENTIAL AND THE PROPERTY OF PROPAK SYSTEMS LTD., AND SHALL NOT BE DISCLOSED TO OTHERS OR REPRODUCED IN ANY MANNER OR USED FOR ANY PURPOSE WHATSOEVER EXCEPT BY WRITTEN CONSENT OF PROPAK.



VIEW 'A-A'  
SCALE: 1:25

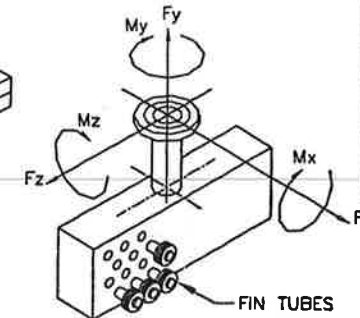


C. OF G.  
DIMS FROM  $\phi$  DATUM  
 X = 1433 mm  
 Y = 3813 mm  
 Z = 2350 mm

NOTE:  
 WEIGHTS SHOWN IN DIAGRAM INCLUDE 50% EXCESS FOR DYNAMIC LOADING  
 LIFTING DIAGRAM WEIGHT: 20700 KG, (WITHOUT IMPACT LOADING)  
 INCLUDES: COOLER STRUCTURAL STEEL, BUNDLES & LOUVRES

LIFTING DIAGRAM  
 FOR COOLER ASSEMBLY  
 AC-210/211/212/220/230

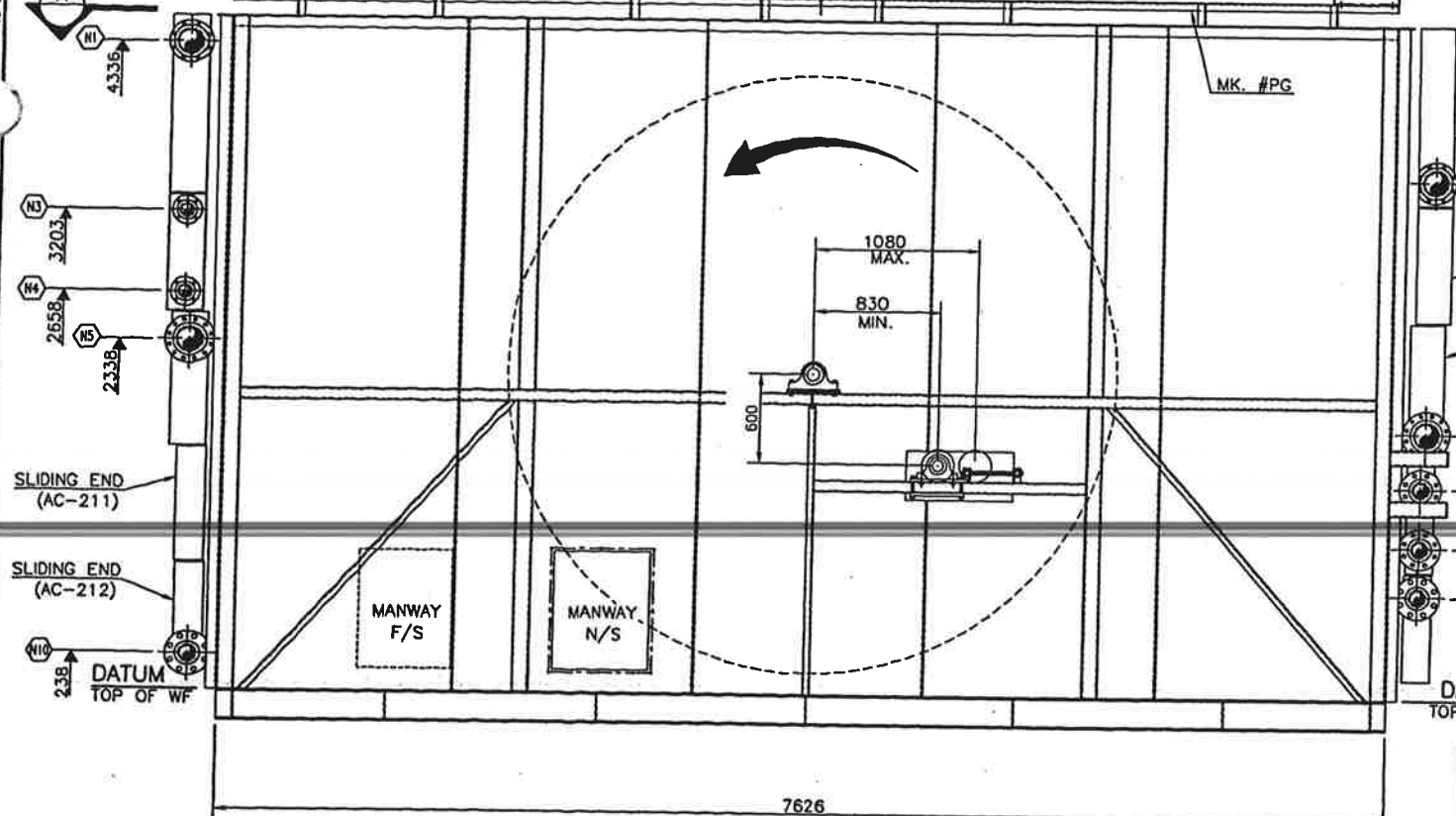
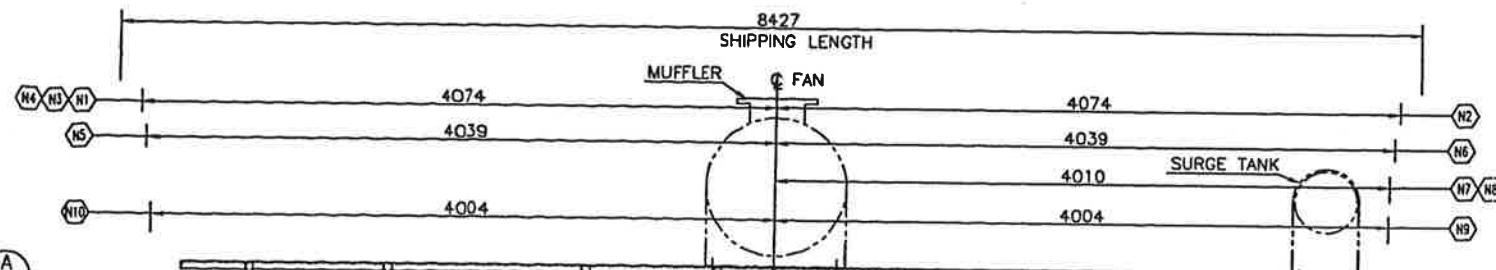
MK	SIZE	RATING	FACING	SERVICE	$\phi$ ELEVATION
N1	168	150#	RFWN	EJW (AC-220) INLET	SPEC.
N2	168	150#	RFWN	EJW (AC-220) OUTLET	SPEC.
N3	89	150#	RFWN	AJW (AC-230) INLET	SPEC.
N4	89	150#	RFWN	AJW (AC-230) OUTLET	SPEC.
N5	168	300#	RFWN	1st STAGE INTERCOOLER (AC-210) INLET	SPEC.
N6	168	300#	RFWN	1st STAGE INTERCOOLER (AC-210) OUTLET	SPEC.
N7	114	600#	RFWN	2nd STAGE INTERCOOLER (AC-211) INLET	SPEC.
N8	114	600#	RFWN	2nd STAGE INTERCOOLER (AC-211) OUTLET	SPEC.
N9	114	900#	RFWN	3rd STAGE AFTERCOOLER (AC-212) INLET	SPEC.
N10	114	900#	RFWN	3rd STAGE AFTERCOOLER (AC-212) OUTLET	SPEC.



MAXIMUM ALLOWABLE 168 O/D NOZZLE LOADS		MAXIMUM ALLOWABLE 114 O/D NOZZLE LOADS	
Fx	1800 lb	Fx	1500 lb
Fy	2260 lb	Fy	1200 lb
Fz	2260 lb	Fz	1500 lb
Mx	3160 ft-lb	Mx	1200 ft-lb
My	4500 ft-lb	My	1800 ft-lb
Mz	2400 ft-lb	Mz	1200 ft-lb

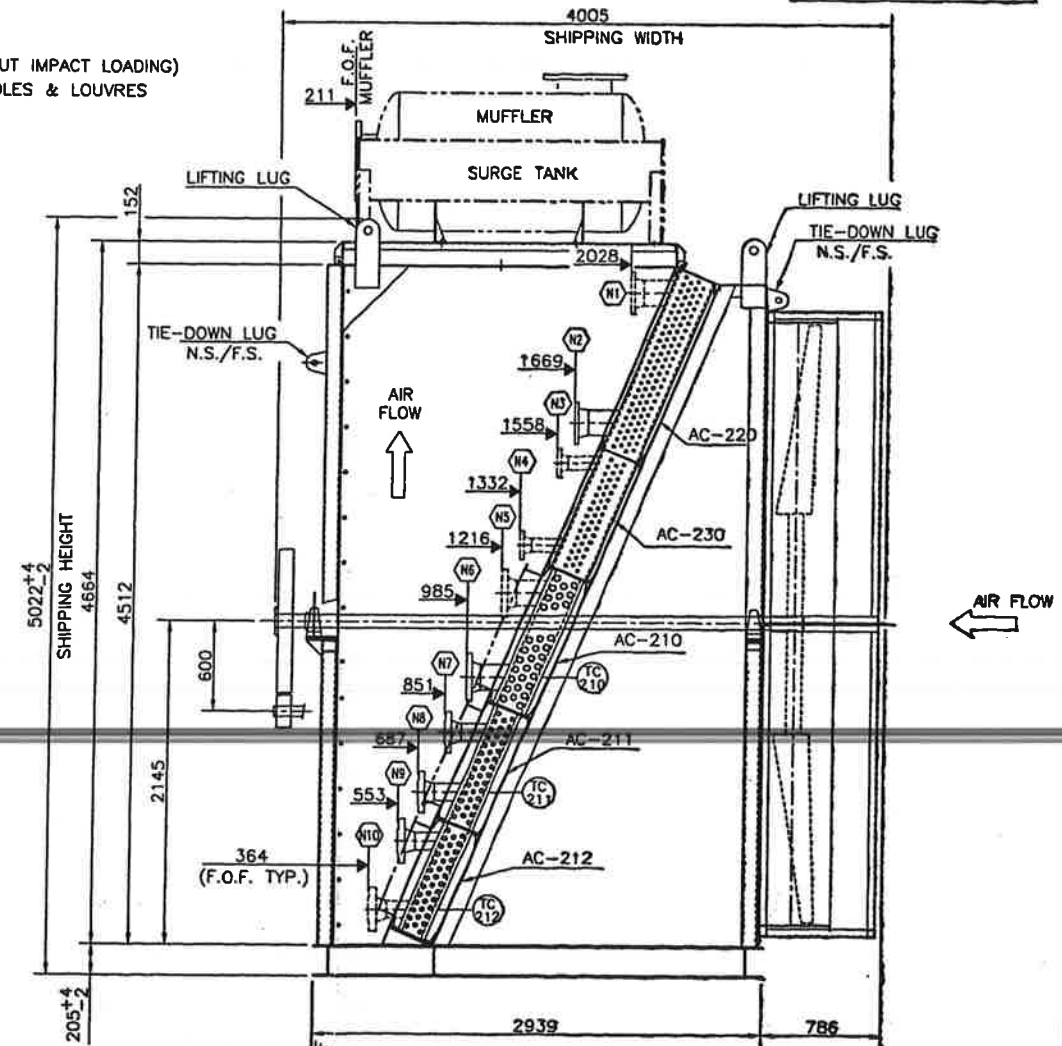
MAXIMUM ALLOWABLE 89 O/D NOZZLE LOADS	
Fx	900 lb
Fy	760 lb
Fz	900 lb
Mx	600 ft-lb
My	900 ft-lb
Mz	600 ft-lb

MAXIMUM ALLOWABLE NOZZLE LOAD



DRIVE END VIEW  
SCALE: 1:25

DURING FIELD INSTALLATION TACK WELDS, WHICH ARE LOCATED AT THE SLIDING END OF EACH BUNDLE AND WHICH ATTACH HEADER BOX T-BARS TO THE BUNDLE SIDE CHANNEL, MUST BE REMOVED. THESE WELDS WILL BE COLORED RED OR ORANGE.



SIDE ELEVATION  
SCALE: 1:25

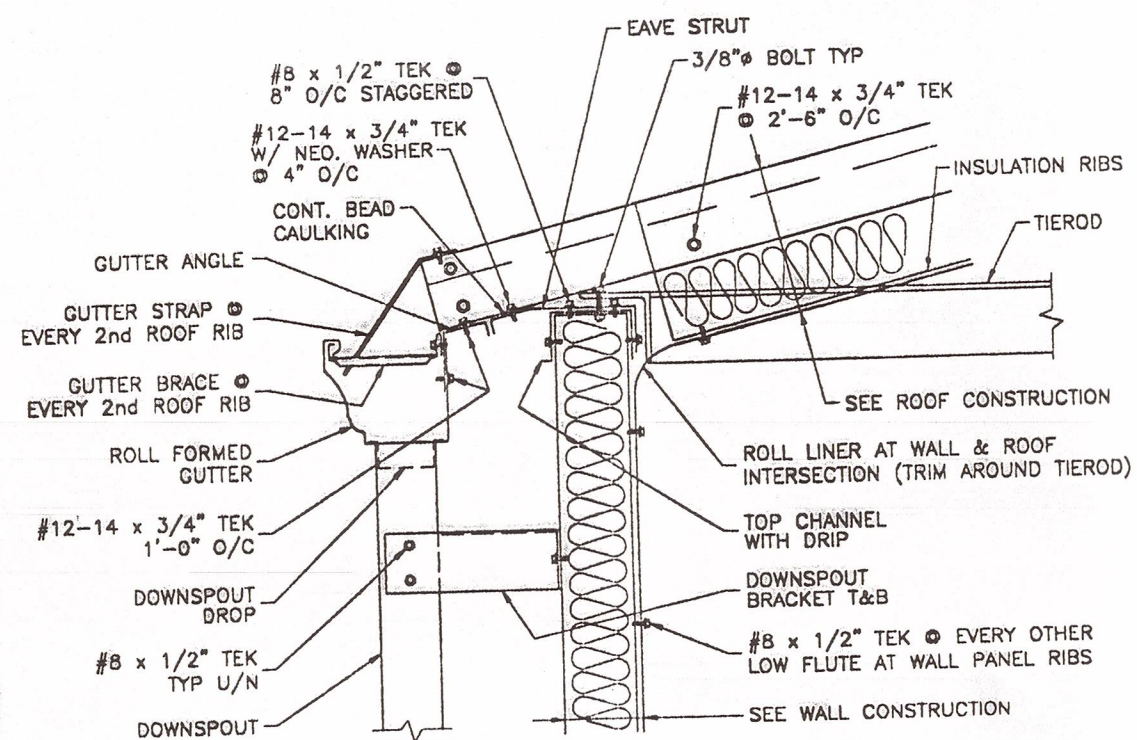
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MECH/STRUCT.	BY	ELECTRICAL	BY	CHECKED						DWG. No.: D-LYT-99404-238-SKT	SHT. 1 OF 1	REV. SKT
DATE	DATE	DATE	DATE									
PROJECT	DATE	SCALE	AS NOTED									

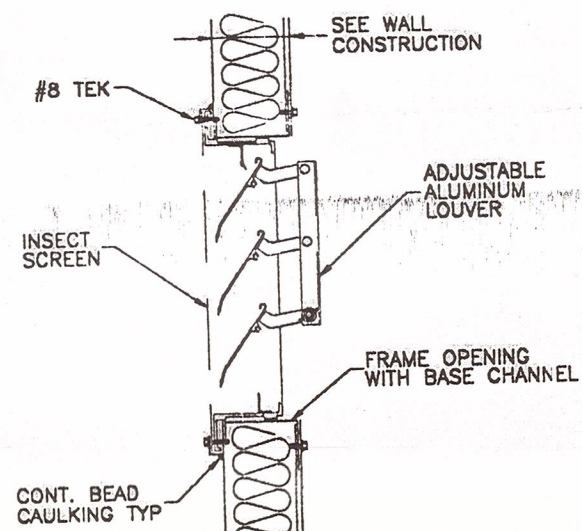
GENERAL NOTES		GENERAL NOTES		REVISION	
DATE: 2000.09.25 4:24pm	FILE NAME: J:\jobs99\DWG\99404\Comp\Misc\LYT-99404-238-SKT-01.dwg	SKT No.	ISSUED FOR DOCUMENTATION	D. DOR	00/09/15
				BY	DATE
				CKD	ENG



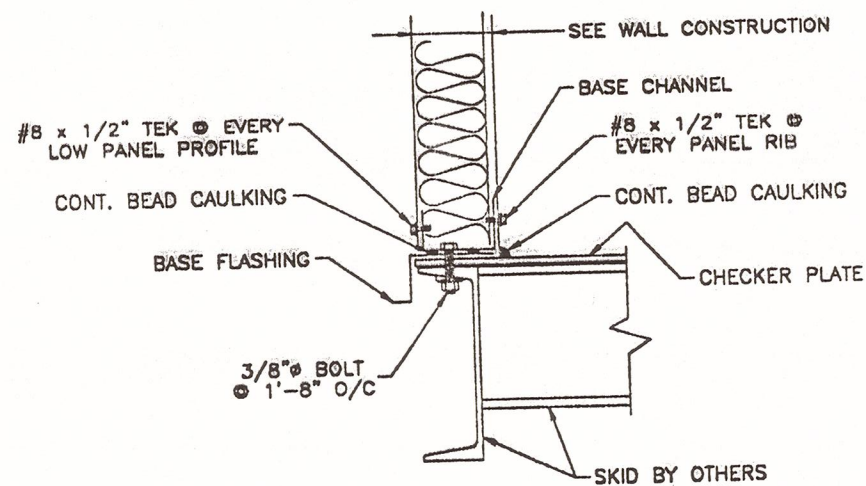




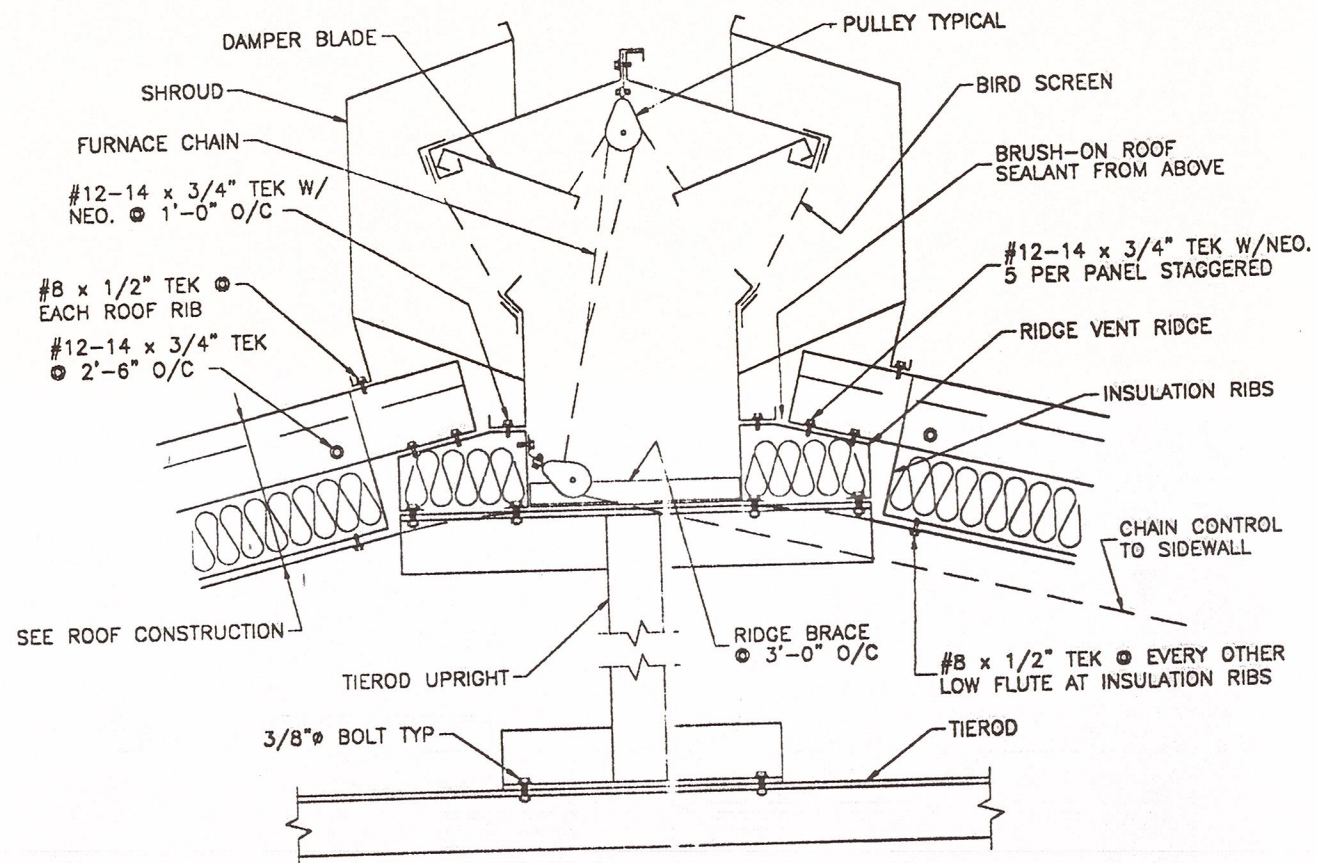
EAVE DETAIL



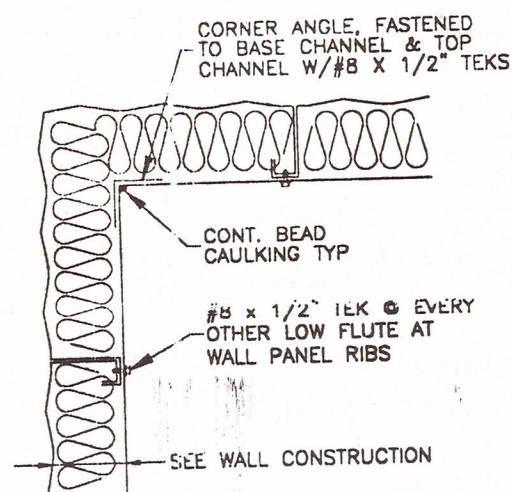
ADJUSTABLE LOUVER DETAIL



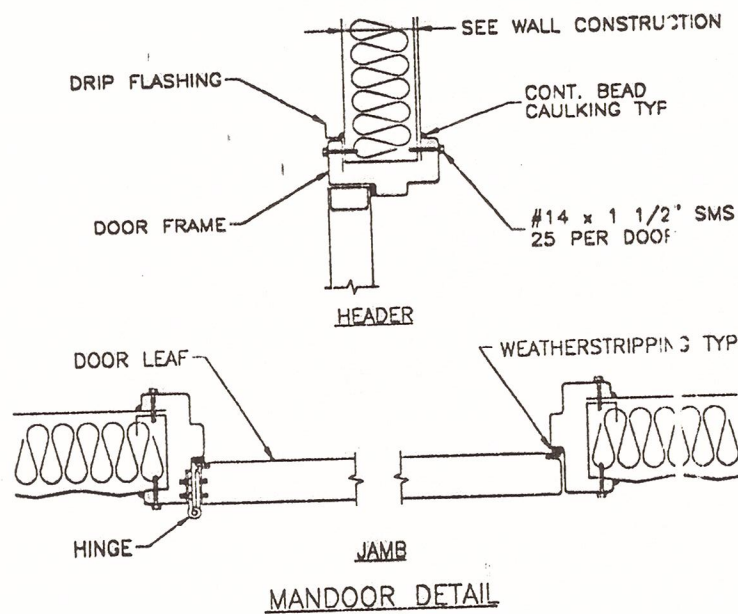
BASE DETAIL



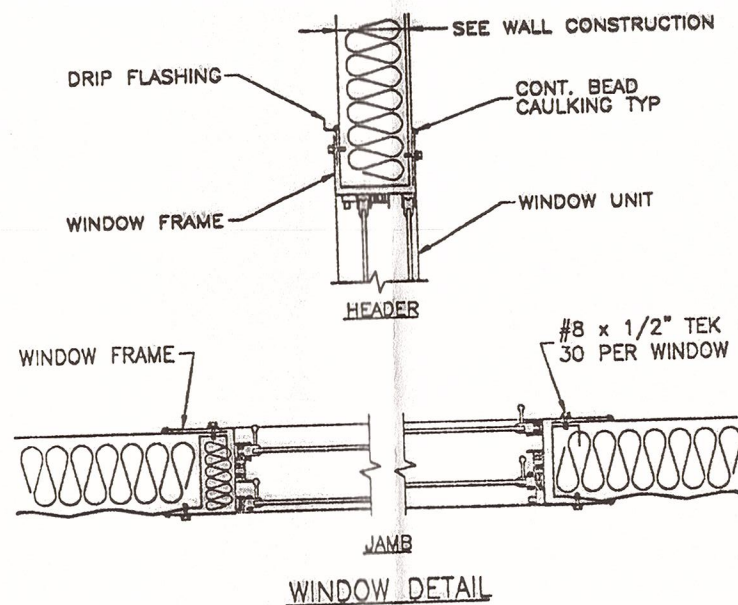
RIDGE DETAIL



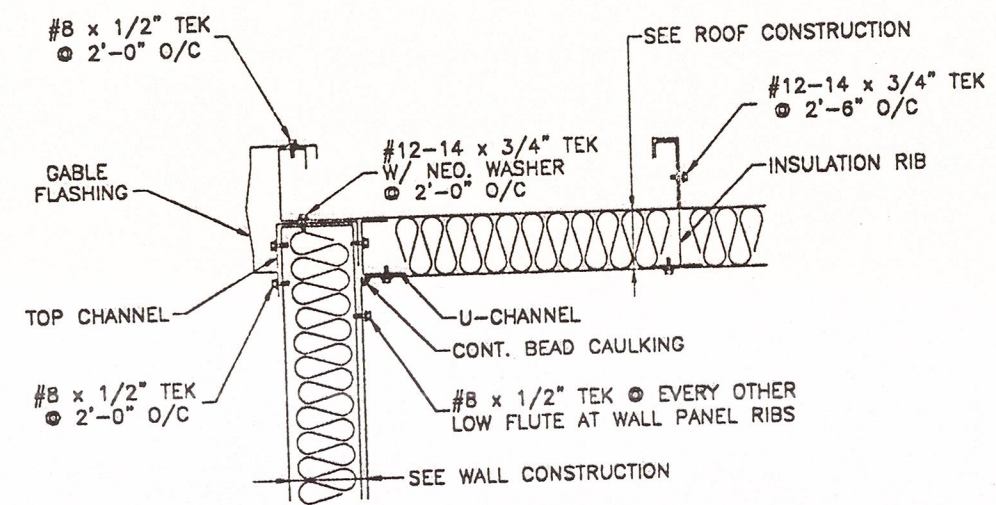
BUILDING CORNER DETAIL



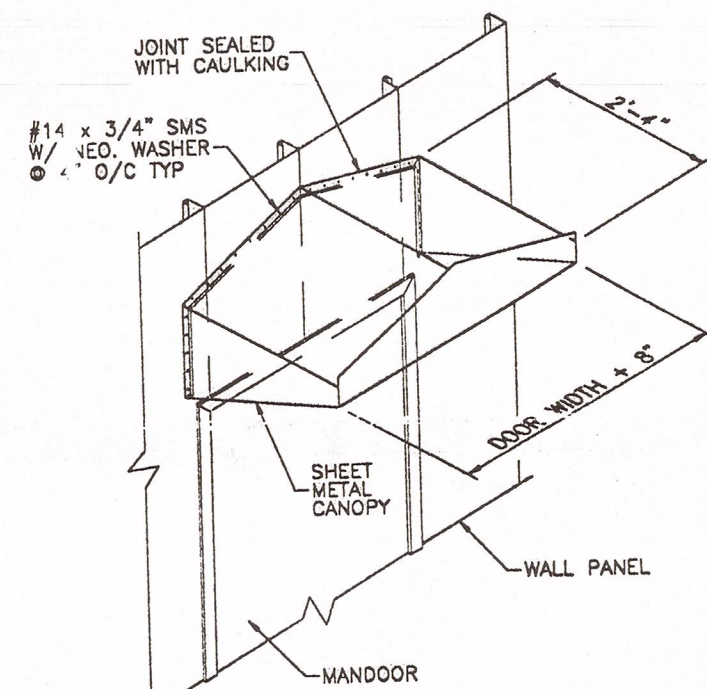
MANDOOR DETAIL



WINDOW DETAIL

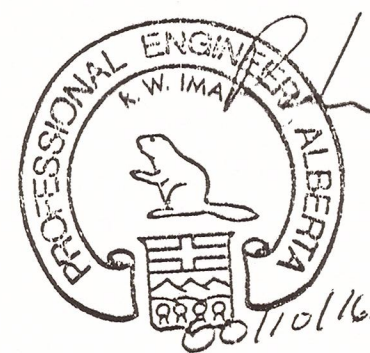


GABLE DETAIL

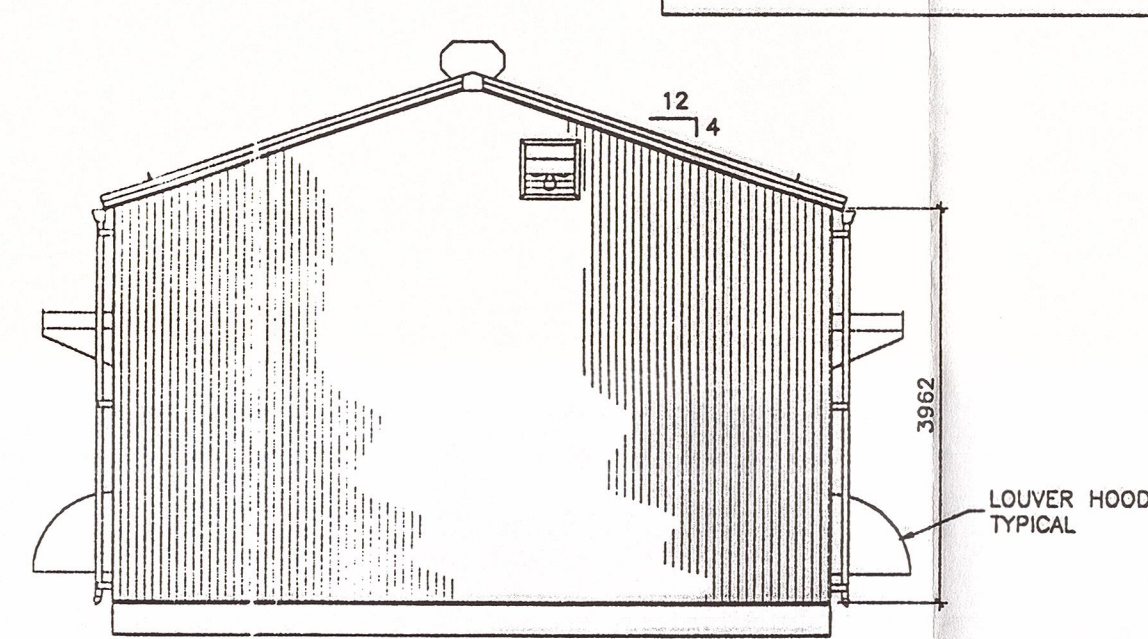
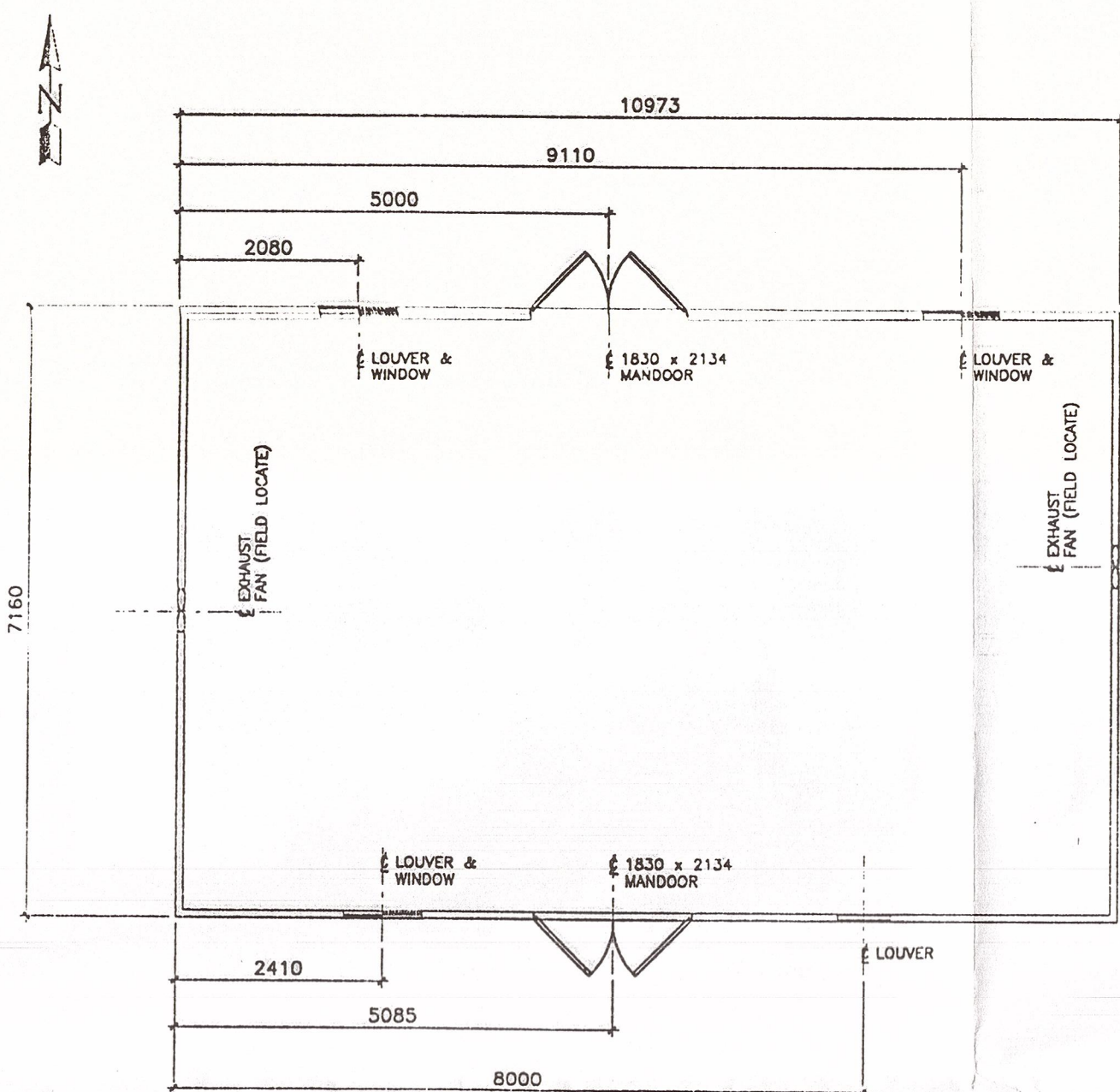


SHEET METAL CANOPY DETAIL

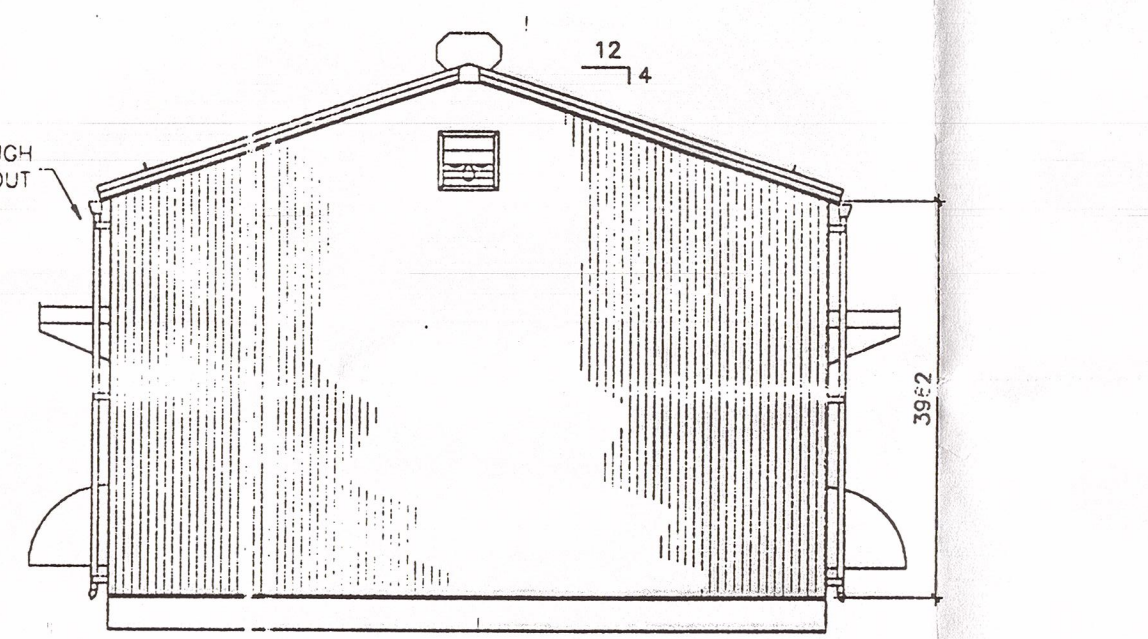
BUILDING DESIGN LOADS (Kpa)			
GROUND SNOW LOAD - $S_g = 2.0$ KPA		$S_r = 0.10$ KPA	
HOURLY WIND PRESSURE $q_{1/30} = 0.50$ KPA			
SEISMIC ZONE $Z_a = 0$		$Z_v = 1$ , $V = 0.05$	
ISSUED AS BUILT	DESCRIPTION	BY	DATE
		BS	15 OCT 20
		708-17th AVENUE NISKU, ALBERTA T9E 7T1 PHONE: (403) 955-2951 FAX: (403) 955-7721	
CLIENT:	PROPAC SYSTEMS	DRAWN BY:	BS   CHECKED BY:
TITLE:	1478 HP STOCK COMPRESSOR PACKAGE	SCALE:	NTS
LOCATION:	AIRDRIE, ALBERTA	DATE:	15 OCT 2000
SHEET DESCRIPTION:	TYPICAL BUILDING DETAILS	JOB NUMBER:	80-2644-E
		SHEET:	2644-
		REV. 0:	



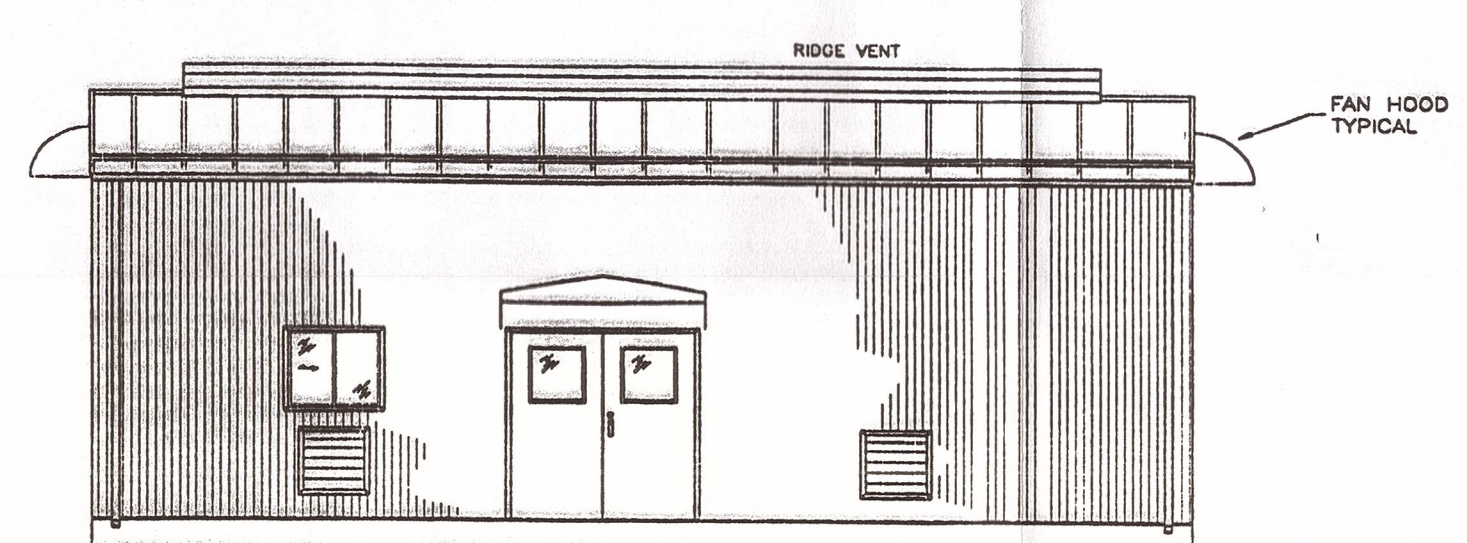




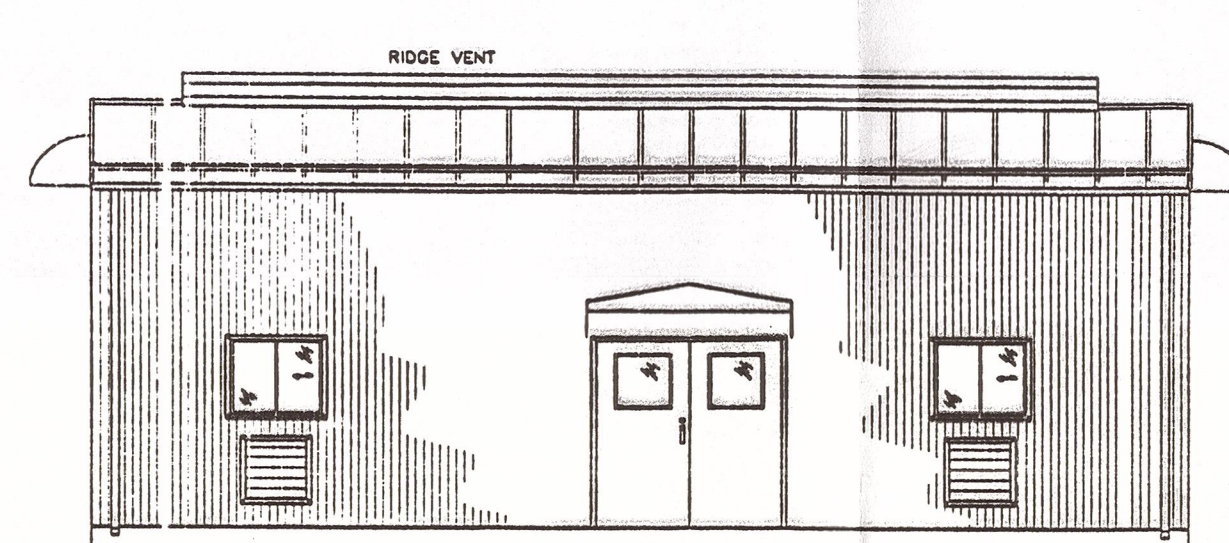
FAST ELEVATION



WEST ELEVATION



SOUTH ELEVATION

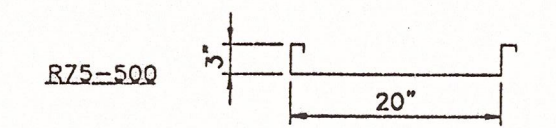


NORTH ELEVATION

- (F1) 2 ONLY WALL MOUNT EXHAUST FANS, ENERTECH MODEL NO. ET12-2, C/W EXPLOSION PROOF MOTOR BIRD SCREEN & HOOD
- (R1) 2 - ONLY 10973mm CONTINUOUS ICE RAKE, FINISH: GALVANIZED
- (V1) ONE ONLY 9144mm LONG CONTINUOUS RIDGE VENT C/W 152mm THROAT, BIRD SCREEN AND MANUALLY OPERATED DAMPER, FINISH: GALVALUME

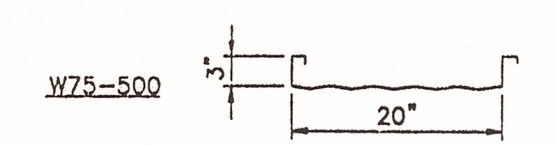
ROOF CONSTRUCTION:

- 22 GA. GALVALUME STEEL INTERLOCKING STRUCTURAL RIB-ROOF PANELS ( PROFILE R75-500 ), 5000 SERIES PAINT SYSTEM TO COLOUR: "UN-PAINTED"
- R 20 ( 6 " ) FIBREGLASS BATT INSULATION C/W 6 MIL POLY VAPOUR BARRIER.
- 24 GA. WHITE ALUMINUM, FLUTED PROFILE LINER PANEL



WALL CONSTRUCTION:

- 22 GA. GALVALUME STEEL INTERLOCKING STRUCTURAL RIB WALL PANELS ( PROFILE W75-500 ), 5000 SERIES PAINT SYSTEM TO COLOUR: "UNPAINTED"
- R 12 ( 3 " ) FIBREGLASS BATT INSULATION C/W 6 MIL POLY VAPOUR BARRIER.
- 24 GA. WHITE ALUMINUM, FLUTED PROFILE LINER PANEL



TRIM COLOURS:

- GABLE FLASHING AND HIGHSIDE FASCIA FLASHINGS (SINGLE SLOPE BUILDINGS) AND ALL NOTED FLASHINGS TO BE PREPARED 5000 SERIES PAINT SYSTEM TO COLOUR: GALVALUME

- (D1) TWO ONLY 1830 X 2134 STEEL INSULATED DOUBLE WALK-IN DOOR C/W HARDWARE AS FOLLOWS:
  - \*DOOR LEAF-20 GA. STEEL 1.75" THK HONEYCOMB CORE (R)
  - \*DOOR FRAME-16 GA. PRESSED STEEL
  - \*BUTT HINGES-"TAYMOR" #25-4170N NRP
  - \*PANIC HARDWARE-"VON-DUPRIN" 44TP
  - \*LOCKCYLINDER-"DOREX" #501CHR KA
  - \*GLASS-.25" X 20" X 24" SINGLE GLAZED
  - \*CHECK CHAIN-"TAYMOR" #25-4850U25
  - \*THRESHOLD-"MAKLOC" 18 GA. PRESSED STEEL
  - \*WEATHERSTRIP-"KN CROWDER" #W-2 ALUM./VINYL
  - \*SWEEP-"SHANAHAN" #DS-9 STEEL/VINYL
  - \*HEADBOLT/FOOTBOLT (INACTIVE LEAF ONLY)
  - \*MAKLOC STANDARD CANOPY

DOOR LEAF FINISH: TAN  
DOOR FRAME FINISH: TAN

- (W1) 3 ONLY 914 X 914 (NOM. SIZE) DOUBLE GLAZED ALUMINUM SLIDING WINDOW C/W ALUMINUM CENTER LOCK, AND FIBREGLASS CLOTH SCREEN, TRIM- MILL FINISH ALUMINUM

- (L1) 4-ONLY 812 X 812 MANUAL ADJ. LOUVERS C/W SCREEN & HOOD

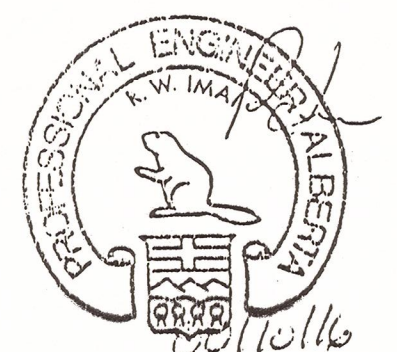
- (E1) 2 - ONLY 10973mm LONG CONTINUOUS EAVESTROUGH C/W DOWNSPOUT ASSEMBLY, FINISH: MTERO BROWN

BUILDING DESIGN LOADS (Kpa)	
GROUND SNOW LOAD - S <sub>s</sub>	= 2.0 KPA S <sub>r</sub> = 0.10 KPA
HOURLY WIND PRESSURE @1/30	= 0.50 KPA
SEISMIC ZONE	Z <sub>a</sub> = 0, Z <sub>v</sub> = 1, V = 0.05

REV.	DESCRIPTION	BY	DATE

**MAXLOC BUILDINGS INC.**  
708-17th AVENUE  
NSRD, ALBERTA  
T8E 7T1  
PHONE: (403) 955-2951  
FAX: (403) 955-7721

CLIENT:	PROPAK SYSTEMS	DRAWN BY:	BS	CHECKED BY:	
TITLE:	1478 HP STOCK COMPRESSOR PACKAGE	SCALE:	1:75 UNO	DATE:	15 OCT 2000
LOCATION:	AIRDRIE, ALBERTA	JOB NUMBER:		SHEET:	
SHEET DESCRIPTION:	FLOOR PLAN AND ELEVATION	BO-2644-E		2544-	REV. 0







**INSTRUCTIONS  
AND  
PARTS LIST**

**6.00-INCH STROKE TYPE HOS  
GAS COMPRESSOR**

**15.00 / 9.50 / 6.00 / BAL x 6HOS4-3**

**PROPAK SYSTEMS LTD.**

**D-R GFC ORDER NUMBER: C1619 & C1621  
CUSTOMER UNIT #: 99-404-150 & 99-420-150**

**SERIAL NUMBERS:**

**6HF853**

**6HC2654 / 6HC2655 / 6HC2656 CYLINDERS**

**6HF854**

**6HC2657 / 6HC2658 / 6HC2659 CYLINDERS**

**DRESSER-RAND**

**Gas Field Compressors**

10/10/2000

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Printed in U.S.A.



# TABLE OF CONTENTS

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## HOS COMPRESSOR

THIS DRESSER-RAND SERVICE MANUAL HAS BEEN PREPARED SPECIFICALLY TO COVER THOSE UNITS LISTED ON THE TITLE PAGE. THIS PORTION OF THE MANUAL IS PRODUCED AT TULSA, OKLAHOMA AND CONTAINS THESE FOUR SECTIONS.

**FRONT MATTER**

**Safety Labels & General Information**

**SECTION A**

**Standard Instructions**

**SECTION B**

**Illustrated Parts List**

**SECTION C**

**Accessory Literature**

---

**FRONT MATTER**

**CONTENTS**

---

**SAFETY PRECAUTIONS**

---

**SAFETY LABELS**

**TECHNICAL COMPRESSOR TRAINING**

## SAFETY PRECAUTIONS

THE INSTALLATION, OPERATION, AND MAINTENANCE OF A COMPRESSOR AND ITS AUXILIARY COMPONENTS MAY INVOLVE CERTAIN HAZARDS WHICH ARE UNIQUE TO THIS TYPE OF EQUIPMENT. THE FOLLOWING LIST OF SAFETY PRECAUTIONS MUST BE THOROUGHLY READ AND REVIEWED WITH ALL PERSONNEL PRIOR TO WORKING WITH OR ON THE COMPRESSION EQUIPMENT OR SYSTEMS. FAILURE TO HEED THESE WARNINGS CAN RESULT IN AN ACCIDENT CAUSING PERSONAL INJURY OR PROPERTY DAMAGE.

- Do not operate this equipment in excess of its rated capacity, speed, pressure, and temperature, nor otherwise than in accordance with the instructions contained in the Instruction Book. Operation of the equipment in excess of the conditions set forth in the sales contract will subject it to stresses and strains which it was not designed to withstand.
- All electric motor and control wiring must be carefully installed in accordance with the National Electric Code, the Occupational Safety and Health Act of 1970 (OSHA), and any other code requirements at the installation site.
- Piping subject to temperatures in excess of 175°F (79.4°C) which may be contacted by personnel must be suitably guarded or insulated.
- Ventilation of areas and buildings containing compressors handling hazardous gas must be designed to prevent recirculation or concentration of leaking or vented gases.
- The compressor must be fitted with safety valves to limit the discharge and interstage pressures to a safe maximum. NEVER install an intervening line valve between a compressor cylinder and that safety valve.
- Safety valves must have their settings tested at least once a year, and more often under extreme conditions, using an appropriate bench test.
- If a safety valve blows during operation, stop the unit immediately and determine the cause.
- ~~Pressure relieving devices that are vented to the atmosphere must have their outlet connections directed away from possible operator positions.~~
- Rotating equipment must not be placed in operation without adequate guarding of exposed rotating parts.
- Service on a machine shall always start with cleaning the surrounding area outside the machinery to remove oil which could cause the maintenance personnel to slip.
- Volatile flammable liquids must not be used as a cleaning agent for engine or compressor parts. A safety solvent should be used and the parts thoroughly dried before assembly.
- Carbon tetrachloride must not be used as a cleaning solvent. Appropriate provisions for ventilation should be made when using other halogenated solvents.
- When working with or near pickling or caustic solutions, all appropriate safety precautions must be taken with respect to adequate ventilation and adequate eye and body protection.

## Safety Precautions

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- Consult OSHA regulations regarding cleaning materials and their use.
- Air jets must not be used for cleaning work clothes, because of the risk that the jet might enter the blood stream via body openings or small skin wounds.
- When air jets are used for cleaning workpieces, for sandblasting or for spray painting, hands and eyes must be adequately protected against flying debris.
- Whenever the compressor is shutdown for repairs, positive steps must be taken to prevent the prime mover from being inadvertently restarted. These positive actions are described in the Instruction Book. In addition, a warning sign bearing a legend "WORK IN PROGRESS - DO NOT START", or similar wording, shall be attached to the starting equipment.
- Whenever an engine or compressor is shutdown, and overheating is suspected, a minimum period of 30 minutes must elapse before the crankcase is opened. Premature opening of the crankcase on an overheated machine can result in a crankcase explosion.
- Prior to opening a reciprocating engine or compressor, or undertaking a major overhaul, the unit must be positively blocked against rollover and movement of the running gear. When the unit is equipped with a flywheel locking device, this device must be engaged to prevent rollover. Blocking the crankshaft against rotation or blocking the crossheads against movement are alternate methods of securing the running gear for maintenance work.
- Never open a compressor cylinder or any other part of the compression system without first completely relieving all pressure within the unit and taking all necessary precautions to prevent accidental repressuring of the system.
- Compressors handling toxic or flammable gases must be isolated from the process piping by means of blinds, or double valves, and bleeder when major maintenance is required. Before opening such compressors the equipment should be purged or evacuated. Minor adjustments may be performed without blinding provided that adequate precautions, such as depressuring, are taken to protect personnel. Check valves must not be relied upon for isolating the compressor.
- Incorrect placement of the inlet and discharge valves in a compressor cylinder can cause an extremely hazardous condition. Refer to the comprehensive Service Manual before installing valves.
- After any overhaul of an engine or compressor, the unit must be barred through at least one complete revolution to ensure that there are no mechanical interferences within the machine. During this rotation, control and regulating devices for the compressor must be in the "full load" position.
- Established operating and maintenance procedures, as well as basic safety precautions, must be reviewed with operating and maintenance personnel at regular intervals of not more than 6 months. Newly assigned operators must be trained in the safe operation of the equipment before they are permitted to operate it.

## Safety Labels

THE COMPRESSION OF GAS SHOULD BE UNDERSTOOD TO BE INTRINSICALLY HAZARDOUS. PROPER MAINTENANCE OF THE COMPRESSOR AND ASSOCIATED EQUIPMENT, ALONG WITH SAFE MAINTENANCE PRACTICES, IS ESSENTIAL FOR THE SAFETY OF OPERATORS AND MAINTENANCE PERSONNEL. THESE PEOPLE MUST READ, AND UNDERSTAND, THE SERVICE MANUALS WHICH HAVE BEEN PREPARED SPECIFICALLY FOR THE EQUIPMENT.

IN ADDITION, DRESSER-RAND COMPANY SUPPLIES SAFETY LABELS AND HAS MADE THEM AVAILABLE FOR AFTERMARKET PURCHASE. THESE LABELS ARE INTENDED TO WARN THE OPERATORS AND MAINTENANCE PERSONNEL OF POTENTIAL HAZARDS.

THE SAFETY LABELS THAT APPEAR ON THE FOLLOWING PAGES ARE AVAILABLE FROM DRESSER-RAND COMPANY. WE RECOMMEND THAT LABELS BE PURCHASED TO UPGRADE EQUIPMENT ALREADY INSTALLED, TO RE-LABEL EQUIPMENT WHICH HAS BEEN PAINTED OR TO REPLACE DEFACED LABELS.

SIGNAL WORDS ARE USED TO IDENTIFY LEVELS OF HAZARD SERIOUSNESS. THEIR SELECTION IS BASED ON THE LIKELY CONSEQUENCE OF HUMAN INTERACTION WITH THE HAZARD IN TERMS OF:

- DEGREE OF SEVERITY (minor injury, severe injury, death)
- THE PROBABILITY OF SEVERITY (will result, could result)



**DANGER** - Immediate hazards which WILL result in severe personal injury or death.



**WARNING** - Hazards or unsafe practices which COULD result in severe personal injury or death.



**CAUTION** - Hazards or unsafe practices which COULD result in minor personal injury or product or property damage.

# Safety Labels

## Full-Size Labels



**▲ DANGER**

**PRESSURIZED EQUIPMENT**  
RELIEVE ALL GAS PRESSURE WITHIN THE CYLINDER BEFORE SERVICING.  
FAILURE TO DO SO WILL RESULT IN SERIOUS INJURY OR DEATH.

R79453  
R79453P1  
R79453P2



**▲ WARNING**

**SPRING IN COMPRESSION**  
USE LONG STUDS WITH NUTS TO RELIEVE SPRING COMPRESSION WHEN REMOVING COVER.  
FAILURE TO DO SO COULD RESULT IN SERIOUS INJURY OR DEATH.

R79453A  
R79453AP1  
R79453AP2



**▲ DANGER**

**PRESSURIZED EQUIPMENT**  
RELIEVE ALL GAS PRESSURE FROM THE CYLINDER AND UNLOADER BEFORE SERVICING.  
FAILURE TO DO SO WILL RESULT IN SERIOUS INJURY OR DEATH.

R79453B  
R79453BP1  
R79453BP2



**▲ DANGER**

**EXPLOSIVE VAPORS**  
DO NOT OPEN ACCESS DOORS IF OVERHEATED PARTS ARE SUSPECTED. LET OVERHEATED PARTS COOL.  
FAILURE TO DO SO WILL RESULT IN SERIOUS INJURY OR DEATH.

R79453C  
R79453CP1  
R79453CP2



**▲ DANGER**

**ROTATING PARTS**  
DO NOT OPERATE WITHOUT GUARDS IN PLACE.  
FAILURE TO DO SO MAY RESULT IN SERIOUS INJURY OR DEATH.

R79453D  
R79453DP1  
R79453DP2



**▲ DANGER**

**TOXIC GASES**  
WEAR PROTECTIVE BREATHING APPARATUS WHEN SERVICING THIS EQUIPMENT.  
FAILURE TO DO SO WILL RESULT IN SERIOUS INJURY OR DEATH.

R79453E  
R79453EP1  
R79453EP2



**▲ WARNING**

**SLIPPERY WHEN WET**  
FIX LEAKS AND CLEAN UP SPILLS.  
FAILURE TO DO SO COULD RESULT IN SERIOUS INJURY OR DEATH.

R79453F  
R79453FP1  
R79453FP2



**▲ DANGER**

**ELECTRICAL HAZARD**  
DISCONNECT AND LOCK OUT ALL ELECTRICAL POWER BEFORE PERFORMING MAINTENANCE.  
FAILURE TO DO SO WILL RESULT IN SERIOUS INJURY OR DEATH.

R79453H  
R79453HP1  
R79453HP2



**▲ DANGER**

**PRESSURIZED EQUIPMENT**  
ENSURE INLET AND DISCHARGE VALVES ARE PLACED IN PROPER LOCATIONS.  
FAILURE TO DO SO WILL RESULT IN SERIOUS INJURY OR DEATH.

R79453J  
R79453JP1  
R79453JP2



**▲ DANGER**

**TRAPPED PRESSURIZED GAS**  
LEAVE NUTS ON LONG STUDS UNTIL VALVE COVER O-RING IS VISIBLE.  
FAILURE TO DO SO WILL RESULT IN SERIOUS INJURY OR DEATH.

R79453K  
R79453KP1  
R79453KP2



**▲ CAUTION**

**NOISE HAZARD**  
WEAR PROPER EAR PROTECTION WHEN WORKING NEAR THIS EQUIPMENT.  
FAILURE TO DO SO MAY RESULT IN HEARING LOSS.

R79453L  
R79453LP1  
R79453LP2



**▲ CAUTION**

**HOT SURFACE**  
AVOID CONTACT.  
FAILURE TO DO SO MAY RESULT IN SERIOUS INJURY.

R79453M  
R79453MP1  
R79453MP2



**▲ DANGER**

**HIGH PRESSURE FLUID**  
CHECK FOR HYDRAULIC LEAKS USING WOOD OR CARDBOARD TO AVOID FLUID INJECTION INTO BODY TISSUE.  
FAILURE TO DO SO WILL RESULT IN SERIOUS INJURY OR DEATH.

R79453N  
R79453NP1  
R79453NP2



**▲ WARNING**

**RECIPROCATING PARTS**  
STAY CLEAR OF MOVING PARTS WHILE PERFORMING MAINTENANCE.  
FAILURE TO DO SO COULD RESULT IN SERIOUS INJURY.

R79453V  
R79453VP1  
R79453VP2



**▲ DANGER**

**CRANKCASE HAZARD**  
DO NOT WORK IN CRANKCASE UNTIL POWER DRIVER IS LOCKED OUT AND CRANKSHAFT IS BLOCKED TO PREVENT MOVEMENT.  
FAILURE TO DO SO WILL RESULT IN SERIOUS INJURY OR DEATH.

R79453W  
R79453WP1  
R79453WP2

# Safety Labels

## Truncated Labels \*



R79453P3



R79453AP3



R79453BP3



R79453CP3



R79453DP3



R79453EP3



R79453FP3



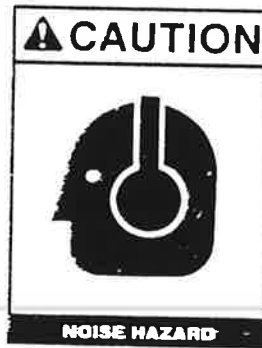
R79453HP3



R79453NP3



R79453WP3



R79453LP3



R79453MP3

\* For Limited  
Space Applications



R79453VP3





R79453HP1



R79453VP1



11065554



R79453AP3



R79453DP3



R79453VP1



R79453P1



R79453LP1



R79453P1



R79453DP1



R79453CP1



R79453LP1



R79453WP1



R79453MP1



R79453FP1



R79453FP1



R79453DP1



R79453FP1



R79453HP1



R79453EP1



R79453LP1



R79453WP1



R79453MP1



R79453EP1



11065562



R79453HP1



R79453DP1



R79453VP1



R79453P1



R79453KP2



R79453P1

NOTE: PRODUCT SAFETY LABELS ARE TO BE APPLIED TO EACH SIDE OF OPERATING EQUIPMENT. SAFETY LABELS ARE SHOWN ONLY ON ONE HALF OF UNIT FOR CLARIFICATION.



# Safety Labels

## SAFETY LABEL ORDERING FORM

(\* Indicates normally in-stock item)

Part No.	Size	Label Name	Qty.	Part No.	Size	Label Name	Qty.
R79453	10.8 x 6.5	PRESSURIZED EQUIPMENT	_____	R79453L	10.8 x 6.5	NOISE HAZARD	_____
R79453P1*	5.4 x 3.25		_____	R79453LP1*	5.4 x 3.25		_____
R79453P2	4.0 x 2.4		_____	R79453LP2	4.0 x 2.4		_____
R79453A	10.8 x 6.5	SPRING IN COMPRESSION	_____	R79453M	10.8 x 6.5	HOT SURFACE	_____
R79453AP1	5.4 x 3.25		_____	R79453MP1*	5.4 x 3.25		_____
R79453AP2	4.0 x 2.4		_____	R79453MP2	4.0 x 2.4		_____
R79453B	10.8 x 6.5	PRESSURIZED EQUIPMENT	_____	R79453N	10.8 x 6.5	HIGH PRESSURE FLUID	_____
R79453BP1	5.4 x 3.25		_____	R79453NP1	5.4 x 3.25		_____
R79453BP2*	4.0 x 2.4		_____	R79453NP2*	4.0 x 2.4		_____
R79453C	10.8 x 6.5	EXPLOSIVE VAPORS	_____	R79453V	10.8 x 6.5	RECIPROCATING PARTS	_____
R79453CP1*	5.4 x 3.25		_____	R79453VP1*	5.4 x 3.25		_____
R79453CP2	4.0 x 2.4		_____	R79453VP2	4.0 x 2.4		_____
R79453D	10.8 x 6.5	ROTATING PARTS	_____	R79453W	10.8 x 6.5	CRANKCASE HAZARD	_____
R79453DP1*	5.4 x 3.25		_____	R79453WP1*	5.4 x 3.25		_____
R79453DP2	4.0 x 2.4		_____	R79453WP2	4.0 x 2.4		_____
R79453E	10.8 x 6.5	TOXIC GASES	_____	R79453P3	3.2 x 2.4	PRESSURIZED EQUIPMENT	_____
R79453EP1*	5.4 x 3.25		_____	R79453AP3*	3.2 x 2.4		SPRING IN COMPRESSION
R79453EP2	4.0 x 2.4		_____	R79453BP3	3.2 x 2.4		
R79453F	10.8 x 6.5	SLIPPERY WHEN WET	_____	R79453CP3	3.2 x 2.4	EXPLOSIVE VAPORS	_____
R79453FP1*	5.4 x 3.25		_____	R79453DP3*	3.2 x 2.4		ROTATING PARTS
R79453FP2	4.0 x 2.4		_____	R79453EP3	3.2 x 2.4		
R79453H	10.8 x 6.5	ELECTRICAL HAZARD	_____	R79453FP3	3.2 x 2.4	SLIPPERY WHEN WET	_____
R79453HP1*	5.4 x 3.25		_____	R79453HP3	3.2 x 2.4		ELECTRICAL HAZARD
R79453HP2	4.0 x 2.4		_____	R79453LP3	3.2 x 2.4		
R79453J	10.8 x 6.5	PRESSURIZED EQUIPMENT	_____	R79453MP3	3.2 x 2.4	HOT SURFACE	_____
R79453JP1	5.4 x 3.25		_____	R79453NP3	3.2 x 2.4		HIGH PRESSURE FLUID
R79453JP2*	4.0 x 2.4		_____	R79453VP3	3.2 x 2.4		
R79453K	10.8 x 6.5	TRAPPED PRESSURIZED GAS	_____	R79453WP3	3.2 x 2.4	CRANKCASE HAZARD	_____
R79453KP1*	5.4 x 3.25		_____				
R79453KP2	4.0 x 2.4		_____				

# **DRESSER-RAND**

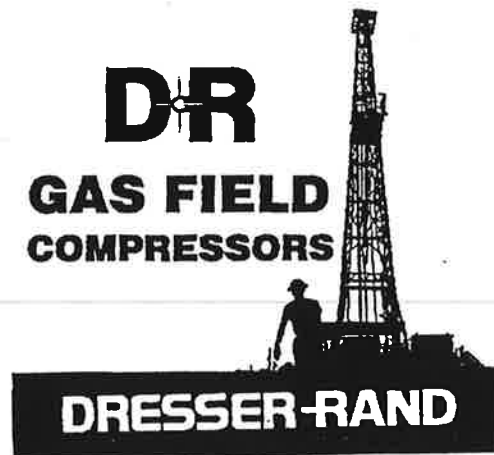
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## **TECHNICAL COMPRESSOR TRAINING**

THE TRAINING DEPARTMENT OF DRESSER-RAND PROVIDES INSTRUCTIONAL PROGRAMS WHICH OFFER A PRACTICAL APPROACH TO TECHNIQUES FOR INSTALLING, OPERATING, MAINTAINING, REPAIRING AND TROUBLESHOOTING RECIPROCATING DRESSER-RAND GAS FIELD COMPRESSORS.

BOTH FACTORY SCHOOLS AND SPECIFIC COMPRESSOR ON-SITE PROGRAMS ARE DESIGNED FOR COMPRESSOR MECHANICS, MAINTENANCE SUPERVISORS, MECHANICAL AND PROCESS ENGINEERS, AND COMPRESSOR OPERATORS. THESE SCHOOLS ARE CONDUCTED BY FULL TIME INSTRUCTORS AND PRODUCT ENGINEERS.

FOR FURTHER INFORMATION PLEASE CONTACT YOUR DRESSER-RAND SALES OFFICE OR THE TRAINING DEPARTMENT AT (918) 252-9007 OR 1-800-480-3788.





**INSTRUCTIONS**  
**for**  
**OPERATING**  
**and**  
**SERVICING**

**HOS**  
**COMPRESSOR**

**DRESSER-RAND**

**GAS FIELD COMPRESSORS**

## ⚠ WARNING

DO NOT OPERATE THIS EQUIPMENT IN EXCESS OF ITS RATED CAPACITY, SPEED, PRESSURE AND TEMPERATURE, NOR OTHERWISE THAN IN ACCORDANCE WITH THE INSTRUCTIONS CONTAINED IN THIS MANUAL. OPERATION OF THE EQUIPMENT IN EXCESS OF THE CONDITIONS SET FORTH IN THE SALES CONTRACT WILL SUBJECT IT TO STRESSES AND STRAINS WHICH IT WAS NOT DESIGNED TO WITHSTAND.

FAILURE TO HEED THIS WARNING MAY RESULT IN AN ACCIDENT CAUSING PERSONAL INJURY OR PROPERTY DAMAGE.

## FOREWORD

READ THE INSTRUCTION BOOK CAREFULLY BEFORE COMMISSIONING THE UNIT.

This manual contains important instructions and information on the operation and servicing of the Dresser-Rand HOS compressor and cylinders. ***THE IMPORTANCE OF GETTING THIS INSTRUCTION MANUAL INTO THE HANDS OF THE PERSON IN CHARGE OF OPERATING THE COMPRESSOR CANNOT BE OVEREMPHASIZED.*** All personnel involved in the operation and maintenance of the compressor should have access to this manual and be familiar with its contents.

This manual is published solely to provide operating and maintenance instructions for the subject compressor. It contains a detailed description of the compressor and its components; operating instructions and procedures for installation and maintenance.

This manual is divided into two major sections.

- (1) **FRONT MATTER;** containing WARNING, FOREWORD, SAFETY SUMMARY, STATEMENT OF WARRANTY, LIMITATIONS of LIABILITY and other comments of interest to our customers.
- (2) **TECHNICAL SECTION;** consisting of five chapters.
  - CHAPTER 1, INTRODUCTION
  - CHAPTER 2, LUBRICATION
  - CHAPTER 3, OPERATING AND TROUBLESHOOTING
  - CHAPTER 4, MAINTENANCE
  - CHAPTER 5, GENERAL DATA & SPECIFICATIONS

Do not remove the stainless steel nameplates that are attached to the machine. These plates give serial numbers that are necessary when communicating with Dresser-Rand about the equipment.

Also, do not remove safety labels. If these labels are removed or defaced, new ones should be obtained from Dresser-Rand Company. **Refer all communications to the nearest Dresser-Rand Authorized Packager or the Dresser-Rand Gas Field Compressor Group.**

## SAFETY PRECAUTIONS

Warnings and cautions appearing throughout this instruction manual are of paramount importance to personnel and equipment safety. Prior to any attempt to operate, maintain, troubleshoot, or

troubleshoot, or repair any part of the compressor, all DANGERS, WARNINGS and CAUTIONS should be thoroughly reviewed and understood. Refer to the Safety Summary which follows later. The information immediately following defines "signal words" as they are used in this manual.

**SIGNAL WORDS ARE USED TO IDENTIFY LEVELS OF HAZARD SERIOUSNESS. THEIR SELECTION IS BASED ON THE LIKELY CONSEQUENCE OF HUMAN INTERACTION WITH THE HAZARD IN TERMS OF:**

- DEGREE OF SEVERITY (minor injury, severe injury, death)
- THE PROBABILITY OF SEVERITY (will result, could result)

## **▲ DANGER**

The word DANGER signifies immediate hazards which WILL result in severe personal injury or death. In our Instruction Book, this should be construed to be a VERY STRONG Warning (see below).

## **▲ WARNING**

The word WARNING refers to hazards or unsafe practices which COULD result in severe personal injury or death. This is found quite often in the Instruction Book due to its association with unsafe practices.

## **▲ CAUTION**

The word CAUTION refers to hazards or unsafe practices which COULD result in minor personal injury or product or property damage. This word is found frequently in the Instruction Book due to the fact that bad maintenance practices or procedures can so often result in damage to the compressor. Because what constitutes a "minor" injury is open to debate, we have upgraded many CAUTIONS to WARNINGS in recent years.

### **NOTE**

This is advisory in nature and is not intended to warn. SERVICE NOTES refer to specific procedures, tools or information that will assist maintenance personnel in completing a specific task. NOTES are used to highlight more general, but not crucial, information.

The operation and maintenance of a compressor and its auxiliary components may present certain hazards which are unique to this type of equipment. The following list of safety precautions must be thoroughly read and reviewed by all personnel prior to working with or on the compressor equipment and systems. These general statements are expanded upon in the sections of the manual appropriate to their application. **Failure to heed these precautions can result in an accident causing personal injury, death or property damage.**

### SAFETY SUMMARY

- A. All electric motor and control wiring must be carefully installed in accordance with the National Electric Code, the Occupational Safety and Health Act of 1970 (OSHA) and any other code requirements at the installation site.
- B. Piping subject to temperatures excess of 175° (80°C) which may be touched by personnel must be suitable guarded or insulated.
- C. It is imperative that all gases lighter or heavier than air, active or inactive, toxic, combustible, obnoxious, objectional, or in any way harmful to personnel or equipment, be piped away from the compressor. There must not be any manifolding of vent tubing or piping; nor can back pressure be allowed to develop in any vent line. Gases may be recirculated as required by the process, but in any case must be controlled and/or disposed of in accordance with OSHA regulations and local pollution laws.
- D. The compressor must be fitted with safety valves or rupture disks to limit the discharge pressures to a safe maximum. NEVER install an intervening valve between a compressor cylinder and the safety valve or disk.
- E. Safety valves must have their settings tested at least once a year, and more often under extreme operating conditions, using an appropriate bench test.
- F. If a safety valve or rupture disk blows during operation, stop the unit immediately and determine the cause.
- G. Pressure relieving devices that are vented to the atmosphere must have their outlet connections directed away from operator stations.
- H. Rotating equipment must not be placed in operation unless adequate safeguards have been provided to protect operating personnel.
- I. Service on a machine shall always start with cleaning the floor and the outside of the machinery to remove oil, which could cause maintenance personnel to slip.
- J. Volatile flammable liquids must not be used as a cleaning agent for compressor parts. A safety solvent must be used and the parts thoroughly dried before assembly.
- K. Carbon tetrachloride, perchlorethylene, methylethylketone and similar solvents must not be used as cleaning agents. Appropriate provisions for ventilation must be made when using any halogenated or organic solvents.
- L. When working with or near pickling or caustic solutions, all appropriate safety precautions must be taken with respect to adequate ventilation, and eye and skin protection.
- M. Consult OSHA regulations covering cleaning materials and their use.
- N. Air jets must not be used for cleaning work clothes, due to the risk of air entering the bloodstream via body openings or small skin wounds. When air jets are used for cleaning parts, sandblasting or for spray painting, skin and eyes must be adequately protected against flying debris.
- O. Whenever a compressor is shut down for repairs, positive steps must be taken to prevent the prime mover from being inadvertently energized and started. These positive actions are described in this Instruction Book. In addition, a warning sign bearing a legend "WORK IN PROGRESS DO NOT START", or similar wording, shall be attached to the starting equipment.

- P. Whenever the compressor is shut down because overheating is suspected, a minimum period of 30 minutes must elapse before the crankcase is opened. Premature opening of the crankcase can result in a crankcase explosion.
- Q. Prior to opening the compressor, or undertaking a major overhaul, the unit must be positively blocked against rollover and movement of the running gear. When the unit is equipped with a barring or flywheel locking device, this device must be used to prevent rollover. Blocking of the crankshaft or crossheads is an alternate method of preventing accidental rollover.
- R. Never open a compressor cylinder or any other part of the compression system without first completely relieving all pressure within the unit and taking all necessary precautions to prevent accidental pressurizing of the system.
- S. Compressors handling toxic or flammable gases must be isolated from the process piping by means of blinds, or double valves and bleeders, when major maintenance is required. Before opening such compressors the equipment MUST be purged or evacuated.
- T. Corrective action must be taken when the cylinder vent gas leakage is excessive or when there is a sudden increase in the leakage rate.
- U. Lifting hoists and similar equipment must be regularly tested and have a sufficient safety factor for the weight to be lifted. Also, ensure that lifting devices are properly rigged before any lifting is attempted.
- V. After any overhaul of the compressor, the unit must be barred through at least one complete revolution to ensure that there are no mechanical obstructions within the machine.
- W. Established operating and maintenance procedures, as well as basic safety precautions, must be reviewed with the operating and maintenance personnel at regular intervals not to exceed six months. Newly assigned operators must be thoroughly trained in the safe operation of this equipment before they are permitted to operate it.
- X. Never use an air impact wrench for FINAL tightening of fasteners. An impact wrench cannot impart the proper bolt or stud pre-stress. See Chapter 5 of this manual for detailed fastener tightening requirements and procedures.
- Y. Special attention should be paid to all detailed DANGER, WARNING and CAUTION statements located throughout this manual, and to all SAFETY LABELS affixed to the equipment.



**WARRANTY, REMEDY, DISCLAIMER**

**A.** Dresser-Rand warrants that the equipment manufactured and delivered by Dresser-Rand under the terms of this Agreement will be free from defects in material and workmanship until the earliest to occur of the following events:

1. One year after startup.
2. Eighteen (18) months after shipment by packager.
3. Twenty-four (24) months after shipment by Dresser-Rand to Packager.

The Packager shall be obligated to promptly report any claimed defects in writing to Dresser-Rand immediately upon discovery and, in any event, within the above period. After notice from Packager and substantiation of the claim, Dresser-Rand shall, at its option, correct such defect either by suitable repair to such equipment or part, or by furnishing replacement equipment or part(s), as necessary, to the original ex-works point of shipment.

**B.** DRESSER-RAND MAKES NO OTHER WARRANTY OR REPRESENTATION OF ANY KIND. ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE HEREBY DISCLAIMED.

**C.** With respect to equipment, parts and work not manufactured or performed by Dresser-Rand, Dresser-Rand's only obligation shall be to assign to Packager whatever warranty Dresser-Rand receives from the manufacturer.

**D.** Dresser-Rand shall not be liable for the cost of any repair, replacement, or adjustment to the equipment or parts made by the Packager or for labor performed by the Packager or others, without Dresser-Rand's prior written approval.

**E.** No equipment or part furnished by Dresser-Rand shall be deemed to be defective by reason of normal wear and tear, failure to resist erosive or corrosive action of any fluid or gas, or of Packager's failure to properly store, install, operate or maintain the equipment in accordance with good industry practices or specific recommendations of Dresser-Rand.

**F.** The Packager shall not operate equipment which is considered to be defective without first notifying Dresser-Rand in writing of its intention to do. Any such use of the equipment will be at the Packager's sole risk and expense.

**G.** The repair or replacement of the equipment, spare or replacement part(s) by Dresser-Rand under this Warranty schedule shall constitute Dresser-Rand's sole obligation and Packager's sole and exclusive remedy for all claims of defects regarding the equipment and parts furnished hereunder.

**H.** The compressor owner should contact an authorized Dresser-Rand Packager for all required warranty or non-warranty service.

## LIMITATIONS OF LIABILITY

- A. The remedies of the Packager set forth herein are exclusive and the total liability of Dresser-Rand with respect to claims under this Agreement or regarding the equipment, spare or replacement parts and services incidental thereto as furnished hereunder, whether based in contract, tort (including negligence and strict liability) or otherwise, shall not exceed the purchase price of the services or the unit of equipment or part(s) upon which such liability is based.
- B. Dresser-Rand shall in no event be liable for any consequential, incidental, indirect, special or punitive damages arising out of this Agreement or any breach thereof, or any defect in, or failure of, or malfunction of the equipment or part(s) hereunder, including but not limited to claims based on loss of use, lost profits or revenue, interest, lost goodwill, work stoppage, impairment of other goods, loss by reason of shutdown or non-operation, increased expenses of operation, cost of purchase of replacement power or claims of Packager or customers of Packager for service interruption whether or not such loss or damage is based on contract, tort (including negligence and strict liability) or otherwise.

## COMMENTS OF INTEREST TO OUR CUSTOMERS

### GENERAL

Service Manuals are furnished for every Dresser-Rand Compressor. If additional details of your job are required, we will be happy to furnish this information.

This book is intended to cover many of the special points of operating and maintenance of the compressor components, and to supplement the experience and mechanical ability of a competent engineer.

Dresser-Rand service is available to every compressor owner. We have a continued interest in the welfare of our machinery. We wish to build and stand by every unit so that the purchase of this compressor will always be considered a wise investment.

### CONSULTATION

Our engineering department welcomes inquiries regarding any phase of compressor practice, operation and repairs or changes to meet unexpected conditions. Our sales department and branch representatives will confer with you on any prospective installation or change. Call, write or wire our branch offices for information and advice on any point.

### INSPECTION

These compressors will operate satisfactorily for years with little special attention. A preventative maintenance schedule will do much to ensure optimum performance of the unit, while avoiding possible difficulties at some inconvenient time.

### RENEWAL PARTS

If you will write us fully about your trouble or unusual wear, we may be able to make helpful suggestions that will correct your problem. We keep standard parts on hand for replacement when required.

### SERVICE

Dresser-Rand distributors maintain a force of highly trained Field Service Representatives, skilled in compressor work, who are available for installation, inspection or repair. They can be secured on reasonable notice. Contact your nearest Dresser-Rand distributor for service information.

Proper erection and starting of the compressor is extremely important. The success of a unit frequently depends on how it is installed. We strongly urge that such work be supervised by skilled Field Service Representatives, who are thoroughly familiar with construction, and who can also instruct the operators in the care and handling of the equipment.

Many customers, especially those operating several units, have Field Service Representatives make periodic inspections to prevent malfunctions and to ensure the best possible operating results. These representatives can explain how to operate D-R units to achieve the greatest possible operating results with the greatest efficiency and economy, while obtaining the longest possible equipment life.

# Table of Contents for Type HOS Instructions

---

## CHAPTER 1 - INTRODUCTION

Paragraph	Page
1-1. GENERAL INFORMATION .....	1-2
1-1.1. Ratings and Performance Characteristics .....	1-2
1-1.2. Design Improvements .....	1-2
1-2. SERIAL NUMBERS .....	1-3
1-2.1. Frame .....	1-3
1-2.2. Cylinders .....	1-3
1-2.3. Cylinder Nameplate Information .....	1-4
A. Cylinder Type, Serial Number, Bore & Stroke .....	1-4
B. Maximum Allowable Working Pressure .....	1-5
C. Maximum Allowable Discharge Gas Temperature .....	1-5
B. Hydrostatic Test Pressure .....	1-5

## CHAPTER 2 -LUBRICATION

Paragraph	Page
2-1. GENERAL .....	2-2
2-2. FRAME AND RUNNING GEAR LUBRICATION SYSTEM .....	2-2
2-2.1. Main Oil Pump .....	2-3
A. Main Oil Pump Removal & Disassembly .....	2-3
B. Main Oil Pump Assembly & Installation .....	2-4
2-2.2. Oil Pressure Regulation Valve .....	2-5
2-2.3. Oil Pressure Safety Relief Valve .....	2-6
2-2.4. Hand Oil Priming Pump .....	2-6
A. Hand Oil Priming Pump Removal & Disassembly .....	2-7
B. Hand Oil Priming Pump Assembly & Installation .....	2-8
2-2.5. Oil Pressure Gauges .....	2-8
2-2.6. Low Oil Pressure Shutdown Protection .....	2-9
2-2.7. Oil Cooler (Heat Exchanger) .....	2-9
2-2.8. Oil Filter .....	2-10
2-2.9. Frame Oil Recommendations .....	2-11
A. General Requirements .....	2-11
B. Viscosity Requirements .....	2-11
C. Inspection .....	2-11
D. Oil Change Schedule .....	2-11
2-2.10. Frame Oil Level .....	2-12
2-2.11. Frame Breather .....	2-12
2-3. CYLINDER LUBRICATION SYSTEM .....	2-13
2-3.1. Pump-to-Point Lubrication System .....	2-13
A. Lubricator Operation .....	2-13
B. Lubricator Adjustment .....	2-13
2-3.2. Block-type Lubrication System .....	2-15
A. Filling and Purging the System .....	2-18
B. Maintenance and Troubleshooting .....	2-19

## Table of Contents

---

### CHAPTER 2 -LUBRICATION - continued

Paragraph	Page
2-3.3. Cylinder Oil Recommendations .....	2-21
A. General Requirements.....	2-21
B. Service Considerations.....	2-22
C. Inspection.....	2-23
D. Synthetic Lubricants .....	2-23
2-3.4. Break-in and Operation .....	2-23
2-3.5. Extended Shutdown .....	2-25
2-3.6. System Malfunctions and their Causes .....	2-25

### CHAPTER 3 -OPERATION & TROUBLESHOOTING

Paragraph	Page
3-1. GENERAL.....	3-2
3-2. PREPARATION FOR INITIAL START .....	3-2
3-2.1. Alignment Check .....	3-2
3-2.2. Lubrication Systems .....	3-4
3-2.3. Compressor Cylinders .....	3-4
3-2.4. General Inspections and Adjustments .....	3-5
3-2.5. Compressor Cooling System .....	3-5
3-3. CAPACITY CONTROL.....	3-5
3-3.1. Cylinder Clearance Volume .....	3-6
3-3.2. Cylinder Unloading .....	3-6
3-3.3. Suction Pressure Control .....	3-6
3-3.4. Capacity Control Bypass.....	3-6
3-4. COMPRESSOR LOADING AND UNLOADING .....	3-6
3-4.1. Loading/Unloading Procedure - Bypass and Discharge Valve Method .....	3-9
3-4.2. Loading/Unloading Procedure - Vent Valve Method .....	3-9
3-5. INITIAL START-UP .....	3-9
3-6. BREAK-IN AND OPERATION .....	3-11
3-7. SUGGESTED ROUTINE STARTING PRACTICES .....	3-11
3-8. ROUTINE STOPPING .....	3-13
3-9. EMERGENCY OR NON-SCHEDULED SHUTDOWN .....	3-13
3-10. SHUTDOWN FOR AN EXTENDED PERIOD .....	3-13
3-11. ROUTINE OPERATION AND MAINTENANCE .....	3-14
3-11.1. Daily.....	3-14
3-11.2. Weekly .....	3-15
3-11.3. Monthly.....	3-15
3-11.4. Every Three Months .....	3-16
3-11.5. Every Six Months.....	3-16
3-11.6. Annually.....	3-17
3-12. TROUBLESHOOTING BY SYMPTOM .....	3-18

### CHAPTER 4 -MAINTENANCE

Paragraph	Page
4-1. GENERAL.....	4-3

**CHAPTER 4 -MAINTENANCE - continued**

Paragraph	Page
4-2. SAFETY PRECAUTIONS .....	4-4
4-3. FRAME .....	4-4
4-4. CRANKSHAFT .....	4-7
4-5. CRANKSHAFT OIL SEAL .....	4-7
4-6. ACCESSORY EQUIPMENT .....	4-7
4-7. MAIN BEARINGS .....	4-7
4-7.1. Checking Bearing Clearance .....	4-8
4-7.2. Replacing a Main Bearing .....	4-8
4-7.3. Bearing Crush .....	4-10
4-7.4. Checking Crankshaft Thrust .....	4-10
4-8. CROSSHEAD / CONNECTING ROD ASSEMBLY .....	4-11
4-8.1. Crosshead .....	4-12
4-8.2. Connecting Rods .....	4-12
4-8.3. Connecting Rod Bearings .....	4-12
A. Stretch Micrometer Procedure .....	4-13
4-8.4. Replacing Connecting Rod Bearings .....	4-15
4-8.5. Crossheads and Pins .....	4-16
4-8.6. Removing Crosshead and Connecting Rod .....	4-16
4-8.7. Replacing Small End Bushing .....	4-18
4-8.8. Replacing Crosshead Pin and Bushing .....	4-20
4-8.9. Crosshead Shoe Replacement and Piston Rod Runout Adjustment .....	4-20
A. Crosshead Shoe Replacement .....	4-22
B. Piston Rod Runout Adjustment .....	4-22
4-9. COMPRESSOR CYLINDERS .....	4-23
4-9.1. Removing and Installing Compressor Cylinders .....	4-25
A. Removing Compressor Cylinder .....	4-26
B. Installing Compressor Cylinder .....	4-26
4-9.2. Disassembly and Assembly of Pistons & Piston Rods .....	4-27
A. Piston and Rod Disassembly .....	4-28
B. Piston and Rod Assembly .....	4-28
4-10. INSTALLING PISTON ROD AND ADJUSTING END CLEARANCE .....	4-32
4-11.1. INSPECTION / MAINTENANCE OF CYLINDER BORES .....	4-34
A. Honing .....	4-35
4-12. NON-METALLIC COMBINATION PISTON & RIDER RINGS .....	4-36
4-12.1. Handling Instructions .....	4-36
4-12.2. Establishing Ring Wear Rate .....	4-36
4-12.3. Replacing Rings .....	4-37
4-12.4. Installing Rings .....	4-38
4-12.5. Breaking-in Combination Rings .....	4-40
4-13. PISTON ROD PRESSURE PACKING .....	4-40
4-13.1. Packing Rings .....	4-40
4-13.2. Packing Gasket .....	4-43
4-13.3. Packing Cases .....	4-44
4-13.4. Installing the Packing .....	4-44
4-13.5. Packing Operation & Maintenance .....	4-46
4-13.6. Inspecting the Packing .....	4-46
4-13.7. Replacing the Packing .....	4-47
4-14. PISTON ROD OIL SCRAPER RINGS .....	4-47
4-15. BALANCE CYLINDER (If Used) .....	4-49
4-16. COMPRESSOR VALVES .....	4-50
4-16.1. Description of Operation .....	4-51
4-16.2. Valve Maintenance Recommendations .....	4-52

## Table of Contents

---

### CHAPTER 4 -MAINTENANCE - continued

Paragraph		Page
4-16.3.	Removing the Valves – O-Ring Valve Cover .....	4-55
4-16.4.	Disassembling & Servicing the Valve.....	4-57
4-16.5.	Refacing Valve Seats .....	4-59
4-16.6.	Reconditioning the Stop Plate .....	4-60
4-16.7.	Assembling the Valve .....	4-61
4-16.8.	Installing the Valves – O-Ring Valve Cover.....	4-62
4-17.	REGULATION DEVICES .....	4-64
4-17.1.	Inlet Valve Unloaders.....	4-65
	A. Control and Vent Piping.....	4-67
	B. Unloader Cleanliness.....	4-67
	C. Removing Operator, Unloader and Valve Assembly.....	4-68
	D. Disassembling Cage and Plunger .....	4-69
	E. Installing Valve, Cage and Plunger .....	4-69
	F. Disassembling Unloader Cover and Operator.....	4-69
	G. Installing the Unloader.....	4-71
	H. Adjusting the Stroke.....	4-72
4-17.2.	Variable Volume Clearance Pockets.....	4-72
	A. Construction.....	4-72
	B. Maintenance.....	4-72
4-17.3.	Fixed Volume Clearance Pockets .....	4-74
	A. Control and Vent Piping.....	4-75
	B. Clearance Pocket Cleanliness.....	4-76
	C. Removing the Clearance Pocket Assembly .....	4-76
	D. Disassembling Actuating Piston Housing .....	4-77
	E. Disassembling Clearance Valve Sleeve .....	4-77
	F. Servicing the Gland Seal .....	4-77
	G. Assembling Actuating Piston Housing .....	4-79
	H. Assembling Clearance Valve Sleeve.....	4-79
	I. Installing Clearance Pocket Assembly .....	4-79

### CHAPTER 5 –GENERAL DATA & SPECIFICATIONS

Paragraph		Page
5-1.	GENERAL AND OPERATING DATA.....	5-2
5-2.	ASSEMBLY FITS AND CLEARANCES .....	5-4
5-3.	TIGHTENING REQUIREMENTS.....	5-6

---

## **HOS**

### **CHAPTER 1**

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<b>Paragraph</b>	<b>Page</b>
1-1. GENERAL INFORMATION .....	1-2
1-1.1. Ratings and Performance Characteristics .....	1-2
1-1.2. Design Improvements .....	1-2
1-2. SERIAL NUMBERS .....	1-3
1-2.1. Frame .....	1-3
1-2.2. Cylinders .....	1-3
1-2.3. Cylinder Nameplate Information .....	1-4
A. Cylinder Type, Serial Number, Bore & Stroke .....	1-4
B. Maximum Allowable Working Pressure .....	1-5
C. Maximum Allowable Discharge Gas Temperature .....	1-5
D. Hydrostatic Test Pressure .....	1-5

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### 1-1. GENERAL INFORMATION

The first HOS ever built came out in the form of a 2 throw in late 1980 (YRH101). Approximately a year and a half later, the first 4 throw emerged (YRH113), and in early 1984 the 6 throw made its debut (YRH174). Since the first HOS was introduced back in 1980, over 650 (and counting) frames have made their way into the gas field market. Within this time, there have been numerous design improvements, both in the frame and respective cylinders. The following sections center on these improvements and the performance capability of the HOS compressor.

#### 1-1.1. Ratings and Performance Characteristics

Maximum Allowable Operating Rod load: 60,000 lbs compression and tension

Stroke:	<b>6.00" STROKE</b>	<b>7.00" STROKE</b>
Maximum Speed	1200 PRM	1000 RPM
Minimum Loaded Speed:	500 RPM	500 RPM
Maximum BHP/Throw:	1000 HP	1100 HP*
Piston Rod Diameter:	2.50 in.	2.50 in.
Cylinder Sizes Available:	3.50" - 26.50"	3.50" – 26.50"
Maximum Cylinder Working Pressures:	130 –8800 psig	130 – 8800 psig

Direction of Rotation: Counter-clockwise from pump end view

\* Applies to 2 & 4 throw; 1000 for 6 throw

#### 1-1.2. Design Improvements

- 1985** - *Increased radii and wall thickness within frame access windows:* This area was determined to be a weak link on some frames due to a casting cooling phenomenon known as "shrink". Incorporating this change insured a proper cooling rate and eliminated the potential for any shrinkage to develop, thus maintaining the integrity of the frame casting itself.
- 1987** - *Combined piston rings:* These rings replaced the moly micarta type rings. This type of non-metallic ring supports the piston off the bore thus increasing bore life and reducing the potential for scuffing.
- 1988** - *PF valving:* This D-R ported valve replaced the I-R channel type and Hoerbiger plate valve. It's unique valve plate design and material improved efficiency and reliability substantially.
- 1994** - *Plug unloaders and partial PF inlet valves:* As a result of the number of problems the recip industry has encountered with finger type valve unloaders, D-R developed a partial valve and plug unloader design to replace the old finger type. This greatly improved the reliability on unloading devices while improving cylinder loaded and unloaded efficiencies.

- 1994 - *Internal crankshaft counter weight:*** On 2 and 4 throw frames, an internal counterweight was added onto the oil pump end of the crankshaft. Another weight was then mounted externally onto the coupling hub or flywheel. In conjunction, these weights considerably reduced the horizontal moments on these frames. The 6 throw frame due to its cylinder phasing is inherently balanced and does not have a need for counterweights.
- 1995 - *Gas cooled HOS cylinders:*** With the introduction of the gas cooled cylinder line-up, this enabled the customer to make a competitive choice for the application at hand.
- 1996 - *Nodular iron crossheads:*** Due to the poor casting quality associated with the cast steel crosshead, the switch to a high strength nodular iron material was made. Not only did this dramatically improve the casting quality, but this material has better strength characteristics for reversing loads than the previously supplied cast steel.
- 1998 - *Precision type main bearings:*** This replaced the shim adjustable type bearing thus making them much easier to service. Since this involved a physical change with the frame itself, all frames with this upgrade have a serial number greater than 799 (ex: 6HF800 or 6HF1045).
- 1998 - *Internal counterweighted crankshaft:*** This design improvement takes 1994's improvement one step further by eliminating the need for an external weight. The crankshaft now has a weight assembled onto both ends. This required a crankshaft change and once again, all frames that are supplied with this upgrade will have a serial number of 800 or larger.
- 1999 - *Frame oil filter:*** The standard single frame oil filter is now mounted on the frame and piped to the oil header to ease packaging costs and ensure cleanliness downstream of the filter.

### **1-2. SERIAL NUMBERS**

Correspondence concerning your compressor and related equipment must include the serial numbers of the equipment about which you are writing. A complete record of serial numbers and other data on your Dresser-Rand compressor is kept at the factory; giving the serial numbers in your correspondence and parts orders helps us in providing prompt service.

#### **1-2.1. Frame**

The compressor frame serial number applies to the frame and running gear parts. It is located on a nameplate, which is attached to the side of the frame at the oil pump end. The serial number is also permanently stamped directly below the nameplate in the frame metal. It consists of several letters and numbers. Always give the complete serial number (for example, 6HF-1090).

#### **1-2.2. Cylinders**

Each compressor cylinder has its own serial number, which is stamped on a nameplate attached to the cylinder. The cylinder serial number consists of letters and numbers like the frame (for example, 6HC-705). The cylinder nameplate also includes other data; this is described in the section that follows.

### 1-2.3. Cylinder Nameplate Information

Each cylinder manufactured by Dresser-Rand has a nameplate attached to it. The nameplate attached to compressor cylinders is shown in Figure 1-1. The nameplate contains information, which allows both the customer and Dresser-Rand to identify a particular cylinder. In addition, the performance information given provides a guide for the operation of each cylinder. The following is an explanation of some of the terms used on a nameplate.

**DRESSER-RAND**  
GAS FIELD COMPRESSORS

CYLINDER TYPE  SER NO

BORE: NOM.  IN. BORE LINERED  IN.

MAX. ALLOWABLE WORKING PRESSURE  PSI

HYDROSTATIC TEST PRESSURE  PSI

MAX. DISCHARGE TEMPERATURE  °F

5710 S. GARNETT ROAD  
TULSA, OKLAHOMA, U.S.A.

TP-4609A

**Figure 1-1. Cylinder Nameplate**

#### A. Cylinder Type, Serial Number, Bore & Stroke

The type of compressor the cylinder is installed upon is stamped in the first block of the nameplate. The next block is for the serial number of the cylinder. The cylinder serial number is the most important item stamped on the nameplate, for it allows the customer, the distributor and the manufacturer to identify a particular cylinder, its specifications, the parts used to build it and the performance conditions for which it was designed. This is important in that it allows tracking of a particular cylinder throughout its history, no matter what frame it may be installed on in later years. Always give this serial number when ordering spare parts. This will expedite the handling of your order and help prevent shipment of incorrect parts.

The next block on the nameplate is where the cylinder bore size is stamped. The cylinder bore is the inside diameter of the cylinder. If there is a liner present, the cylinder bore is the inside diameter of the liner. There is a block for lined bores on the current nameplate. This is also the nominal piston diameter. Liners of different thicknesses can be installed in a given cylinder to vary the bore diameter.

### **B. Maximum Allowable Working Pressure**

The maximum allowable working pressure, or MAWP, is the maximum gas pressure permitted in the cylinder. The cylinder may be operated for short periods of time at pressures up to this figure provided that other factors (such as driver horsepower, maximum bearing loads and piping and vessel limitations) do not prohibit this. Safety valve settings are usually much lower than this figure, and may never exceed it in any case.

### **C. Maximum Allowable Discharge Gas Temperature**

This is the highest temperature to which any compressor cylinder parts should be exposed.

### **D. Hydrostatic Test Pressure**

The pressure at which the cylinder has been hydrotested. Hydrostatic tests are always done at pressures greater than the MAWP.

**DRESSER-RAND****LUBRICATION**

## HOS

### Chapter 2

Paragraph	Page
2-1. GENERAL .....	2-2
2-2. FRAME AND RUNNING GEAR LUBRICATION SYSTEM .....	2-2
2-2.1. Main Oil Pump .....	2-3
A. Main Oil Pump Removal & Disassembly .....	2-3
B. Main Oil Pump Assembly & Installation .....	2-4
2-2.2. Oil Pressure Regulation Valve .....	2-5
2-2.3. Oil Pressure Safety Relief Valve .....	2-6
2-2.4. Hand Oil Priming Pump .....	2-6
A. Hand Oil Priming Pump Removal & Disassembly .....	2-7
B. Hand Oil Priming Pump Assembly & Installation .....	2-8
2-2.5. Oil Pressure Gauges .....	2-8
2-2.6. Low Oil Pressure Shutdown Protection .....	2-9
2-2.7. Oil Cooler (Heat Exchanger) .....	2-9
2-2.8. Oil Filter .....	2-10
2-2.9. Frame Oil Recommendations .....	2-11
A. General Requirements .....	2-11
B. Viscosity Requirements .....	2-11
C. Inspection .....	2-11
D. Oil Change Schedule .....	2-11
2-2.10. Frame Oil Level .....	2-12
2-2.11. Frame Breather .....	2-12
2-3. CYLINDER LUBRICATION SYSTEM .....	2-13
2-3.1. Pump-to-Point Lubrication System .....	2-13
A. Lubricator Operation .....	2-13
B. Lubricator Adjustment .....	2-13
2-3.2. Block-type Lubrication System .....	2-15
A. Filling and Purging the System .....	2-18
B. Maintenance and Troubleshooting .....	2-19
2-3.3. Cylinder Oil Recommendations .....	2-21
A. General Requirements .....	2-21
B. Service Considerations .....	2-22
C. Inspection .....	2-23
D. Synthetic Lubricants .....	2-23
2-3.4. Break-in and Operation .....	2-23
2-3.5. Extended Shutdown .....	2-25
2-3.6. System Malfunctions and their Causes .....	2-25

# Lubrication

## 2-1. GENERAL

The importance of selecting the correct lubricating oil and then properly maintaining the lubricating system cannot be over-emphasized. Using a lubricating oil not suited to the application can shorten the service life of the compressor and lessen its efficiency, as will a poorly maintained lubricating system. Use only a high grade of oil that meets the general, physical and chemical requirements as specified in this section.

Do not wait for lubrication difficulties to appear. If there is some question as to the correct lubricant to use for a particular application, consult a reputable oil supplier.

Lubrication of contact surfaces is intended not only to reduce friction and wear between parts but also to carry away any heat developed where high speeds and loads are encountered. If the compressor lubricating system is to accomplish these purposes, it is essential that the correct oil is used and that the following recommendations for maintaining the lubricating system are closely observed.

## 2-2. FRAME AND RUNNING GEAR LUBRICATION SYSTEM

The standard lubrication system is diagrammed in Figure 2-1. The oil is drawn into the crankshaft-driven gear type oil pump from the frame sump. The pump forces the oil first through a cooler and then through a filter before it is delivered to the main bearing oil header, which is a pipe cast into the frame. The oil is delivered to each main bearing through holes drilled in the bearing saddles to the oil header. From the main bearings, oil passes through drilled passages in the crankshaft to the crankpin bearing. A rifle-drilled hole in the connecting rod conducts oil from the crankpin to the connecting rod pin in the small end of the rod. The pin then feeds oil to the connecting rod bushing and to the crosshead which then feeds oil to the guides. After passing through and lubricating the various parts, the oil drains back into the sump area.

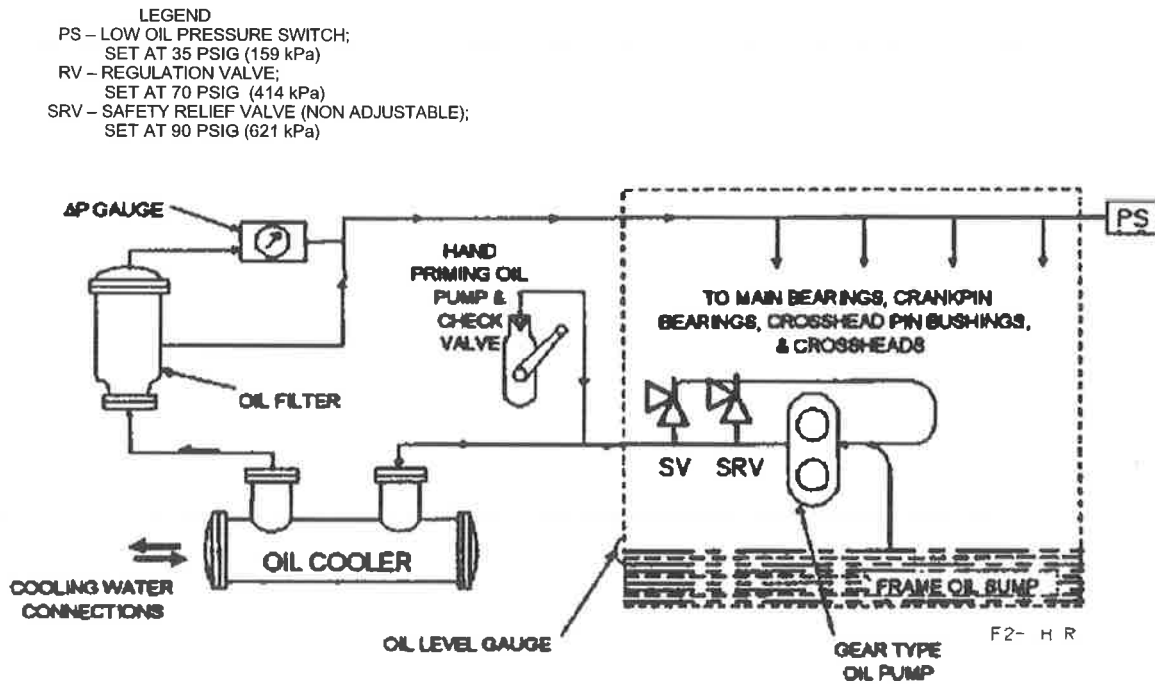


Figure 2-1. Typical Frame and Running Gear Lubrication System

Relief valves, a differential pressure gauge and a low oil pressure shutdown switch are incorporated into the standard system. These items are described in greater detail in the text that follows.

In addition to the standard equipment, optional equipment may be incorporated into the system for a particular application.

A hand-operated priming pump is included in the standard system to permit pre-lubrication of the bearings and to build up a slight pressure in the lubricating system prior to start-up. There is a check valve built into the pump to prevent the reverse flow of oil through the priming pump circuit when the main pump is operating.

An optional motor-driven auxiliary oil pump can be used instead of the hand-operated priming pump. When the auxiliary pump is used, a check valve must be located in the priming pump discharge line to the main oil pump discharge.

### 2-2.1. Main Oil Pump

The main oil pump supplies oil under pressure to the frame and running gear lubrication system. This pump is internally mounted inside the frame, as shown in Figure 2-2, and is direct-driven off the end of the crankshaft by a dowel and hub drive arrangement. The oil pump should not be dismantled unless it has lost capacity.

#### A. Main Oil Pump Removal & Disassembly

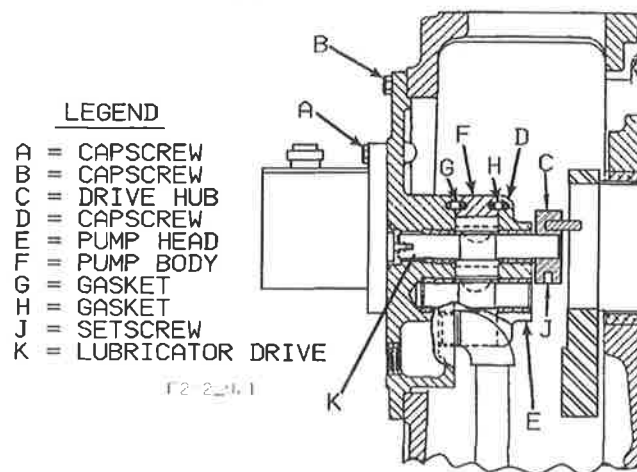
The main oil pump is internally mounted in the frame and is directly driven off the end of the crankshaft by a pin and hub drive arrangement. The oil pump should not be dismantled unless it is suspected that it has lost capacity.

### **▲ CAUTION**

**All precautionary measures specified by the Occupational Safety and Health Act of 1970 (OSHA) must be complied with when storing, handling, or using solvents.**

Deposits of hard lacquer in the pump assembly are not usually objectionable unless they are extensive enough to cause binding. Deposits of this nature in the pump can often be removed by flushing the pump with a safety solvent, without disassembling it.

1. Disconnect the oil pump discharge pipe and the hand oil pump piping (if used) from the frame end cover at the oil pump end of the unit.
2. Remove the shaft-driven lubricator unit (if used) from the end cover by disconnecting the lube lines and taking out capscrews (A) as shown in Figure 2-2. Use a straight pull to disengage the drive.
3. Remove the frame end cover and oil pump assembly by first removing capscrews (B) and then carefully pulling the assembly away from the frame.
4. Take the drive hub (C) off the pump drive shaft by removing the setscrews (J).



5. The oil pump head (E) and pump body (F) are both removed by taking out the long cap screws (D) that fasten the parts to the frame end cover. These parts are also doweled together. Work carefully when separating the parts so that the plastic gaskets (G) and (H) are not damaged.
6. The pump gears and their shafts can now be removed from the frame end cover. Before removing the gears, mark them so that they can be re-meshed in the same relative position.

### **▲ CAUTION**

All precautionary measures specified by the Occupational Safety and Health Act of 1970 (OSHA) must be complied with when storing, handling, or using solvents.

7. Clean the pump parts in a safety solvent and examine the gears, shafts, and bushings for excessive wear. If these parts are badly worn they can be replaced, but it is generally more economical to install a new pump.

### **B. Main Oil Pump Assembly & Installation**

1. If new shaft bushings are to be installed, they must be shrink fitted (by freezing) into the frame end cover and pump head.
2. Reassemble the pump body and head over the gears and shafts, being sure to place the plastic gaskets (G) and (H) on each end of the pump body (F). Orient the end cover, pump body and pump head with the dowels, then insert and tighten cap screws (D) evenly. The total end clearance in the pump gears should be 0.006 to 0.009 inch (0.15 to 0.23 mm). Turn the pump shaft by hand to check for any binding in the pump.



3. Slide the drive hub onto the pump shaft with the key in place, but do not fasten it in place at this time. Snug one of the hub setscrews against the shaft just tight enough to hold the hub in place during installation.
4. Install the end cover and pump assembly on the frame, being careful to align the slot in the drive hub with the pin in the end of the crankshaft. Replace the capscrews (B) and tighten them evenly.
5. Replace the shaft-driven lubricator (if used) on the frame end cover. An O-ring seal is placed between the parts. Be sure the drive shafts are engaged properly, then tighten the capscrews (A).

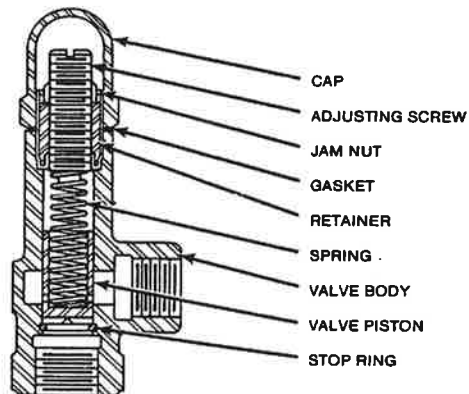
### SERVICE NOTE

Access to the hub can be gained through the top inspection opening in the frame.

6. Position the drive hub on the pump shaft to obtain end clearance of about 1/16 inch (1.6 mm) between the hub and crankshaft. *It is important that this end clearance be established to prevent end thrust on the pump gears.* Lock the drive hub in this position with the setscrews (J). There is a tapped hole in the hub and the setscrews must be inserted into this hole. Tighten the first screw firmly against the shaft, then run a second one on top of it and tighten it to keep it from working loose. Rotate the crankshaft through 360° to ensure the crankshaft dowel pin does not bind in the hub slot in any position.
7. Replace any piping and frame covers that were removed. Check the piping connections for leaks after all piping is installed.

### 2-2.2. Oil Pressure Regulation Valve

The oil pressure regulation valve, illustrated in Figure 2-3, controls the oil pressure to the frame lubrication system. Any excess capacity is then bypassed to the main oil pump suction. The valve is preset to relieve at approximately 55-60 PSIG (378-413 kPa). However, field adjustment may be performed to compensate for differences in oil viscosity. To increase oil pressure, remove the valve cap and turn the screw clockwise. Under normal operating conditions oil pressure should be kept as near 55-60 PSIG (378-413 kPa) as possible.



TP-1330-B

Figure 2-3. Oil Pressure Regulation Valve

If the regulating valve can no longer maintain system pressure it must be inspected as follows:

To disassemble the valve, remove the valve cap (see Figure 2-3) and its gasket, then remove the locknut, the adjusting screw, retainer, spring and piston in that order. It is not necessary to remove the stop ring under the piston. Examine the parts for wear and/or scoring. Replace any defective parts, after cleaning all parts to be reused. Assembly is the reverse of the disassembly procedure.

### 2-2.3. Oil Pressure Safety Relief Valve

The oil pressure safety relief valve, illustrated in Figure 2-4, is set to relieve when excessive pressures results. This can happen during cold oil starting, when the oil is viscous and pressures are consequently higher, or in the case of a major blockage in the oil system. The currently installed valve is not field adjustable, nor is it field repairable. If the valve malfunctions, order a new valve using the part number contained in the compressor parts list. This valve is set at 90 PSIG (620 kPa).

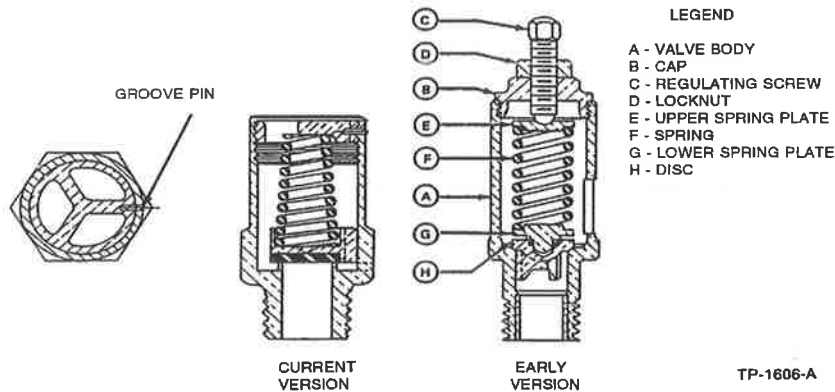


Figure 2-4. Frame Oil Pressure Relief Valves

### 2-2.4. Hand Oil Priming Pump

The standard hand-operated pump or optional motor-driven auxiliary pump is used to pre-lubricate bearing surfaces and build up a slight pressure in the lubricating system before start-up. This pump should require little service.

## ▲ CAUTION

On electric motor driven machines a prelube pump is required. See CHAPTER 5, GENERAL DATA & SPECIFICATIONS for recommended minimum prelube capacities.

The hand oil priming pump, Figure 2-5, may be serviced easily by first closing all connecting valves to isolate it from the system, then by disconnecting its piping and removing the mounting capscrews.

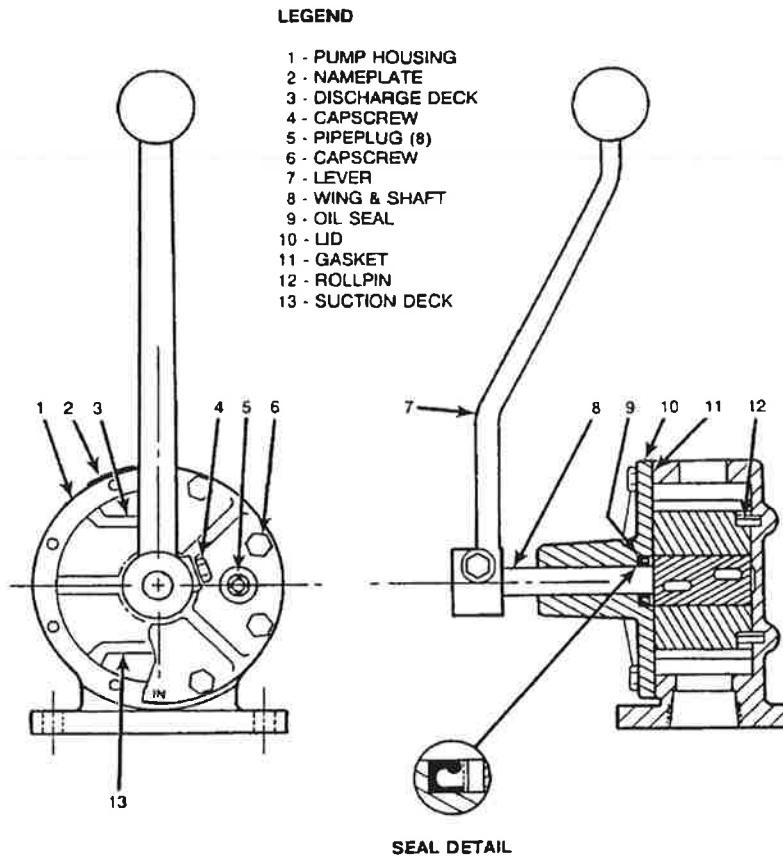


Figure 2-5. Hand Oil Priming Pump

**A. Hand Oil Priming Pump Removal & Disassembly**

1. Loosen the capscREW (4), then slide the pump lever (7) from the shaft.
2. Remove capscREWS (6), then pull the lid (10), wing and shaft assembly (8) and oil seal (9) out of the housing as an assembly.

**NOTE**

Note the inlet and discharge connections and the relationship of these to the internal valves. The fill plug (5) will be correctly located at the three o'clock position upon assembly.

3. Remove the housing gasket (11) and clean the mating surfaces.

## Lubrication

---

4. Slide the wing and shaft assembly out of the lid. Using a hook or screwdriver, pry the oil seal (9) from the lid. Note the orientation of the seal lips.
5. Lift the suction deck assembly (13) and discharge deck assembly (3) out of the housing (1).
6. Check the locating pins (12) for damage and replace as required.

### B. Hand Oil Priming Pump Assembly & Installation

#### **⚠ WARNING**

**All precautionary measures specified by the Occupational Safety and Health Act of 1970 (OSHA) must be complied with when storing, handling, or using solvents.**

1. Clean all components using safety solvent.
2. Inspect all parts for wear or damage. Suction decks, discharge decks and shaft and wing assemblies are sold only as complete assemblies.
3. Install locating pins (12), if removed, then install the suction deck assembly (13) with its valves pointing towards the center of the pump. Install the discharge deck assembly (3) with its valves pointing away from the center of the pump.
4. Lightly lubricate the oil seal assembly (9) and press the oil seal into the lid using an arbor press or hydraulic press and a suitable seal driver. The oil seal lips must face the oil to be sealed.
5. Slide the wing and shaft assembly (8) into the lid.

#### **NOTE**

Be careful not to roll the seal lips during this operation. The raised bosses on the wing should be pointing towards the suction deck so that the lever can be properly connected.

6. Install the housing gasket set (11), slide the lid over the shaft and secure the lid using capscrews (6).
7. Check the shaft end-play. If the end-play exceeds 0.008 inch (0.20 mm) remove the lid and discard one of the housing gaskets.
8. Install the hand lever (7) and secure it with capscrew (4).

### 2-2.5. Oil Pressure Gauges

The standard lubrication system utilizes a pressure gauge containing an integral shutdown switch. In addition, a differential pressure gauge is installed across the oil filter inlet and outlet to enable the operator to constantly monitor the condition of the filter elements. The drop across a new filter with oil at operating temperature is usually less than 5 PSIG (35 kPa). Cold oil or a dirty filter will increase the pressure differential across the filter. The oil pressure on the discharge side of the filter is the approximate pressure to the main bearings.

### 2-2.6. Low Oil Pressure Shutdown Protection

As described in Section 2-2.5, low oil pressure protection is provided by a combination indicating gauge and shutdown switch which monitors the pressure at the end of the main bearing oil header away from the oil pump. The minimum switch shutdown setting is 35 PSIG (243 kPa) decreasing oil pressure. This switch is set at the factory and should not be readjusted. If the packager uses their own shutdown device it must be set at 35 PSIG (243 kPa).

With the crankshaft-driven main oil pump, it is necessary to keep the low oil pressure shutdown device inoperative during compressor start-up to allow the unit to start and build up the oil pressure.

### **▲ CAUTION**

**Whenever the compressor is started, visually check the switch-gauge to ensure adequate system pressure. This is necessary as most control systems have the oil pressure shutdown bypassed for approximately 60 seconds to allow the unit to start and build up the oil pressure. During this time there is no protection against low oil pressure.**

### 2-2.7. Oil Cooler (Heat Exchanger)

The standard oil cooler is a shell and tube type heat exchanger with oil in the shell and water in the tubes. The oil temperature in the frame sump should be maintained within the range given in CHAPTER 5, GENERAL DATA & SPECIFICATIONS under normal conditions. The oil temperature out of the cooler is controlled by regulating the flow of water through the cooler. The oil cooler must be periodically inspected and cleaned if necessary.

***A regular periodic maintenance schedule should be established and followed with any heat exchanger. The following is recommended:***

1. Drain the coolant and oil from the cooler.
2. Remove the bonnets from the heat exchanger and inspect the tubes for erosion or oxide deposits. Scrape the pencils to expose a bright, clean surface. If the pencils are eroded to one-half their original diameter, replace them.
3. Carefully examine the tube bundles for scale or other build-up and clean as required. After cleaning, always inspect the tubes for corrosion or erosion.

### **▲ WARNING**

**All precautionary measures specified by the Occupational Safety and Health Act of 1970 (OSHA) must be complied with when storing, handling, or using solvents.**

4. Clean all interior surfaces. This can be done several ways. Many deposits can be removed by flushing with high-velocity steam or water. For more stubborn deposits, wire brushing and rodding can be employed. Both shell and tube sides can also be chemically cleaned. Make sure any cleaning chemicals are thoroughly flushed from the heat exchanger before putting it back in service.

5. Reassemble the oil cooler. Assembly is the reverse of the disassembly procedure.

### NOTE

At start-up or after a maintenance inspection both shell and tube sides should be carefully vented and must be completely filled.

#### 2-2.8. Oil Filter

The standard oil filter is frame mounted. This filter is a canister type with replaceable element. A pipe plug is provided at the bottom of the filter housing to allow it to be drained.

The oil pressure drop through the filter is monitored by the differential pressure gauge and the filter element should be replaced whenever the pressure drop exceeds 13 to 15 PSIG (91 to 105 kPa) with the oil at operating temperature. Pressure drop with clean oil at operating temperature is approximately 3-5 PSID (21-35 kPa Differential); flow rate varies depending upon the viscosity of the oil.

On early units the oil filter is not frame mounted and uses a different style filter arrangement. The oil pressure drop through the filter is monitored by the differential pressure gauge and the filter element should be replaced whenever the pressure drop exceeds 8 to 10 PSIG (55 to 70 kPa) with the oil at operating temperature. Pressure drop with clean oil at operating temperature is approximately 3-5 PSID (21-35 kPa Differential); flow rate varies depending upon the viscosity of the oil.

To ensure maximum protection for the compressor, check the filter element frequently for clogging or channeling. The filter element should be replaced whenever the frame oil is changed.

Duplex filters can be supplied by Dresser-Rand as optional equipment. If these are installed, a transfer valve enables one filter to be switched "on line" while the other is serviced or placed in the "standby" mode. Service is similar to that for the single filter element described later.

#### ***Oil filter element replacement is as follows:***

1. Stop the compressor, following procedures found in the appropriate section of this Instruction Book.
2. Drain the filter by removing the drain plug.
3. Remove the canister by loosening the lock ring until the canister becomes free.
4. Remove the element and canister together. Then wash the canister with safety solvent. Agitating the solvent during the process will assist in removing loose dirt. The canister should be thoroughly dried before installing a new element.
5. Install the new element with the canister surrounding the element.
6. Tighten the lock ring.
7. Add oil to fill the canister by utilizing the hand oil priming pump until pressure is reached at the gauge.

8. Run the unit, following standard start-up procedure, and observe the filter for leaks. We recommend an observed run of at least ten minutes.

### 2-2.9. Frame Oil Recommendations

Use a good grade of highly refined oil as recommended by a reputable oil supplier or company. The oil selected for use, as a frame lubricant must meet the following requirements.

#### A. General Requirements

The oil must be well-refined petroleum product with low carbon residue. It should not contain fats or fixed oil compounding. Oil containing rust and oxidation inhibitors and a foam depressant is preferred. The oil selected must be substantially non-corrosive to the common bearing metals, with a pour point at least 10°F (5.6°C) below ambient temperature when the unit is started for engine drives.

Multiviscosity lubricants may be used in the crankcase where widely variable ambient temperatures are encountered, provided that the lubricant maintains a viscosity of 115 to 150 SSU (23.7 to 31.8 cSt) at normal operating sump temperature.

When heavier lubricants are used to accommodate higher sump temperatures, crankcase heaters may be required if ambient temperatures fall below 50°F (10°C) to maintain the sump temperature above the pour point.

It is recognized that the oil recommended by the engine manufacturer (when an engine drive is supplied) is normally heavier (in the SAE 40 viscosity range). When this is the case and the user desires to stock only one oil for use in both the engine and compressor crankcases, the heavier weight oil recommended for the engine may also be used in the compressor crankcase. Under cold ambient starting conditions, it is recommended that the oil sump temperature be at least 10 to 20°F (5.6 to 11°C) above the pour point prior to starting for engine drives. This may require the use of auxiliary crankcase heaters.

If sump temperatures above 165°F (74°C) are experienced, the lubricant should be monitored more closely for nitration effects and more frequent oil changes should be scheduled to prevent an increase in long term maintenance problems.

#### B. Viscosity Requirements

The viscosity requirements for the crankcase oil are as shown in Table 2-1.

#### C. Inspection

Conduct all testing of the lubricating oil in accordance with the Standard Methods (latest edition) of the American Society for Testing Materials (ASTM).

#### D. Oil Change Schedule

The oil should be changed every 2000 to 4000 hours, or every 6 months, depending on local conditions, or as indicated by oil analysis. Most reputable oil companies offer laboratory analysis services of oil samples on request. We highly recommend the use of this type service. A once-a-month analysis schedule is recommended when the compressor is operated under severe conditions.

## Lubrication

Where the compressor is operated in an extremely dirty atmosphere, installed outdoors, operated intermittently, handling foul gas, or where the oil reaches high temperatures in a very hot atmosphere, it may be necessary to change the oil more often.

Table 2-1. Crankcase Oil Viscosity Requirements

	SUMP OIL TEMPERATURE		
	Below 145°F (63°C) SAE 20	145-165°F (63-74°C) SAE 30	165-180°F (74-92°C) SAE 40
VISCOSITY AT 100°F (38°C) Saybolt Universal, SSU Kinematic Viscosity, cSt	420 90.5	600 129.5	750 162.5
VISCOSITY AT 210°F (99°C) Saybolt Universal, SSU Kinematic Viscosity, cSt	50 7.3	60 10.5	70 13

### 2-2.10. Frame Oil Level

The amount of oil required may vary slightly from the values listed in Chapter 5 (GENERAL DATA & SPECIFICATIONS). There is a gauge glass located at the oil pump end of the frame, which should be checked periodically, and the oil level maintained as follows:

1. When the unit is running under normal operating conditions, the oil level should be maintained to the line in the center of the sight glass. A filler connection is provided in the frame for adding oil to the sump.

### NOTE

Do not fill to a point where the rotating parts will strike the oil surface; this will cause foaming and loss of oil pressure from the main pump. If the oil level is allowed to drop below the gauge glass, air may be introduced in the oil or oil pump and cause a fluctuating or total loss of oil pressure to the bearings.

### 2-2.11. Frame Breather

The breather, which is mounted on the frame, vents the frames interior to atmosphere while condensing oil vapors and returning the condensed oil to the frame sump. Examine the element at regular intervals and service it as required.

### ⚠ WARNING

All precautionary measures specified by the Occupational Safety and Health Act of 1970 (OSHA) must be complied with when storing, handling, or using solvents.



To service the element, remove the breather's cover. Clean the element by washing it in a safety solvent and allowing it to dry.

### 2-3. CYLINDER LUBRICATION SYSTEM

A mechanical lubricator provides lubrication of the compressor cylinder bores, and pressure piston rod packings. For some applications, "pump-to-point" lubrication is supplied where each lubrication point is fed from an individual lubricator pumping unit. Normally, a metered "Block-type" oil distribution system is furnished with the oil supply coming from the frame. With either method, a check valve is required at the cylinder connection of each oil line to prevent compressed gas from passing back through the lubrication system. Both systems are described below.

Recommendations are given to enable selection of suitable oil for a particular application and to determine an optimum feed rate. For external suction lubricator reservoirs, you must maintain a good grade of lubricant to lubricate internal components. It must be a viscosity grade of ISO 680 compounded with acidless tallow AGMA-8. This provides a high degree of sliding motion under pressure and minimizes wear. It is recommended that the oil be changed at least every 6 months.

#### 2-3.1 Pump-to-Point Lubrication System

HOS compressor cylinders are lubricated by a mechanical lubricator mounted on the frame end cover. The lubricator is directly driven by the oil pump drive shaft. The lubricator drive is shown in Figure 2-2.

##### A. Lubricator Operation

The oil in the lubricator sump is forced by action of the individual pumping units through tubing and check valves to the cylinder bores and piston rod packing. Each pumping unit in the lubricator is adjustable to permit regulation of the oil feed to the various points. Each pump unit is actuated by a rocker or roller type cam follower and cam assembly (see Figure 2-6), causing a plunger piston within the pump body to reciprocate. The pump stroke, thus the pump output, can be varied by adjusting the adjusting sleeve shown in the drawing. Maximum output is achieved with the sleeve fully extended from the pump body.

As the plunger moves downward in stroke, oil is drawn through the suction check valve into the plunger bore from the sight feed reservoir. Removing this volume of oil from the sight feed reservoir creates a vacuum, which causes more oil to be drawn into the reservoir via the suction tube. A small quantity of oil then enters the sight feed nozzle and drips into the reservoir below. The quantity of oil can be determined by counting the drops as they fall. As the plunger moves upward, oil is forced from the plunger bore through the outlet check valve into the feed line to the lubrication point.

##### B. Lubricator Adjustment

***When starting the unit for the first time, prime each lubricator pump as follows:***

1. Remove the sight feed plug and fill the sight feed about one-third full of oil.
2. Manually operate the pump, using the priming stem, until air-free oil is discharged from the pump outlet.

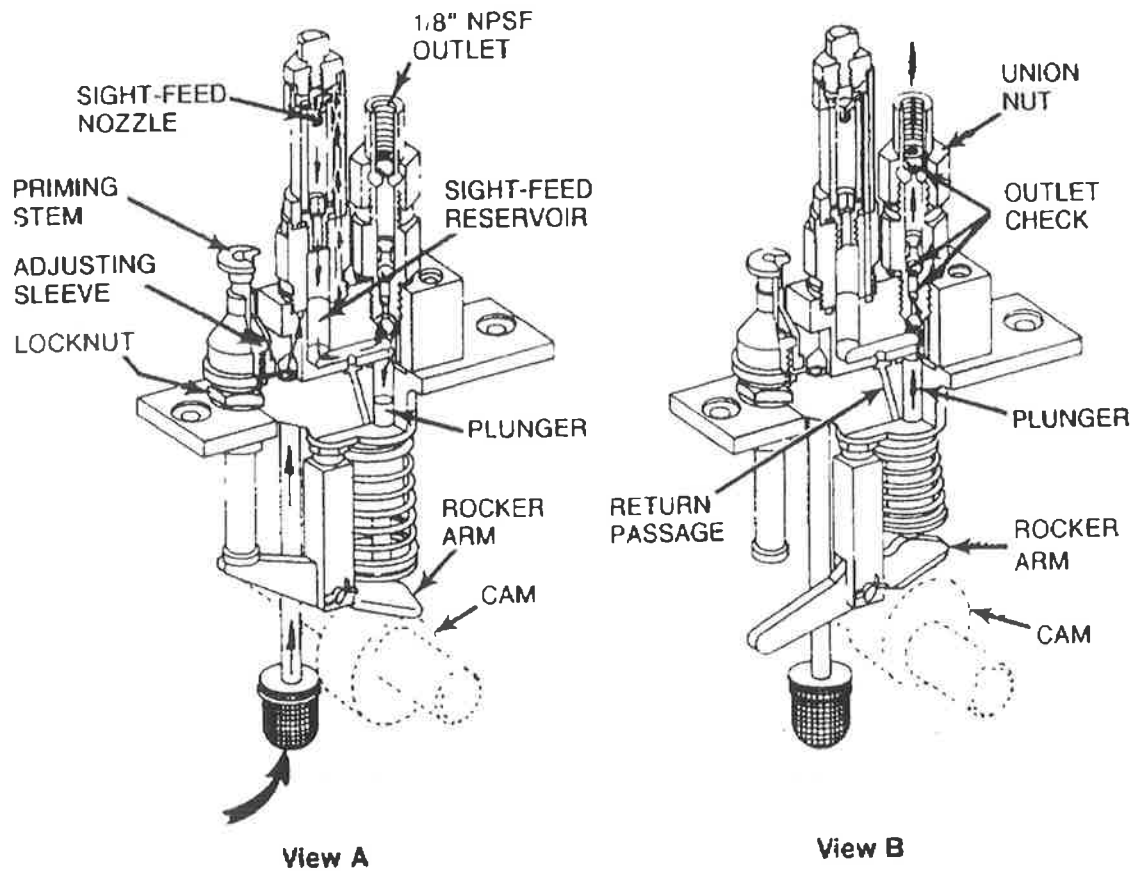


Figure 2-6. Lubricator Pump Assembly

3. Connect the lube feed line to the outlet and continue to hand prime until the line is filled. Connect the other end of the line to the discharge check valve (one at each lube point) and pump a few more strokes to fill the check valve.
4. Refill the sight feed to the one-third full mark, then check the reservoir to make sure it is filled and adjust the pump output (Step 5).
5. With the lubricator in operation, observe the number of drops falling through the sight feed glass over the course of one minute. Adjust the adjusting sleeve to achieve the required number of drops per minute. See Table 2-2. On a good, airtight assembly it is normal for the air in the sight glass to be dissolved in, and gradually replaced by, the oil. This is on no consequence so long as the lubricator reservoir is maintained full and there are no suction side leads in the pumping unit.

**▲ CAUTION**

If the oil level in the sight glass constantly decreases during operation, it indicates that the vacuum created in the sight feed is pulling entrained air from the oil as it passes through. If this continues for any period of time, an air lock in the system can result. When this occurs, the drops normally seen falling in the sight glass will cease. Because no oil is getting to the lubrication point, this can cause serious damage to the compressor. Air lock can be eliminated by refilling the lubricator reservoir, loosening the lube feed line at the pump outlet and manually pumping the unit with the priming stem until no air bubbles are visible in the oil stream. Note that if a fairly rapid loss of oil occurs, the cause is often a leak on the suction side of the pump.

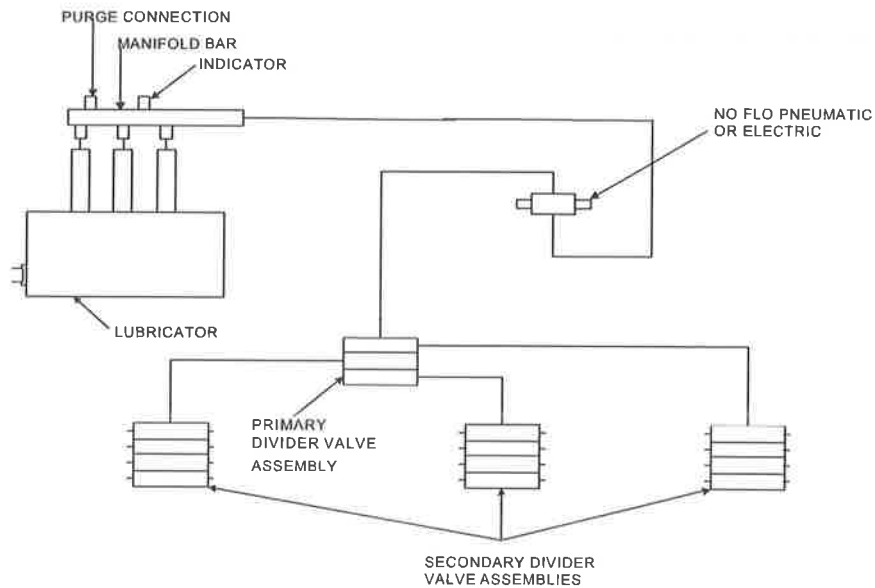
**Table 2-2. Oil Feed Drops per Minute (dpm) Total to Cylinder  
CYLINDER DISCHARGE PRESSURE (PSIG)**

Cylinder Diameter (inches)	25-150	150-300	300-600	600-1500	1500-3000	3000-7500
3 – 6						26-35 dpm
4 – 8	5-14 dpm	11-18 dpm	12-21 dpm	16-28 dpm	21-32 dpm	
8 – 10	7-16 dpm	14-21 dpm	18-26 dpm	21-35 dpm		
10 – 12	9-19 dpm	16-25 dpm	21-32 dpm			
12 – 14	11-23 dpm	19-30 dpm	25-37 dpm			
14 – 16	12-26 dpm	23-35 dpm				
16 – 18	14-30 dpm	25-37 dpm				
18 – 20	16-33 dpm					
20 – 22½	18-37 dpm					
22½ – 26	19-40 dpm					

Drops per minute ÷ .415 = Cubic Inches

**2-3.2. Block-type Lubrication System**

In a metered block-type system, the compressor cylinders are lubricated by a completely integrated unit, which is mounted at the pump end of the frame, and driven directly by the main oil pump drive shaft. One or more conventional mechanical “force-feed” lubricator pumping elements pumps oil under pressure in measured quantities. The system operates as follows: (See Figure 2-7 for a typical installation.) Oil is pumped into a single main line through a filter and a flow switch. The oil is then discharged into the divider valve assembly and from there to various points on the cylinder(s). (The number of lubricator pumping elements varies with the number of cylinders on the frame.) When only a single cylinder is used (in conjunction with a balance cylinder), the extra block outlets are manifolded together and connected back to one of the drain connections in the lubricator.



**Figure 2-7. Typical Block-Type System Schematic**

The flow switch can be used to sound an alarm, or it can be connected to a shutdown device on the driver. The lubrication system is a single-line, progressive, positive displacement system which divides pump output into pre-determined, proportional amounts. It then distributes these amounts to the points of lubrication.

In this type system, the pistons within each divider block assembly are cycled by input flow, continuously dividing and distributing lubricant until input flow ceases. By varying piston diameters, the amount of lubricant received by one point can be changed relative to the amount received by other points in the assembly. The piston not only divides the flow, but also proportions the flow. Due to the valve arrangement, this dividing and proportioning action starts again when input flow is resumed. This assures positive lubricant delivery to each point. Figure 2-8 shows how each piston is "valved" by the completion of a full stroke of a previous piston.

Each divider valve assembly consists of 3 to 8 valve blocks mounted to a base block. O-ring seals between the base and valve blocks provide leak-proof sealing to pressures as high as 6000 PSIG (41.4 Mpa). Lubricant outlets are located in the base block, thus providing easy removal and replacement of worn or contaminated valve blocks without disturbing the base mounting or lubrication lines. All valve blocks are interchangeable in any position on the base block.

One divider valve assembly is capable of serving up to 16 points of lubrication. When more than 16 points of lubrication are to be served, or when good design dictates, a two-stage system is employed. The first stage (the master block) proportions the pump flow, which is subdivided at the second stage (secondary blocks) into the required volumes. In this manner, a multiple number of points can be properly lubricated from one pump supply.

### NOTE

Since the block-type system is based on positive displacement, never block a point intended to be used or try to feed two points from one outlet.

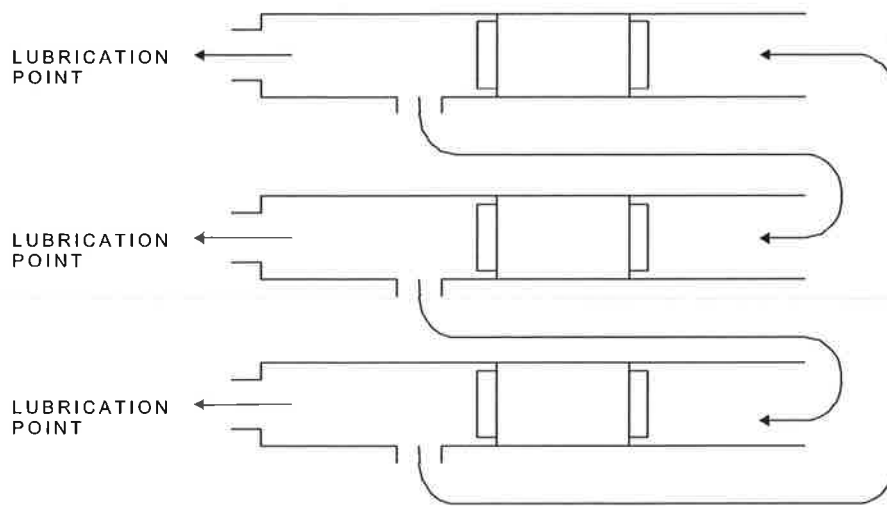


Figure 2-8. Divider Valve Piston Operation

Piston diameters have been selected to provide proper lubrication volumes to each lubrication point. Standard piston sizes result in stroke outputs of 0.006, 0.009, 0.012, 0.018, and 0.024 cubic inches. Each piston makes two strokes (backwards and forwards) per cycle. Two points of lubrication can thus be served from each piston. This type of block is called a "T" (twin-two outlets). The output from each end of a piston can be internally combined to provide twice as much volume to one point. This type of block is called an "S" (single-one outlet).

Table 2-3. Oil Output Per Cycle

PISTON SIZE (VENDOR NO.)	NUMBER OF OUTLETS	VOLUME PER CYCLE (CUBIC INCHES) <sup>1</sup>	RELATIVE PROPORTION
6T	2	.006	1
6S	1	.012	2
12T	2	.012	2
12S	1	.024	4
18T	2	.018	3
18S	1	.036	6
24T	2	.024	4
24S	1	.048	8

<sup>1</sup> One drop equals about 0.002 cubic inches

## Lubrication

The output per cycle of each proportioning piston in any given divider block assembly and its relative value to other proportioning pistons in the same divider block assembly is shown in Table 2-3. Valve blocks are marked "T" for twin and "S" for single.

Keep in mind that while the divider block assemblies supply the relative proportions to points of lubrication, the total volume of oil to all points of the system for any given time period is governed by the lubricator pump supply volume.

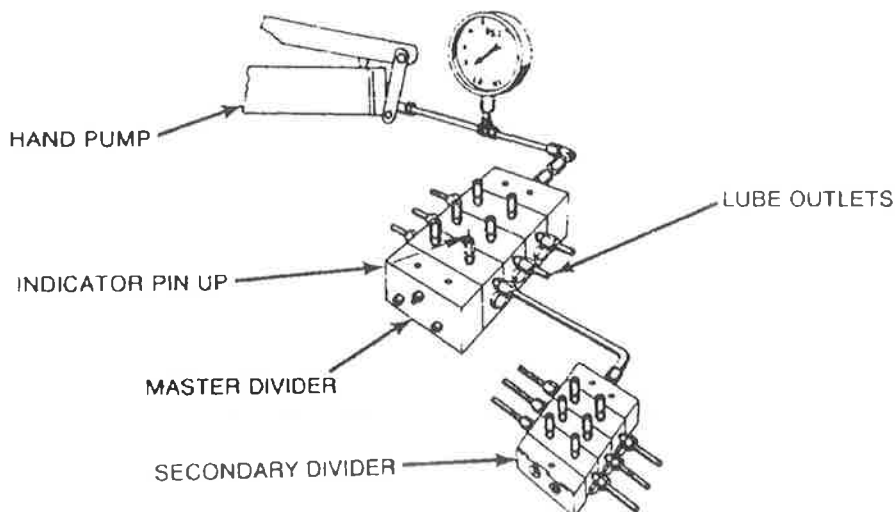
In some installations, the output from two adjacent valve blocks may be internally combined and discharged from one outlet. This is called cross-porting. Newer blocks are externally cross-ported.

### A. Filling and Purging the System

To ensure proper operation of the lubrication system before start-up or after an overhaul, it is imperative that all tubing and components be filled with oil and free air.

#### *To properly fill and purge the system:*

1. Loosen the tube nuts at all injection points. Loosen the tube nuts at the inlets of all secondary divider valves and loosen the four sockethead setscrews at the inlet end of the block. Loosen all alternate outlet plugs on the face of the master divider valve.
2. Remove one alternate outlet plug from the master and connect a manual oil pump to the alternate outlet. (This pump is available from Dresser-Rand. See Figure 2-9.)
3. Operate the manual pump until clear, air-free oil appears at the inlet of the secondary, then tighten the secondary inlet connection. After tightening the inlet connection, continue to pump until clear oil emerges from the four sockethead setscrews, then tighten the setscrews.



**Figure 2-9. Purging Air From Divider Block**

4. Continue to pump until air-free oil is discharge at all injection points served by the secondary divider, then tighten the tube nuts at these points. After all lines to the injection points have been filled and tightened, operate the pump for a few strokes while checking for leaks.
5. Remove the manual pump from the master divider alternate outlet, replace the plug (fingertight), connect the pump to another alternate outlet in the master and repeat the procedure outlined above.
6. After all alternate outlets have been purged, and all alternate plugs replaced (fingertight), connect the manual pump to the check valve on top of the manifold bar.
7. Proceed to loosen the following connections: cap of the atmospheric indicator in manifold bar, inlet connection at the flow-meter, no-flow valve, high-pressure switch and master divider valve. Also loosen the four sockethead setscrews and the inlet end of the master.
8. Operate the manual pump, filing the system from the manifold bar until clear, air-free oil appears at each disconnected point in turn. Tighten loose connections, starting from the atmospheric indicator in sequence to the master divider inlet and sockethead setscrews. Continue pumping until clear oil appears at all master alternate outlets. Tighten all alternate plugs in the master so that the entire system is now completely sealed and oil-tight.
9. Operate the manual pump for a few more strokes to finally check for leads or malfunction. Remove the manual pump and plug the check valve.
10. Disconnect the fittings that connect the lubricator pumps to the manifold and operate each pump manually until a steady flow of oil emerges at the top of the pump line.
11. Connect the pumps to the manifold; the system is now ready to operate. Use the correct, clean, and filtered oil at all stems and be sure the reservoir is adequately filled at all times.

### **B. Maintenance and Troubleshooting**

Performance indicators are used to signal excessive system pressure and localize problem areas. Pin type indicators use a rupture disc, which bursts at a predetermined pressure, and causes an indicator pin will remain out until the disc is replaced and the pin is manually reset. Controls can be installed to sense a pressure signal caused by blockage. This signal can be used to shutdown the compressor or ring an alarm. The rupture disc must be replaced to restore normal operation.

A blockage in the lubrication system may be caused by any of the following:

- Crushed tube line in the system
- Blocked or carboned infection point
- Blocked divider valve assembly

**If blockage occurs anywhere in the divider valve system, proceed as follows:**

### **▲ CAUTION**

**Handle all parts with great care and ensure complete cleanliness. These parts are manufactured to very close tolerances and any nick, scratch, or dirt left on them will interfere with proper operation of the divider block.**

## Lubrication

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1. Connect a manual oil pump, with gauge, to the inlet of the master divider valve and try to cycle the system by pumping oil into the master. If the master divider is equipped with indicators and the blockage is downstream of the master, one of the indicator pins in the master will protrude. Blockage is then down stream of the discharge line common to the protruding pin. If the system will not cycle and no indicator pin is "up" in the master divider, blockage is then within the master divider.
2. If the master divider valve is not equipped with pin-type indicators, remove (one at a time) each alternate outlet plug in the master, which is common to a discharge port. (When plugs are removed, trapped lubricant will usually surge out of the alternate outlet hole which is common to the blocked outgoing line). Pump oil into the inlet of the master after each plug is removed; if pressure drops, the blockage is downstream of the last outlet so tested. While pumping oil into the master, (with all alternate plugs removed), if no oil is discharged at any open port the blockage is within the master divider valve.
3. Proceed to the secondary divider valve, which is downstream from the blocked port, and remove each alternate plug, which is common to a discharge port. Insert the manual pump into the alternate outlet port back at the master divider valve, which serves as a lubricant to this secondary assembly. Pump oil into the master alternate outlet; if lubricant is discharged freely through each of the alternate outlets in the secondary, blockage is not in the secondary divider valve but is downstream of it.
4. Connect the manual pump into each alternate outlet (one at a time) of the secondary block. If, while pumping oil into one of the secondary alternate outlets, pressure builds up, the blockage has been located. Look for crushed lines, or a blocked injection point.
5. If the secondary divider valve will not cycle or discharge lubricant through the open alternate ports, blockage is within the divider valve. If the divider is blocked internally, it must be removed, disassembled and cleaned.
6. Before disassembling the divider valve, remove only the piston enclosure plugs and with strong finger pressure, work the piston back and forth without removing it. If all pistons are moveable, replace the enclosure plugs and retest the assembly by pumping oil in the inlet. (The particle of dirt, which may have caused the internal blockage, may now be dislodged and the assembly may be back in working condition with no further service to be performed.)

### **⚠ WARNING**

**All precautionary measures specified by the Occupational Safety and Health Act of 1970 (OSHA) must be complicated with when storing, handling, or using solvents.**

7. If piston is jammed, proceed with further disassembly, first making a note of valve block positions on the base (for example: Inlet-6S-24T-9T). With individual valve blocks on the bench, remove the piston enclosure screws. Working with one block at a time, remove the piston. If it appears to be stuck, try removing it from the other direction. The piston may have to be forced out of the block by tapping it with a brass rod. When the piston is removed, flush the piston and block with a suitable solvent. Blow out all ports thoroughly and use a small piece of soft wire to probe the passageways. Inspect the cylinder bore for scratches or score marks. Inspect the piston in the same manner. If either of these parts is damaged, replace the valve block. If the block and piston both appear to be in good condition, reassemble the parts, making sure the piston slides smoothly and snugly in the bore. The final step is to disassemble and clean the base block.



8. After the entire assembly has been cleaned, blown-out, inspected and found to be in working condition, assemble the divider valve, positioning the valve blocks on the base in their original order. Test the operation of the assembly with a manual oil pump. If it now functions properly, replace the divider assembly in the system and test for proper system operation.

### 2-3.3. Cylinder Oil Recommendations

Four classifications of lubricating oil have been developed to cover the normal lubrication requirements of compressor cylinders. The physical and chemical properties of the four oil types generally recommended for these units are listed in Table 2-4. (This table is general in nature and covers conditions and pressures not necessarily applicable to HOS compressors.)

Selection of the proper type of oil for your particular application normally will be determined by the discharge temperature and also by the gas quality with respect to "wetness". Consideration also must be given to the local operating conditions. Review this set of oil selection instructions with your oil supplier and compare your particular operating conditions with those listed in Table 2-4 for the various type cylinder oils.

In addition to the operating conditions given in Table 2-4, the following information also must be considered when selecting the type of oil to be used in a particular application.

For Type 2 and 3 oils, the gases handled must be dry; that is, gases which do not carry suspended liquid, contain water vapor or other condensables which remain in the super-heated vapor state throughout the compression cycle. For Type 2X and 3X oils, the gases handled occasionally may carry small quantities of suspended liquid into the cylinder or may deposit some condensation in the cylinder. type 2 oils are generally used when the operator wishes to use internal-combustion engine lubricating oil.

#### A. General Requirements

These oils are well-refined petroleum products of the general types listed. They should be prepared from selected stocks of either naphthionic or paraffinic type, processed to minimize deposit formation. Superior rust-preventative properties also are desired. The pour point must be consistent with the lowest ambient gas intake and cylinder temperatures to be encountered. The pour point always must be sufficiently lower than ambient temperature to permit the proper rate of oil feed by the lubricator. In handling low-temperature gases, select oil of suitably low pour point, on the basis of intake and cylinder temperatures, to maintain a fluid of lubricant in the cylinder.

Type 2 - Internal-combustion engine lubricating oil of the following classes:

- Straight mineral oil.
- Additive-treated, non-detergent oil.
- Detergent engine oil.

Type 2X- Compounded compressor cylinder oil with 5% compounding is recommended. This oil must be capable of providing an improved state of boundary lubrication and must resist the washing effect of the particular condensate involved.

Type 3- Rust and/or oxidation-inhibited oil or straight mineral oil is acceptable.

Type 3X- Compound compressor cylinder oil with 5 to 10% compounding is recommended.

**Table 2-4. Standard Cylinder Oil Recommendations**

Operating Conditions	Type 2	Type 2X	Type 3	Type 3X
Discharge Temp. (°F) (°C)	Max. 350° Max. 177°	Max. 350° Max. 177°	> 350° > 177°	> 350° > 177°
Condensed water vapor present	NO	POSSIBLE	NO	POSSIBLE
Suspended liquid present	NO	POSSIBLE	NO	POSSIBLE
Special Requirements: Cylinder with discharge pressure of 2000 to 7000 PSIG (13.8 to 48.27 Mpa)	NO	NO	REQUIRED	REQUIRED
Flash Point (°F) (Open Cup) (°C)	380° Min. 193° Min.	380° Min. 193° Min.	410° Min. 210° Min.	410° Min. 210° Min.
Viscosity @ 100°F (38°C) Saybolt Universal SSU Kinematic Viscosity cSt	--- ---	780 Max. 168.4 Max.	--- ---	--- ---
Viscosity @ 210°F (99°C) Saybolt Universal SSU Kinematic Viscosity cSt	60 Min. 10.2 Min.	72 Min. 13.3 Min.	105 Min. 21.5 Min.	105 Min. 21.5 Min.
Sulfated Ash	0.50 Max.	---	---	---
Neutralization Value (color); Total Acid Number Strong Acid Number	--- 0.00 Max	--- 0.00 Max	--- 0.00 Max	--- 0.00 Max
Carbon Residue (Conradson)	0.45 Max. <sup>1</sup>	0.45 Max. <sup>1</sup>	0.65 Max.	0.65 Max.

NOTES: <sup>1</sup> = Ash-free basis

This oil must be capable of providing an improved state of boundary lubrication and must resist the washing effect of the particular condensate involved.

**B. Service Considerations**

1. On multi-stage and circular type compressors, or other applications involving high cylinder discharge temperatures, it is necessary to use higher viscosity oil than is normal.
2. When a gas being compressed is saturated with water or hydrocarbons, it is mandatory that a 3X oil be used.
3. Certain lubricating oil additives will cloud the glycerin-water often used in lubricator sight feeds, necessitating frequent changes of the mixture.

4. On services that are compressing air, it is recommend that a synthetic type lubricant is used.

**▲ CAUTION**

**The continuous or intermittent carry-over of liquid to compressor cylinders requires the installation of efficient separators.**

**C. Inspection**

All tests of cylinder lubricants should be conducted in accordance with the Standard Methods (latest edition) of the American Society for Testing Materials (ASTM).

**D. Synthetic Lubricants**

In general, our experience with synthetic lubricants indicates that they will do a commendable lubrication job when the compressor is correctly prepared, the lubricant properly selected, and the lubricant is supplied in sufficient quantity.

Past experience has shown that it is difficult to properly break in new compressor cylinders, particularly larger sizes, on synthetic lubricants. Therefore, we recommend that cylinders first be broken in (at least 150 hours of running time or until the bore surfaces have taken on a glazed appearance) using a 3X oil. After the break-in period, switch to a grade of synthetic lubricant per the lubricant manufacturer's recommendation.

In those few cases where it is absolutely impossible to break in the compressor cylinders on a mineral oil due to system contamination, note that the danger of cylinder scuffing does exist. Extreme cleanliness of suction piping is absolutely mandatory if scuffing is to be avoided because the film thickness of a synthetic lubricant is generally less than with mineral oil. We further recommend that the particular grade of synthetic lubricant be on the higher side of the available viscosity range.

It is important that the quantity of synthetic lubricant fed to the cylinder be ample to wet the entire bore surface and that actual inspections be carried out within a few hours after switching to synthetic lubrication to determine that the feed rate is adequate. We recommend that the lubricator be adjusted to provide approximately double the flow of synthetic lubricant as opposed to mineral base oil during initial start-up and break-in.

Occasionally, units must be started and broken in during low ambient temperatures. Due to the extremely high viscosity index of most synthetic lubricants, take precautions to ensure that the lubricant is warm enough to flow properly.

It must be again pointed out that synthetic lubricants should not be used in the compressor unless the unit has been correctly prepared.

**2-3.4. Break-in and Operation**

Because of the wide range of compressor cylinder sizes and designs, as well as the varying operating conditions encountered at different compressor installations, it is not practical to specify a rigid break-in schedule for the compressor cylinders. On compressor units the break-in of compressor and cylinder end parts is done concurrently, with the load and speed gradually being increased during the break-in period.

## Lubrication

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The compressor cylinders must be broken in gradually because it is necessary that mating parts establish a satisfactory running fit with each other. To do this, there must be a certain amount of wear between the mating parts. Also, during this break-in period, the cylinders may be exposed to dirt, welding beads and other foreign material. This is normally the most critical period in the service life of the cylinder and the demands on the cylinder lubricant are the most extreme at this time.

During the break-in runs, it is also necessary to feed the maximum amount of lubricant in order to help flush out wear particles and foreign material.

Prior to starting the unit for the first time, check to see how many compartments in the compressor cylinder lubricator are used to lubricate the cylinder bores and the piston rod packings. Fill these particular compartments with the break-in oil selected and adjust each of the pump units in these compartments for maximum oil feed. Disconnect all lubricator lines at the cylinders and packing glands; then, operate the lubricator pump(s) manually until oil appears at each broken connection. This may require the compressor to be rotated in order to manually pump each plunger. Reconnect the piping and operate the pump(s) several strokes to assure an initial supply of oil at each point of lubrication when the machine is started. Also, during the priming period check lubricator piping and connections for possible leaks; any leaks found should be corrected at this time.

### NOTE

If the compressor cylinders are being lubricated by a block-type oil distribution system, all piping and components in that system must be filled with oil and purged of air; this must be done manually, following the instructions found later in this chapter.

The following time schedule is generally applicable for lubricating the compressor cylinders during the break-in period, when the cylinders will ultimately be lubricated with a petroleum based product:

For the first full week of operation the lubricator pumping units should be adjusted for maximum feed rate. As the cylinder wears in, occasional inspections should be made to the cylinder bore to see if it is taking on a glazed appearance. Should any trouble develop (usually in the form of increased temperatures) as the oil is being diluted, increase the pumping rate until a glaze is formed on the cylinder walls.

It is usually desirable to reduce to a minimum the quantity of oil from the lubricator to the compressor cylinders and rod packing from the standpoint of oil economy, coupled with the need to avoid excessive oil in the discharge and carbon build up in the packing. Because of the widely differing conditions under which these units operate (the variety of cylinder sizes, pressures, temperatures, and types of gas handled) it is impossible to establish any ironclad rule for the quantity of oil required for cylinder and piston rod lubrication. The ideal condition is to feed the minimum quantity that will adequately lubricate the surfaces. This minimum quantity can be established only after several weeks of operation and experience.

We offer as guidelines the following:

- Under normal operating conditions, the amount of cylinder oil required for the various cylinder sizes and pressures are displayed in Table 2-2. These feed rates are approximate and are based on an empirical formula that varies to suit the particular conditions of service of the compressor cylinders and the gas compressed. The figures given are the suggested normal feed rates when clean and dry conditions prevail in the compressor cylinder. Wet and dirty air or compressed gas may require increased feeds as conditions dictate.

- The feed rates given are the totals for the cylinder bore and packing, and are based on an average sized drop (with 14,000 drops equaling one pint of oil at 75°F). Any variation in drop size will require recalculation. To determine the feed rate for each individual feed, divide the drops given in the table by the number of lubricator lines (feeds) to the cylinder. Adjusting the oil feed rate at the lubricator will increase or decrease the flow rate the same amount to each lubrication point. Check all lubrication points to determine the optimum amount. Again, the figures given are only an approximation. For a more detailed lubrication rate requirement refer to the packager guidelines and/or compressor lubrication schematic. Good judgement is required whenever the particular conditions of service are out of the ordinary.

### NOTE

The figures given in Table 2-2 are for gravity and vacuum type sight feed lubrication. Feeds to cylinder bores never should be less than two drops per feed per minute, under any circumstances.

Oil feed rates to the piston rod packing also will depend upon the condition of the air or gas compressed. Under normal clean and dry conditions, four to five drops of oil per feed per minute should be satisfactory. During the first few weeks, it is better to feed too much oil than too little. After the packing rings have seated themselves on the rod, the lubrication to the packing should be just enough to maintain a very light film of oil on the rod.

The compressor cylinder bores, valves, and gas passages should be carefully examined each time before and shortly after any reduction is made in cylinder lubrication, and the reduction must be made in small steps. The correct oil feed is that which will just maintain a light film on the cylinder walls. A puddle of oil in the counterbore at the end of the cylinder or in the discharge passage can be evidence of over-lubrication or unsuitable oil. The appearance of any dry spots on the cylinder walls is definite evidence of inadequate lubrication or an improper combination of temperature, gas characteristics and oil.

### 2-3.5. Extended Shutdown

When the compressor is shut down for more than a few days, it is recommended that precautions be taken to keep the cylinders in good condition during the shutdown period. An extra quantity of oil should be pumped to the cylinder bore and piston rod packing, by manually operating the mechanical lubricator pumping units, just prior to shutting down the compressor when an extended shutdown is planned. Periodically thereafter, oil should be manually pumped to the cylinders while barring the unit one and quarter revolutions.

### 2-3.6. SYSTEM MALFUNCTIONS AND THEIR CAUSES

1. Pump does not discharge lubricant:
  - Empty reservoir
  - Air entrainment

2. Pump repeatedly ruptures disc:
  - Clogged filter
  - Blocked main line, divider valve or injection point
  - Disc pressure rating incorrect for the system
  
3. Divider valve does not cycle:
  - Contaminated or stuck piston
  - High pressure downstream; broken tube line serving this valve
  
4. Divider valve leaks:
  - Valve block screws loose
  - O-ring not installed
  - O-ring damaged
  
5. Divider valve repeatedly ruptures disc:
  - Blocked line downstream
  - Blocked injection point
  - Improperly drilled tube fitting
  - Rupture disc pressure rating incorrect for system

6. Flow meter does not register counts:
- Loss of lube supply
  - Broken line
  - Inoperative divider valve in flow meter
  - Damaged linkage
  - Loss of air supply
  - Inoperative air valve
  - Inoperative air cylinder or counter
7. No-flow valve fails to properly shut down:
- Incorrect adjustment
  - Valve improperly installed
  - Stuck or contaminated piston

**DRESSER-RAND****OPERATION & TROUBLESHOOTING****HOS  
Chapter 3**

<b>Paragraph</b>		<b>Page</b>
3-1.	GENERAL .....	3-2
3-2.	PREPARATION FOR INITIAL START .....	3-2
3-2.1.	Alignment Check .....	3-2
3-2.2.	Lubrication Systems .....	3-4
3-2.3.	Compressor Cylinders.....	3-4
3-2.4.	General Inspections and Adjustments.....	3-5
3-2.5.	Compressor Cooling System.....	3-5
3-3.	CAPACITY CONTROL .....	3-5
3-3.1.	Cylinder Clearance Volume .....	3-6
3-3.2.	Cylinder Unloading.....	3-6
3-3.3.	Suction Pressure Control.....	3-6
3-3.4.	Capacity Control Bypass.....	3-6
3-4.	COMPRESSOR LOADING AND UNLOADING .....	3-6
3-4.1.	Loading/Unloading Procedure – Bypass and Discharge Valve Method.....	3-9
3-4.2.	Loading/Unloading Procedure – Vent Valve Method .....	3-9
3-5.	INITIAL START-UP .....	3-9
3-7.	BREAK-IN AND OPERATION .....	3-11
3-7.	SUGGESTED ROUTINE STARTING PRACTICES .....	3-11
3-8.	ROUTINE STOPPING .....	3-13
3-9.	EMERGENCY OR NON-SCHEDULED SHUTDOWN .....	3-13
3-10.	SHUTDOWN FOR AN EXTENDED PERIOD .....	3-13
3-11.	ROUTINE OPERATION AND MAINTENANCE .....	3-14
3-11.1.	Daily .....	3-14
3-11.2.	Weekly .....	3-15
3-11.3.	Monthly.....	3-15
3-11.4.	Every Three Months.....	3-16
3-11.5.	Every Six Months.....	3-16
3-11.6.	Annually.....	3-17
3-12	TROUBLESHOOTING BY SYMPTON.....	3-18



### 3-1. GENERAL

The operator should carefully read this section before the unit is prepared for its initial start. The purpose of this section is threefold; first, to familiarize the operator with the requirements of the unit; second, to outline the recommended procedures for starting, loading and stopping the unit; and third, to assist the operator in setting up an efficient inspection and maintenance schedule. Optimum performance can be obtained by closely adhering to the instructions in this section.

After the operators have started the machine a number of times, and have received experience in caring for it, starting will become a routine procedure. However, there are a number of special precautions that must be taken when starting a compressor for the first time. Carelessness or lack of knowledge can result in serious damage to the equipment and to personal injury. If possible, an experienced erection engineer should supervise the initial start of the unit; even then, the regular operators should be well acquainted with the details of the machine, the precautions to be taken when starting, and the reasons for them.

When the unit is checked out prior to initial start-up, it is an excellent idea to log important clearances and runout figures. This will establish benchmark readings for these clearances, which will allow calculation of wear rates and establish a meaningful maintenance schedule. It is equally important to log these same clearances after any major overhaul.

### 3-2. PREPARATION FOR INITIAL START

#### NOTE

On a new compressor no internal inspections are required. (If the machine has set for over 6 months refer to Section 3.2.3)

#### CAUTION

**Refer to the instructions supplied by the manufacturer of the compressor driver when preparing the unit for start-up; carefully follow the manufacturer's recommendations. This also applies when placing into operation accessory equipment items such as coolers, filters, pumps, and similar equipment.**

Thoroughly inspect the entire machine to be certain there are no loose parts or tools where they can cause damage or interfere with start-up.

#### 3-2.1. Alignment Check

#### CAUTION

**It is extremely important that the driver-to-compressor alignment be checked before start-up.**

### NOTE

The following procedure is designed for a standard flex type coupling alignment.

A check of the drive alignment is required before starting the unit. The purpose of this drive alignment check is to verify that, during positioning of the skid, the alignment of the driver crankshaft to the compressor crankshaft has not shifted. The following procedure applies to the coupling drive arrangement normally supplied:

1. Make a suitable fixture to mount two dial indicators at the coupling hub.
2. After the fixture is securely fastened to the coupling hub, mount a dial indicator to read on the outer rim of the compressor coupling hub and another indicator to read on the face of the hub.
3. Rotate the driver through one complete revolution and bring both indicators to the top vertical position with the respect to the driver flywheel; then, using a marking pencil or chalk, place reference marks on the flywheel and flywheel housing. These will be the zero reference marks.
4. Mark the flywheel housing at the 90°, 180° and 270° positions. These marks will be used as reference points to take the dial indicator readings.
5. Using a bar, shift both crankshafts against their stops in the same direction.
6. Zero the dial indicators, with the driver flywheel at the top vertical reference marks, then rotate the driver to the 90° mark and take an indicator reading; repeat at the 180° and 270° marks and then return to the starting point. Recheck the zero settings at the starting point. Be sure the driver and compressor crankshafts are first shifted per Step 5 before recording the indicator reading at each reference point.
7. Compare the dial indicator readings to determine the main point of misalignment. If readings taken at the 180° reference point indicate that the driver is high or low at the drive coupling end, this will, in most cases, indicate that the driver end of the skid is not properly leveled with respect to the compressor end. Correct this misalignment by raising or lowering the driver by readjusting the shimming at the driver mounting points.
8. When it has been determined that all possible misalignment has been corrected by raising or lowering the driver, take a final set of indicator readings at each of the reference points. The coupling misalignment should be as close to zero as possible and must not exceed 0.005 inch (0.13 mm) Total Indicator Reading when the equipment is up to operating temperature. Therefore a tolerance for thermal growth should be considered when performing this cold alignment procedure. (See CHAPTER 5 for specifications). If further alignment adjustments are necessary, do this by adding or removing shims from the driver mounting points and by moving the driver sideways, if required, using jack screws against the sides of the driver base.

### NOTE

In most cases, Dresser-Rand specifies coupling misalignment limits that are much tighter than those allowed by the coupling manufacturers. Always adhere to the Dresser-Rand limits.

### 3-2.2. Lubrication Systems

1. Refer to CHAPTER 2, LUBRICATION for a detailed description of the compressor frame and running gear lubrication system, and the compressor cylinder lubrication system. Recommendations for selecting the proper oils for frame and cylinder lubrication will also be found in CHAPTER 2. *The operator should be thoroughly familiar with the lubrication requirements of the compressor before starting the machine.*
2. The following procedure should be used to check the entire frame lubricating system prior to starting the compressor for the first time:
  - A. The rust preventative coating applied to the lube system at the factory is soluble with the recommended lubricating oils and need not be removed.

### CAUTION

**All precautionary measures specified by the Occupational Safety and Health Act of 1970 (OSHA) must be complied with when storing, handling, or using solvents.**

- B. Check all oil piping for tight connections.
- C. Fill the frame oil sump to the level indicator on the oil level gauge. Refer to CHAPTER 2, LUBRICATION for the grade and quantity.
- D. We recommend the operator use a manual or motor-driven priming pump to circulate the oil and fill the lubricating system (Vent air from oil filter while circulating). The bearings may suffer from a "dry" start. Add oil to the frame sump as required. Do not fill above the level mark on the level gauge because the rotating compressor parts may strike the oil surface, causing foaming and loss of oil pressure.
- E. Continue to operate the priming pump until pressure indication is seen at the gauge. Check external oil piping during this period for tight connections.

### 3-2.3. Compressor Cylinders

#### NOTE

The compressor is normally shipped from the factory with externally fed lube pumps with oil supplied from the frame oil system. Should special oil lubricant be required please consult with the factory.

1. Fill the lubricator box with high-grade lubricating oil. The same oil selected for the frame can be used in the lubricator box. This oil is for lubrication of the camshaft, pump rocker arms and the gears inside the lubricator box.
2. Disconnect all lubrication lines and prime until all air is forced out of the lines and oil appears. Reconnect the lines and cycle the lubricator pumps a short time so the cylinders will be lubricated as soon as the compressor is started. The lubricator feed(s) should be initially set for maximum flow. Once the compressor is started, the oil lines will remain full of oil. After a few days of operation, as the cylinders wear in and the bores become glazed, the oil feed rate can gradually be reduced. This is described in more detail in the break-in instructions, which are found in CHAPTER 2, LUBRICATION.

*If the machine has set for over 6 months proceed with the following:*

3. Remove the outer head and inboard suction valve assembly from each compressor cylinder and inspect the cylinder bores.
4. Reassemble the cylinders using adequate lubricating oil.

### NOTE

For cylinders operating in non-lube service re-assemble cylinders dry.

#### 3-2.4. General Inspections and Adjustments

1. Check, and tighten as required, all bolts and nuts to be sure that all is ready to start. Refer to CHAPTER 5, GENERAL DATA & SPECIFICATIONS for specific tightening recommendations.
2. The piston rod runout has been checked and piston end clearances have been set at the factory. However, if an outboard cylinder support has been installed in the field then the rod runout must be checked prior to starting the unit. Refer to CHAPTER 4, MAINTENANCE for detailed procedures for checking the piston rod runout and piston end clearances. The final settings should be recorded for future reference.
3. Prepare the compressor driver and any accessory equipment for initial starting and operation per the manufacturer's recommendations.

#### 3-2.5. Compressor Cooling System

1. Run coolant through the shell and tube type compressor oil cooler to be sure the cooling system is operative and that all connections are tight. Vent the water side of the cooler and all high points in the piping to remove trapped air.

### 3-3. CAPACITY CONTROL

Capacity control, as used in this context is any means of varying the capacity of the unit to meet the conditions under which the unit is applied. For most engine driven compressors, the simplest method of capacity control is varying the speed of the driver. Another, more long term adjustment, involves changing cylinder sizes. This section covers four of the more common methods used to vary capacity for shorter durations. The first is by adding clearance volume to the cylinder to reduce volumetric efficiency of the cylinder. The second is by cylinder unloading. The third is by varying the suction pressure through use of a suction pressure control valve. A fourth method is through use of a bypass system. Each will be discussed more fully in the following sections.

### **3-3.1. Cylinder Clearance Volume**

The standard compressor cylinder provides for the addition of clearance volume to both the outboard end and frame end of the cylinder. The outer end inlet valve travel is adjustable, thus acting as a variable volume clearance pocket. The outer end is adjustable while the compressor is running. The frame end inlet valve location can be positioned to add fixed clearance to the frame end with the addition of center bolt spacers. The frame end clearance can only be added during a shutdown period. When clearance volume is added, cylinder performance should be checked for adequate rod reversal and volumetric efficiencies. This method of capacity control reduces the horsepower requirements proportionally to the reduction of flow.

### **3-3.2. Cylinder Unloading**

1. Unloading of a cylinder end is done by retracting the suction valve from the unloaded end. This has the effect of reducing the capacity of the machine by the amount of flow the unloaded end is capable of generating. This method of capacity control reduces the horsepower requirements by approximately 50 percent.
2. Unbalanced forces occur when unloading one end of one cylinder; therefore, this type of unloading should not be done unless specifically approved by Dresser-Rand. Approval of loading is also required when using a balancing crosshead or balancing cylinders. A further limitation to single end unloading, on one or both cylinder ends, is imposed when non-reversing loads are imparted to the crosshead pin. If there are numerous loading conditions, combined with speed changes, refer the matter to Dresser-Rand for a complete analysis of the running gear and rod loadings.

### **3-3.3. Suction Pressure Control**

1. Controlling the suction pressure to the compressor can also be used to control capacity. This is most often used when horsepower is limited and the flow rate is higher than the unit can handle. A suction control valve is used to hold the suction pressure to a preset limit, thereby limiting flow. Performance must be run at the desired set point to ensure that temperature and rod load limits of the compressor are not exceeded. This method of capacity control offers the advantage of a stable operating condition for the unit.

### **3-3.4. Capacity Control Bypass**

1. A unit bypass system may be used to control capacity, particularly when the unit is oversized, or when the suction pressure is not stable and has a tendency to fall below a desirable limit. This method utilizes a pressure control valve in the bypass system around the unit, set to operate at the minimum operating point for the compressor. When this method is used, it is important that the bypass gas stream be taken downstream of a process aftercooler. This will avoid an uncontrolled temperature rise during continuous operation. Figure 3-1 illustrates.

## **3-4. COMPRESSOR LOADING AND UNLOADING**

It is important that the compressor be unloaded prior to and during startup. There are two basic methods to loading and unloading a HOS compressor. Which of the two is best suited for a particular installation depends on site conditions. The following should be considered prior to designing the piping system:

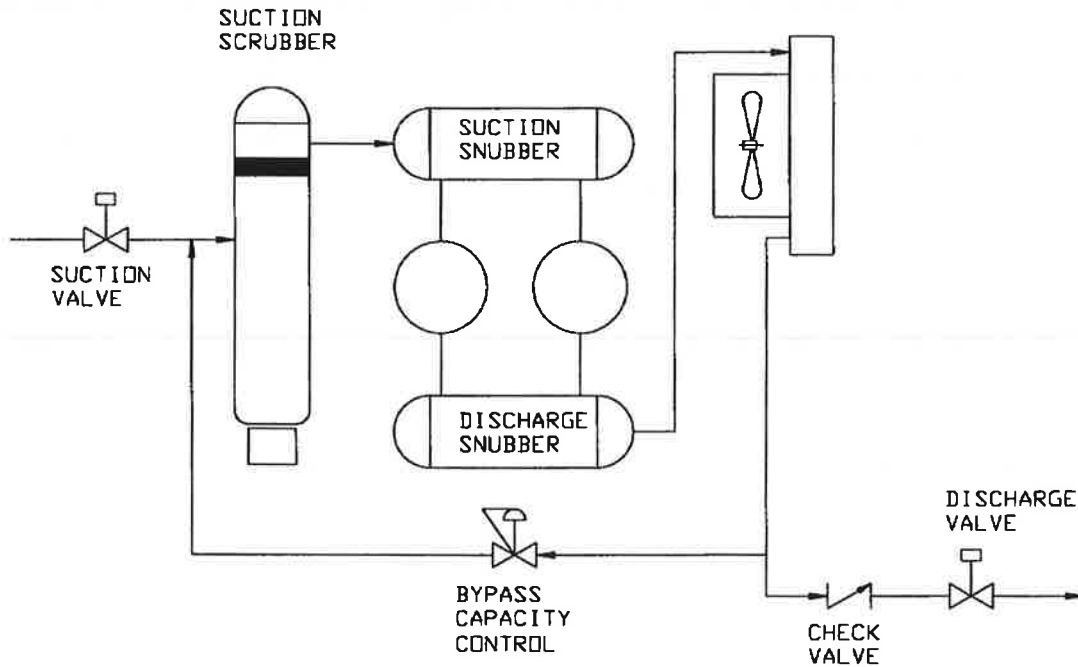


Figure 3-1. Bypass Capacity Control

The two methods are as follows:

- Bypass and discharge check valve method
- Vent valve method

Probably the simplest, most reliable and safest method is by use of a bypass and discharge check valve. This is illustrated in Figure 3-2. With this set-up, there is little danger of exceeding rated rod load and the rate of loading can be controlled by the rate of closing the bypass valve. On multiple-stage units, this set-up works well for sequence loading because each block valve is opened or closed separately. It should be noted that with this method, when the compressor cylinders and piping are pressurized to suction gas pressure the load on the unit will be dependent on the sizing of the bypass valve and associated piping. Also, the sizing of the bypass valve and piping will be the limiting factor on the period of time the unit can be bypassed without excessive gas heating.

The other method of loading and unloading is the vent valve method. This is illustrated in Figure 3-3. This method results in the venting of excess gas during loading which may not be acceptable in certain situations at particular sites. Also, during idling periods the compressor will pull partial vacuum on the suction piping downstream of the suction valve and it is extremely important that the unit is purged prior to loading. Additionally, the suction valve must be fully open prior to closing the vent valve to prevent the possibility of generating excessive rod loads.

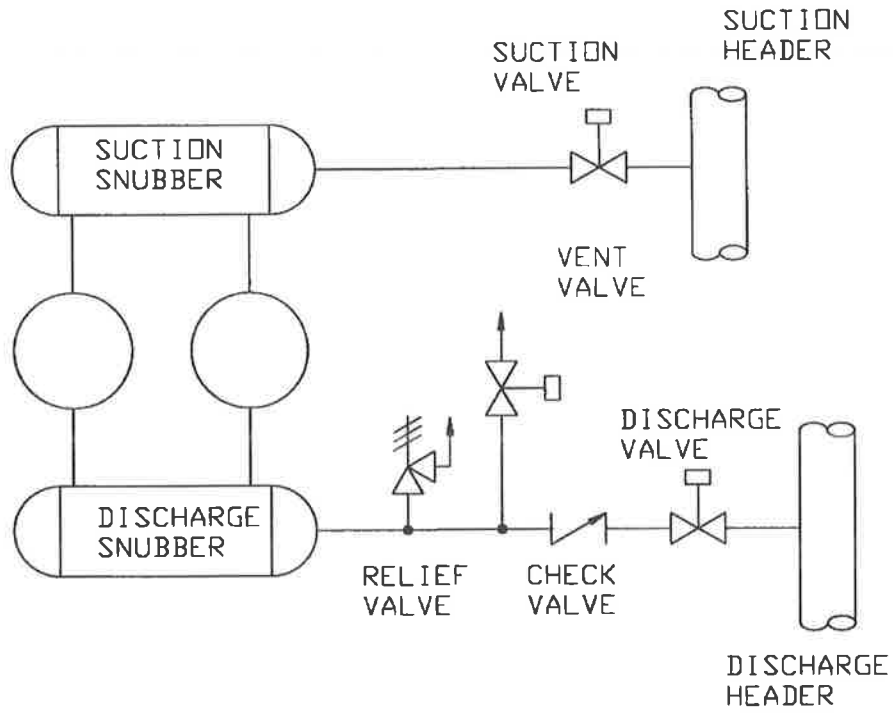


Figure 3-2. Bypass and Discharge Check Valve Method

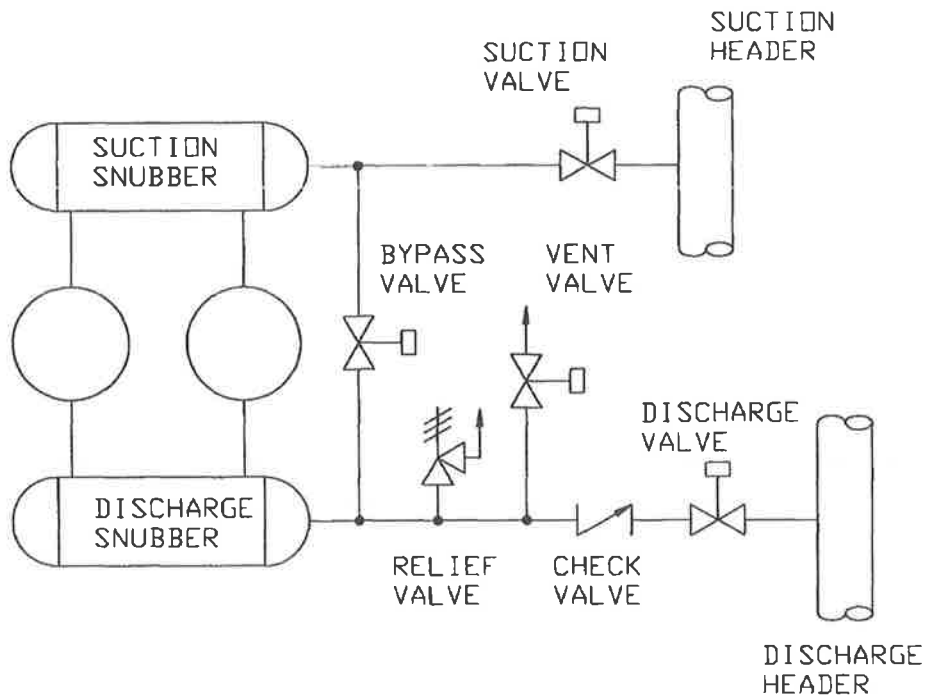


Figure 3-3. Vent Valve Method

### 3-4.1. Loading/Unloading Procedure - Bypass and Discharge Check Valve Method

1. Prior to starting the unit, ensure the suction and discharge valves are closed. Then, open the bypass valve and the vent valve to de-pressurize the compressor cylinders and piping to atmosphere.
2. Start the driver and allow it to idle and warm up; after ten minutes of warm-up bring it up to fast idle.
3. Open the discharge valve, which will allow discharge pressure to back up against the discharge check valve.
4. Partially open the suction valve to purge the compressor cylinders and piping.
5. Pressurize the compressor cylinders and piping by closing the vent valve and opening the suction valve.
6. Load the unit by closing the bypass valve.
7. Reverse the preceding steps to UNLOAD.

### 3-4.2. Loading/Unloading Procedure - Vent Valve Method

1. Prior to starting the unit, ensure the suction and discharge valves are closed. Then, open the vent valve to pressurize the compressor cylinders and piping to atmospheric pressure.
2. Start the driver and allow it to idle and warm up; after ten minutes of warm-up, bring it up to fast idle.
3. Open the discharge valve, which will allow discharge pressure to back up against the discharge check valve.
4. Partially open the suction valve to purge the compressor cylinders and piping.
5. Load the unit by opening the suction valve fully, then by closing the vent valve.
6. Reverse the preceding steps to UNLOAD.

### 3-5. INITIAL START-UP

1. When starting the compressor for the first time, it is extremely important that the operators are alert for unusual or abnormal pressures, temperatures, noises and other conditions. Indicating gauges and thermometers should be closely monitored during this initial starting period.
2. Read the following break-in instructions before starting the compressor. The procedure, which follows, applies generally to the initial start of the unit; some modifications to this procedure may be required when starting a particular machine.
  - A. As far as is practical, check the inlet and discharge lines for foreign objects. Check all line valves for proper location, flow direction, and position.



- B. Operate the priming oil pump to pre-lubricate the compressor bearings and to build up a slight pressure in the frame and running gear lubrication system.

### CAUTION

**On electric motor driven machines a prelube pump is required. See CHAPTER 5, GENERAL DATA & SPECIFICATIONS for recommended minimum prelube capacities.**

- C. Manually operate each lubricator pumping unit, by pushing down the plunger cap, to ensure that oil is being fed into the cylinder bores and piston rod packing. This can be confirmed by motion of the cycle indicator pin in the distribution blocks. This may require the compressor to be rotated in order to manually pump each plunger.
- D. Walk around the machine to double check that all equipment is ready for start-up and that all personnel in the area are aware that the unit will be started.

### WARNING

**The operator must ensure that the driver will not start, by grounding the ignition and closing the fuel gas valve on engine driven units or by ensuring that the power cannot be turned on with electric motor driven units, before barring the unit over.**

- E. Release the driver flywheel lock, if fitted. Bar the compressor over a few times to be sure all moving parts are clear and also to ensure that lubricating oil is distributed to all running surfaces. Disengage the barring device prior to start-up.
- F. Turn on the cooling water to the frame oil cooler.
- G. Start the driver according to the manufacturer's instructions.

### CAUTION

**The machine must be immediately shut down if an abnormal condition exists, and the cause found and corrected before restarting the unit.**

- H. After the compressor is started, observe the frame oil pressure and check the cooling water temperature. Watch for signs of excessive heating, unusual noises or other abnormal conditions.
- I. If everything appears normal, operate the machine continuously for 30 minutes at no load. On engine driven units, the engine speed can be varied from idle to mid-range speed during this period.

### CAUTION

**Never operate any compressor at maximum speed with no load. The piston rod load may be exceeded at this condition.**

- J. At the end of the 30 minute period, if no problems are identified the compressor is ready to purge and load for the operation and service that the unit is intended for. When placing the unit in service, pay particular attention to the break-in considerations that are given in the following instructions.

### NOTE

Verification of proper cylinder bore lubrication is not final until the bore has been checked after the unit has been shut down under load. Lubrication rates vary depending on load conditions.

### 3-6. BREAK-IN AND OPERATION

1. The normal procedure for "breaking in" a new compressor involves several short runs at gradually increasing speed and load. The type of driver and the particular operating conditions will dictate the break-in requirements and procedures.

### CAUTION

**Compressor cylinders should be set up according to performance data sheets before loading.**

2. Sometime during the break-in period, while the unit is not in operation, tighten the cylinder mounting flange nuts, packing gland nuts and all other exposed nuts and bolts. When first subjected to full load and temperature conditions, gasket material will crush; if joints are not tightened up at this time, oil, water, or gas leaks may start later or stud breakage may occur. Check all foundation bolts to ensure they are tight. Tightening requirements are given in CHAPTER 5, GENERAL DATA & SPECIFICATIONS.
3. Because of the wide range of operating conditions, it is not practical to give specific break-in recommendations for the cylinders. The instructions in CHAPTER 4, MAINTENANCE are general and should be modified as required to suit a particular situation.

### 3-7. SUGGESTED ROUTINE STARTING PRACTICES

The routine starting procedure, which follows, is for a typical compressor equipped for manual starting. Some modifications to this procedure may be required to suit a particular compressor and drive arrangement; however, it is important that a standard starting sequence be established and followed consistently by the operators.

1. Check the oil level in the frame sump and add oil as required to bring the level to the mark on the oil level gauge.
2. Operate the priming oil pump to pre-lubricate the compressor bearings and to build up a slight pressure in the frame and running gear lubrication system.

### CAUTION

**On electric motor driven machines a prelube pump is required. See CHAPTER 5, GENERAL DATA & SPECIFICATIONS for recommended minimum prelube capacities.**

3. Manually operate each lubricator pumping unit, by pushing down the plunger cap, to ensure that oil is being fed into the cylinder bores and piston rod packing. This can be confirmed by motion of the cycle indicator pin in the distribution blocks. This may require the compressor to be rotated in order to manually pump each plunger.

### NOTE

If the compressor has been opened to the atmosphere, it should be purged with process gas before being put on line to ensure that no oxygen is present in the cylinders or piping.

4. Unload the compressor. The method of starting-unloading must be established for each compressor, but is generally accomplished by use of a manual bypass system. Blow down the unit prior to starting.

### ▲ CAUTION

**Never operate any compressor at maximum speed with no load. The piston rod load may be exceeded at this condition.**

5. Check to ensure all equipment is ready for start-up and that all personnel in the area are aware that the unit will be started.
6. Bar the unit over once to be sure all moving parts are clear. This is especially important when the unit has just been serviced.
7. Turn on the cooling water and check to be sure the cooling system is operative.
8. Prepare the driver for start-up according to the manufacturer's instructions.
9. Start the driver and run the compressor at no load for ten minutes or until the frame oil warms to 90°F (32°C). Refer also to the driver instructions for warm-up requirements. (When starting an engine driven compressor, the unit is normally warmed up at 800 to 900 RPM and the load then applied before bringing the machine up to operating speed.)

### ▲ CAUTION

**Do not operate the compressor at a speed less than 500 RPM.**

10. When the unit is warmed up and determined to be operating satisfactorily, without any unusual noises, the compressors can be loaded. Build up the discharge pressure gradually, by slowly closing the manual bypass valve. Note the gas temperatures while loading (abnormal temperatures are often the first indications of trouble).
11. Adjust cooling water flow if required.
12. When temperatures and pressures have stabilized, record for future reference as operation and maintenance guidelines.

### 3-8. ROUTINE STOPPING

1. When the compressor drive is an engine, it should be slowed to idle speed.

### **▲ CAUTION**

**Do not operate the compressor at a speed less than 500 RPM.**

2. Unload the compressor by slowly opening the bypass valve. A standard unloading procedure should be set up for each compressor application as they may not all be manual.

### **NOTE**

During normal operations cylinder o-rings may become saturated with gas, especially at pressures above 1000 PSIG. When a compressor is blown down too rapidly the o-rings may blister due to the rapid escape of the gas from the o-rings. This is known as explosive decompression. To avoid this a compressor should be blown down at a moderate rate allowing the gas to escape the o-rings without blistering. If this situation should arise consult your nearest Dresser-Rand Distributor.

3. Allow the compressor to operate at idle speed at no load for several minutes to cool.
4. Stop the driver according to the manufacturer's instructions.
5. Prepare the compressor so that it can be restarted on short notice.

### 3-9. EMERGENCY OR NON-SCHEDULED SHUTDOWN

1. If any emergency occurs requiring immediate shutdown of the compressor, the compressor can be shut down under load.
2. In the event of an automatic safety shutdown, the operator should immediately check to find the cause of the shutdown. If the problem is not readily apparent, the operator should relieve the system of pressure before making a more thorough examination.
3. If it appears that the compressor will not be operating again within ten minutes, turn off the water flow to the cooler and cylinders.

### 3-10. SHUTDOWN FOR AN EXTENDED PERIOD

### **▲ WARNING**

**The operator must ensure that the driver will not start, by grounding the ignition and closing the fuel gas valve on engine driven units or by ensuring that power cannot be turned on with electric motor driven units, before barring the unit over.**

## **Operation and Troubleshooting**

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1. If the compressor is to be shut down for less than a month, the manual frame oil priming pump and the cylinder lubricator pumps should be operated every 30 days and the unit barred one and a quarter revolution.
2. If the compressor is to be shutdown more than a month, the compressor frame and cylinders should be preserved.
3. Refer to the manufacturer's recommendations for the driver and other accessory equipment when planning an extended shutdown of these items.

### **3-11. ROUTINE OPERATION AND MAINTENANCE**

The HOS compressor is designed and built for long periods of continuous full-load operation and should be equipped with automatic safety switches to shut it down in case of low frame oil pressure, vibration, or lack of cylinder lubrication. It can be equipped with additional safety devices to obtain practically any degree of protection desired.

When the unit is first placed in operation, and the machine is operating at normal speed and load and with stable operating pressures and temperatures, all safety alarm and shutdown controls should be carefully checked for correct operation. Never disconnect the safety shutdown devices and allow the unit to run unprotected.

Every compressor requires a certain amount of supervision and care if it is to give continued satisfactory performance and long service life. A time schedule of duties for the operator must be subject to alteration by experience to fit the actual conditions. The following minimum schedule is suggested, based on continuous duty of 720 hours per month.

#### **NOTE**

The time schedule of routine inspections and maintenance for the compressor must be used in conjunction with the schedule and duties recommended by the driver manufacturer. This also applies to other accessory equipment.

#### **3-11.1. Daily**

1. Check the oil level in the frame sump and add oil as required to maintain the level at the line on the oil level gauge. Check that the oil day tank (if so equipped) is filled.
2. Check the oil level in the lubricator drive box and add as necessary. If oil level has increased, check the pumps for leakage past the plungers. Make sure all pumping units are working and inspect distribution blocks for leakage, indicator pins "popped up", or other problems.
3. Keep an hourly log of all gas temperatures, water temperatures and gauge pressures. One of the principal means of keeping track of the physical condition of a compressor and its equipment is by these hourly readings. Watch carefully for any marked changes which indicate further attention is warranted. Use interstage pressures and temperatures to detect abnormal conditions. A decrease in the interstage pressure and temperature means that the lower pressure cylinder has reduced capacity. An increase in interstage pressure and temperature means that the next higher stage cylinder has reduced capacity. These effects can be attributed to leaking valves, worn piston rings or broken parts.

4. If separators are used in the compressor system, a schedule must be established whereby they are periodically drained to prevent a liquid carryover into the compressor cylinders, which can cause serious damage. If automatic drains are furnished, check them for proper operation and to be sure that no liquid has accumulated in the level gauge.

### NOTE

In every case, because of variable operating conditions, the operator should establish the frequency of draining off the various drains. This will be determined by the amount of liquid that collects at each point.

5. Listen for any unusual noises while the machine is operating. These should be investigated immediately.
6. Drain all low points in the discharge piping.
7. Keep the exterior of the compressor and the compressor room floor clean.

### 3-11.2. Weekly

1. After the first week, check all bolts and nuts to see that they are properly torqued. Check monthly thereafter or at each change in operating conditions. (the monthly check period can be extended as experience dictates.)
2. Inspect all loaded joints for motion across the joint during operation. Tighten as required.
3. After the first week, check the runout of the compressor piston rods. Make sure the piston rod is not scored. Check every three months thereafter.
4. Check scraper packing, piston rod packing and distance piece vents for excessive blowby and/or oil leakage.

### 3-11.3. Monthly (ALL WEEKLY checks plus:)

1. Take a sample of the frame oil for analysis. Compare the analysis to one made on a fresh sample straight from the drum. Change oil and filter per analysis or compressor manufacturers recommendations.
2. Lubricate clearance packing grease fittings (see CHAPTER 4, Paragraph 4-13.) and check for free motion by moving the pocket in and out with the unit not operating.
3. Check all safety shutdowns and operation of loading and unloading devices for proper operation.
4. Check crankshaft breather and clean or replace as needed.
5. Clean the lubricator reservoir and pumping units as necessary or according to the manufacturer's instructions.

### 3-11.4. Every Three Months (ALL WEEKLY and MONTHLY checks plus:)

1. Check the crosshead-to-guide clearance by feeler gauge. Check the runout of the compressor piston rods. Visually inspect frame internals.
2. The frame lubricating oil should be changed after 2000 to 4000 operating hours or as monthly analysis indicates. Always clean the filter housing and install new filter elements when the oil is changed.

#### NOTE

When the compressor is being operated in an extremely dirty atmosphere, or where it is installed outdoors, operated intermittently, handling foul gas in the cylinders, or operating with high oil temperatures in a very hot atmosphere, it may be necessary to change the oil more often. Most reputable oil companies offer laboratory analysis of oil samples, the use of this type service is recommended.

3. Check the compressor piston rings and piston rod for wear and the cylinder bore for scoring, and remove any accumulation of foreign material. Replace piston rings if they are worn to their limit. See Chapter 4 (Paragraph 4-14.) for checking the wear rate of, and renewing, TFE piston and rider rings.
4. Check the accuracy of compressor pressure gauges on a dead weight tester; recalibrate them as required.
5. Remove all inlet and discharge valves; clean and inspect the valves for excessive wear and broken parts. Lap seats and guards. Refer to the compressor cylinder instructions.
6. Clean the separator sight glasses (if so equipped).
7. Inspect Beta drive shaft seal (if so equipped) and replace if required.
8. Check anchor bolts for tightness. Tighten as required to the torque values given in CHAPTER 5, GENERAL DATA & SPECIFICATIONS.
9. Inspect drive coupling; tighten as required.

### 3-11.5. Every Six Months (ALL QUARTERLY checks plus:)

1. Check crankshaft end play.
2. Check piston end clearances.
3. Remove, clean, and inspect the piston rod pressure packing rings and oil scraper; renew the rings as required.

### **3-11.6. Annually (ALL SIX MONTH checks plus:)**

1. Check all running gear clearances and compare to benchmark readings. If a change is detected, disassemble and inspect those affected parts.
2. Clean and flush the oil cooler and any other heat exchanger supplied.
3. Remove the compressor pistons and inspect the rings. Record cylinder bore diameters. Inspections of this nature will indicate the replacement schedule for parts that are subject to wear.
4. Safety valves used in the compressor gas system should have their settings tested at least once a year, and more often under extreme conditions, by a hydraulic test.
5. Examine any separators, bottles, dampers and similar equipment that may be used in the compressor system for accumulation of dirt, rust and other foreign material. Remove the vessel from the system and clean it if necessary.
6. Visually inspect the packing cups; re-lap as required.
7. Remove and inspect main bearings and connecting rod bearings.



**3-12. TROUBLESHOOTING BY SYMPTOM**

**Table 3-1. Compressor Troubleshooting Chart**

TROUBLE	PROBABLE CAUSE(S)	REMEDIES
FRAME KNOCKS	<ol style="list-style-type: none"> <li>1. Loose, worn main, crankpin or crosshead bearings.</li> <li>2. Low oil pressure.</li> <li>3. Cold oil.</li> <li>4. Incorrect oil.</li> <li>5. Knock is actually from cylinder.</li> </ol>	<ol style="list-style-type: none"> <li>1. Check clearances and replace bearings accordingly.</li> <li>2. Increase oil pressure; repair leaks.</li> <li>3. Warm oil before loading unit; reduce coolant supply to oil cooler.</li> <li>4. Use proper oil per specifications.</li> <li>5. Tighten piston nut, etc. refer to "Noise in Cylinder"</li> </ol>
COMPRESSOR WILL NOT START	<ol style="list-style-type: none"> <li>1. Power supply failure. (Motor Drive Only)</li> <li>2. Switch gear or starting panel. (Motor Drive Only)</li> <li>3. Oil pressure permissive to start switch.</li> <li>4. Control panel.</li> <li>5. Cylinders pressurized.</li> <li>6. Running gear blocked.</li> <li>7. Barring device/lock engaged.</li> </ol>	<ol style="list-style-type: none"> <li>1. Restore power supply.</li> <li>2. Check circuitry, interlocks, relays. See vendor literature.</li> <li>3. Check oil pressure at header using aux. pump; adjust or replace switch.</li> <li>4. Check electrical connections and settings.</li> <li>5. Unload cylinders.</li> <li>6. Unblock to allow rotation.</li> <li>7. Disengage barring rig or lock.</li> </ol>
CRANKSHAFT OIL SEAL LEAKS	<ol style="list-style-type: none"> <li>1. Faulty seal installation.</li> <li>2. Clogged drain hole.</li> </ol>	<ol style="list-style-type: none"> <li>1. Reset seal per instruction book.</li> <li>2. Clear obstruction.</li> </ol>

Table 3-1. Compressor Troubleshooting Chart (Continued)

TROUBLE	PROBABLE CAUSE(S)	REMEDIES
OIL SCRAPER LEAKAGE	<ol style="list-style-type: none"> <li>1. Worn scraper rings.</li> <li>2. Scraper rings incorrectly assembled.</li> <li>3. Worn or scored piston rod.</li> <li>4. Ring side clearance excessive.</li> </ol>	<ol style="list-style-type: none"> <li>1. Replace rings.</li> <li>2. Assemble per Instruction Book.</li> <li>3. Replace piston rod.</li> <li>4. Replace rings.</li> </ol>
LOW OIL PRESSURE	<ol style="list-style-type: none"> <li>1. Oil pump cavitation.</li> <li>2. Oil foaming from rotating parts hitting oil surface.</li> <li>3. Cold oil.</li> <li>4. Dirty oil filter.</li> <li>5. Oil pressure valve (PCV) incorrectly set.</li> <li>6. Low relief valve setting.</li> <li>7. Defective gauge.</li> <li>8. Plugged sump suction strainer.</li> </ol>	<ol style="list-style-type: none"> <li>1. Replace worn oil pump. 1a. Oil Level too low in sump.</li> <li>2. Reduce oil level in sump.</li> <li>3. Utilize frame oil immersion heater or steam-trace piping.</li> <li>4. Replace elements; clean filter can.</li> <li>5. Set to specifications.</li> <li>6. Replace valve.</li> <li>7. Replace gauge.</li> <li>8. Clean suction strainer.</li> </ol>
NOISE IN CYLINDER	<ol style="list-style-type: none"> <li>1. Loose piston.</li> <li>2. Piston hitting outer head or frame head.</li> <li>3. Loose crosshead jam nut.</li> <li>4. Broken or leaking valve.</li> <li>5. Piston rings broken.</li> <li>6. Liquids</li> </ol>	<ol style="list-style-type: none"> <li>1. Tighten piston assembly to piston rod per instructions.</li> <li>2. Adjust end clearance to specifications.</li> <li>3. Tighten jam nut.</li> <li>4. Repair or replace valves.</li> <li>5. Replace piston rings.</li> <li>6. Remove liquids.</li> </ol>

**Table 3-1. Compressor Troubleshooting Chart (Continued)**

TROUBLE	PROBABLE CAUSE(S)	REMEDIES
PACKING OVERHEATING	<ol style="list-style-type: none"> <li>1. Lubrication failure.</li> <li>2. Improper lube oil or feed rate.</li> <li>3. Insufficient cooling.  (Especially with water-cooled packing.)</li> <li>4. Inadequate side clearance.</li> </ol>	<ol style="list-style-type: none"> <li>1. Replace lubrication check valve or lubricator pump.</li> <li>2. Use correct oil; increase feed rate.</li> <li>3. Clean coolant passages, install water filter, increase supply pressure or rate. Reduce coolant temperature at inlet.</li> <li>4. Replace packing rings.</li> </ol>
PACKING LEAKAGE AND/OR BLOWBY	<ol style="list-style-type: none"> <li>1. Worn packing rings.</li> <li>2. Improper lube oil or lube oil feed rate. (Blue Hot)</li> <li>3. Dirt in packing.</li> <li>4. Pressure increase too fast.</li> <li>5. Rings incorrectly assembled.</li> <li>6. Improper end or side clearance.</li> <li>7. Packing vent plugged.</li> <li>8. Scored piston rod.</li> <li>9. Excessive rod runout.</li> </ol>	<ol style="list-style-type: none"> <li>1. Replace packing rings.</li> <li>2. Use correct oil or increase feed rate.</li> <li>3. Clean packing, piping and ensure gas supply is clean.</li> <li>4. Reduce pressure and increase at lower rate.</li> <li>5. Reassemble per Instruction Book.</li> <li>6. Check and adjust clearances.</li> <li>7. Unblock and provide low-point drains.</li> <li>8. Replace piston rod.</li> <li>9. Check crosshead clearances and piston to bore clearances.</li> </ol>

Table 3-1. Compressor Troubleshooting Chart (Continued)

TROUBLE	PROBABLE CAUSE(S)	REMEDIES
EXCESSIVE CARBON ON VALVES	<ol style="list-style-type: none"> <li>1. Too much cylinder lube oil.</li> <li>2. Wrong cylinder lube oil, too light; high carbon residue.</li> <li>3. Oil carryover from inlet or previous stage.</li> <li>4. Broken or leaking valves; high temperature.</li> <li>5. Excessive pressure ratio across cylinder; high temperature.</li> </ol>	<ol style="list-style-type: none"> <li>1. Adjust supply rate.</li> <li>2. Use correct oil for application. See chart in Instruction Manual.</li> <li>3. Install separator/drain system.</li> <li>4. Replace or repair valves.</li> <li>5. Clean intercoolers; valves. Look for failed valve in cylinder, upstream or downstream.</li> </ol>
HIGH DISCHARGE TEMPERATURE	<ol style="list-style-type: none"> <li>1. Excessive ratio across cylinder. Rings leaking on next higher stage.</li> <li>2. Fouled intercooler or piping.</li> <li>3. Leaking discharge valves or piston rings.</li> <li>4. High inlet gas temperature.</li> <li>5. Fouled cylinder water jackets.</li> <li>6. Improper cylinder lube oil or lube feed rate.</li> </ol>	<ol style="list-style-type: none"> <li>1. Replace leaking inlet valves or piston rings.</li> <li>2. Clean intercooler or piping; reduce lube feed rate.</li> <li>3. Repair/replace parts as necessary.</li> <li>4. Clean intercooler.</li> <li>5. Clean water jackets.</li> <li>6. Use correct lube oil and correct the feed rate.</li> </ol>
RELIEF VALVE POPPING	<ol style="list-style-type: none"> <li>1. Faulty relief valve.</li> <li>2. Leaking inlet valves or piston rings on next higher stage.</li> <li>3. Obstruction, blind flange or valve closed in discharge line.</li> </ol>	<ol style="list-style-type: none"> <li>1. Test valve and reset per manufacturer's instructions.</li> <li>2. Repair/replace defective parts.</li> <li>3. Relieve obstruction; open valve.</li> </ol>

**Table 3-2. Valve Troubleshooting Chart**

TROUBLE	REASON OR ACTION TO BE TAKEN
VALVE FAILURE – INLET VALVES	<ol style="list-style-type: none"> <li>1. Make certain that correct parts are being used. In many cases, inlet springs are lighter than discharge springs.</li> <li>2. Investigate the possibility of liquid carryover.</li> <li>3. Consider the possibility of intake pulsations.</li> <li>4. Flutter – Incorrect spring selection.</li> </ol>
VALVE FAILURE – DISCHARGE VALVES	<ol style="list-style-type: none"> <li>1. Make certain that correct parts are being used. In many cases, discharge springs are stiffer than inlet springs.</li> <li>2. Check log of failures to see if failures occur only when a clearance pocket is open. If this is the case, report the situation to Dresser-Rand.</li> <li>3. Consider the possibility of discharge pulsations.</li> </ol>
VALVE FAILURE – BOTH INLET AND DISCHARGE	<ol style="list-style-type: none"> <li>1. Make certain correct parts are installed.</li> <li>2. Check to see if discharge failures are caused by broken pieces of other valves.</li> <li>3. Check for rust, scale or other foreign matter.</li> <li>4. Check for excessive wear of parts caused by grit or insufficient lubrication.</li> <li>5. Consider the possibility of pulsations.</li> <li>6. Stiction – Incorrect lube rate or varnish.</li> </ol>
FAILURE FOLLOWING RECONDITIONING	<ol style="list-style-type: none"> <li>1. Check reconditioning procedures to make sure valve lift was not changed.</li> <li>2. Verify correct parts were installed.</li> </ol>
SEASONAL FAILURES	<ol style="list-style-type: none"> <li>1. Winter failures caused by liquid slugs.               <ol style="list-style-type: none"> <li>A. Piping should be insulated.</li> <li>B. Piping should be steam traced.</li> <li>C. Separators should be installed.</li> </ol> </li> </ol>

**Table 3-2. Valve troubleshooting Chart (Continued)**

TROUBLE	REASON OR ACTION TO BE TAKEN
<p>RAPID WEAR - INLET VALVES ONLY</p>	<ol style="list-style-type: none"> <li>1. Insufficient lubrication rate or incorrect cylinder lube oil.</li> <li>2. Wet gas washing lubrication from valves.</li> <li>3. Cylinder water temperature lower than incoming gas temperature.</li> <li>4. Dirty process gas; install scrubbers.</li> </ol>
<p>RAPID WEAR - DISCHARGE VALVES ONLY</p>	<ol style="list-style-type: none"> <li>1. Insufficient lubrication rate or incorrect cylinder lube oil.</li> <li>2. Dirty process gas; install scrubbers.</li> <li>3. Flutter – Incorrect spring selection.</li> </ol>
<p>BROKEN SPRINGS</p>	<ol style="list-style-type: none"> <li>1. Investigate possibility of gas contaminants causing corrosion; send samples of broken parts to Dresser-Rand.</li> <li>2. Check for grit or other solid matter, which can lodge between coils of compression springs to cause failure.</li> <li>3. Stiction – Incorrect lube rate or varnish.</li> </ol>
<p>BROKEN PLATES (BUT NOT SPRINGS)</p>	<ol style="list-style-type: none"> <li>1. Check valve plates for wear resulting in sharp corners at O.D. or I.D.</li> </ol>

## HOS

### Chapter 4

Paragraph	Page
4-1. GENERAL .....	4-3
4-2. SAFETY PRECAUTIONS .....	4-4
4-3. FRAME .....	4-4
4-4. CRANKSHAFT .....	4-7
4-5. CRANKSHAFT OIL SEAL .....	4-7
4-6. ACCESSORY EQUIPMENT .....	4-7
4-7. MAIN BEARINGS .....	4-7
4-7.1. Checking Bearing Clearance .....	4-8
4-7.2. Replacing a Main Bearing .....	4-8
4-7.3. Bearing Crush .....	4-10
4-7.4. Checking Crankshaft Thrust .....	4-10
4-8. CROSSHEAD / CONNECTING ROD ASSEMBLY .....	4-11
4-8.1. Crosshead .....	4-12
4-8.2. Connecting Rods .....	4-12
4-8.3. Connecting Rod Bearings .....	4-12
A. Stretch Micrometer Procedure .....	4-13
4-8.4. Replacing Connecting Rod Bearings .....	4-15
4-8.5. Crossheads and Pins .....	4-16
4-8.6. Removing Crosshead and Connecting Rod .....	4-16
4-8.7. Replacing Small End Bushing .....	4-18
4-8.8. Replacing Crosshead Pin and Bushing .....	4-20
4-8.9. Crosshead Shoe Replacement and Piston Rod Runout Adjustment .....	4-20
A. Crosshead Shoe Replacement .....	4-22
B. Piston Rod Runout Adjustment .....	4-22
4-9. COMPRESSOR CYLINDERS .....	4-23
4-9.1. Removing and Installing Compressor Cylinders .....	4-25
A. Removing Compressor Cylinder .....	4-26
B. Installing Compressor Cylinder .....	4-26
4-9.2. Disassembly and Assembly of Pistons & Piston Rods .....	4-27
A. Piston and Rod Disassembly .....	4-28
B. Piston and Rod Assembly .....	4-28
4-10. INSTALLING PISTON ROD AND ADJUSTING END CLEARANCE .....	4-32
4-11. INSPECTION / MAINTENANCE OF CYLINDER BORES .....	4-34
A. Honing .....	4-35
4-12. NON-METALLIC COMBINATION PISTON & RIDER RINGS .....	4-36
4-12.1. Handling Instructions .....	4-36
4-12.2. Establishing Ring Wear Rate .....	4-36
4-12.3. Replacing Rings .....	4-37
4-12.4. Installing Rings .....	4-38
4-12.5. Breaking-in Combination Rings .....	4-40
4-13. PISTON ROD PRESSURE PACKING .....	4-40
4-13.1. Packing Rings .....	4-40
4-13.2. Packing Gasket .....	4-43
4-13.3. Packing Cases .....	4-44
4-13.4. Installing the Packing .....	4-44
4-13.5. Packing Operation and Maintenance .....	4-46
4-13.6. Inspecting the Packing .....	4-46

<b>Paragraph</b>		<b>Page</b>
4-13.7.	Replacing the Packing .....	4-47
4-14.	PISTON ROD OIL SCRAPER RINGS .....	4-47
4-15.	BALANCE CYLINDER (If Used) .....	4-49
4-16.	COMPRESSOR VALVES .....	4-50
4-16.1.	Description of Operation .....	4-51
4-16.2.	Valve Maintenance Recommendations.....	4-52
4-16.3.	Removing the Valves – O-Ring Valve Cover.....	4-55
4-16.4.	Disassembling & Servicing the Valve .....	4-57
4-16.5.	Refacing Valve Seats.....	4-59
4-16.6.	Reconditioning the Stop Plate .....	4-60
4-16.7.	Assembling the Valve.....	4-61
4-16.8.	Installing the Valves – O-Ring Valve Cover .....	4-62
4-17.	REGULATION DEVICES .....	4-64
4-17.1.	Inlet Valve Unloaders .....	4-65
	A. Control and Vent Piping.....	4-67
	B. Unloader Cleanliness.....	4-67
	C. Removing Operator, Unloader and Valve Assembly .....	4-68
	D. Disassembling Cage and Plunger.....	4-69
	E. Installing Valve, Cage and Plunger .....	4-69
	F. Disassembling Unloader Cover and Operator.....	4-69
	G. Installing the Unloader.....	4-71
	H. Adjusting the Stroke.....	4-72
4-17.2.	Variable Volume Clearance Pockets.....	4-72
	A. Construction .....	4-72
	B. Maintenance.....	4-72
4-17.3.	Fixed Volume Clearance Pockets.....	4-74
	A. Control and Vent Piping.....	4-75
	B. Clearance Pocket Cleanliness.....	4-76
	C. Removing the Clearance Pocket Assembly .....	4-76
	D. Disassembling Actuating Piston Housing .....	4-77
	E. Disassembling Clearance Valve Sleeve .....	4-77
	F. Servicing the Gland Seal .....	4-77
	G. Assembling Actuating Piston Housing .....	4-79
	H. Assembling Clearance Valve Sleeve.....	4-79
	I. Installing Clearance Pocket Assembly .....	4-79

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### 4-1. GENERAL

This portion of the Instruction Book describes the recommended procedures for disassembling, servicing or replacement, and reassembly of the compressor running gear and cylinders. Service notes have been placed in the text to assist the mechanic. Separate instructions are furnished to cover special or optional equipment.

Good working habits are essential to the performance of satisfactory maintenance work on the compressor. When disassembling a unit, use every available means to keep dirt away from the compressor internals. Cover exposed openings with cloth, kraft paper, cardboard or other suitable material to keep dirt from falling into the frame interior or into the compressor cylinders. Scratches, nicks and rough areas must be removed from machined surfaces. This can be done with fine emery cloth, a fine hone or a mill file. (Do not use emery cloth, or any other finishing method employing abrasives, when working on soft bearing surfaces; such material can become embedded in the bearing metal.)

Mark or tag parts as they are disassembled so that they can be replaced in their original positions. Replace all composition gaskets that are torn, dried or cracked with ones of similar material and thickness. Shims should be marked so that they will be reassembled in their original positions or so that replacement shims can be accurately sized.

Original parts should be thoroughly cleaned in a solvent compatible to the process and to the material of the parts to be cleaned. Inspect parts for wear and other visible defects before re-using them. Generally, unless otherwise stated, parts should be covered with a thin coating of clean lubricant before reassembling.

### **▲WARNING**

**All precautionary measures specified by the Occupational Safety and Health Act of 1970 (OSHA) must be complied with when storing, handling, or using solvents.**

After removal Cotter pins, lockwashers, lock wires and other locking devices must be replaced to prevent the loosening of parts during operation. Always advance a nut in the tightening direction to align cotter pin openings once the required torque or bolt stretch is obtained. Lockwire must always be arranged so that it pulls on the bolt head in the tightening direction.

Running gear clearances and fits and tightening requirements are summarized at the back of this book in CHAPTER 5, GENERAL DATA & SPECIFICATIONS. The specified clearance limits and fits are those to which the parts are originally assembled. Unless otherwise stated, they are for parts that are at room temperature and are generally referred to as "cold" clearances. Some slight changes in clearance can be expected when parts are hot.

Generally, the clearances and fits listed should be checked during maintenance work involving those parts. It is recommended that running clearances be checked with the parts in their assembled positions, wherever possible, since bearing crush, interference fits and other factors can affect the clearance measurement.

Logging important clearances can be of considerable help in determining the wear of parts. It can also be of some benefit in estimating the time interval between scheduled overhauls.

## Maintenance

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Varying operating conditions at different installations make it impractical to specify maximum acceptable clearances. Careful observation of the unit by the operator and good judgment by the mechanic are often the most effective means of determining when clearances have become excessive and adjustment of parts is required.

### 4-2. SAFETY PRECAUTIONS

Observe every safety precaution when working on the compressor frame, cylinders and drive arrangement, especially when making repairs or adjustments inside the frame or cylinders. The following minimum precautions should be taken before working on the compressor.

1. Be certain the main driver is locked out so that there is no possibility of the driver starting. In addition, a warning sign bearing the legend "WORK IN PROGRESS - DO NOT START" must be attached to the starting equipment.
2. Close suction and discharge line valves and bleed off any pressure that may be in the compressor cylinders.
3. Block or brace under a crankshaft web, or block the crossheads, so that the shaft cannot turn while working inside the unit.
4. Service on a machine should always start with cleaning the floor and the outside of the machinery to remove oil which could cause maintenance personnel to slip and injure themselves.
5. Never open a compressor cylinder or any other part of the compression system without first completely relieving all pressure within the unit and taking all necessary precautions to prevent accidental re-pressurizing of the system.
6. Compressors handling toxic or flammable gases must be isolated from the process piping by means of blinds, or double valves and bleed valves, when major maintenance is required. Before opening such compressors the equipment should be purged or evacuated. Minor adjustments may be performed without blinding provided that adequate precautions, such as de-pressurizing the system, are taken to protect personnel. Check valves must not be relied upon for isolating the compressor.
7. Consult OSHA regulations covering cleaning materials and their use. Volatile flammable liquids must not be used as cleaning agents for engine or compressor parts. A safety solvent should be used and the parts dried thoroughly before assembly. CARBON TETRACHLORIDE MUST NEVER BE USED AS A CLEANING SOLVENT. Appropriate provisions for ventilation should be made when using other halogenated solvents.

### 4-3. FRAME

1. The compressor frame (Figure 4-1) is a rigid, cast iron structure designed to provide a suitable mounting for compressor cylinders, crankshaft and other running gear, and to hold all parts in accurate alignment under the stresses and strains involved in operation. Suitable ribs and partitions are incorporated in the frame design to provide maximum strength compatible with reasonable weight.
2. The lower part of the frame forms a sump for the lubricating oil, and a pipe tap connection is located on the end of the frame at the bottom of the oil sump to permit sump draining. An oil level gauge is also located at one end of the frame so that the frame oil level can be checked at all times.

### 4-4

3. The frame contains the crankshaft, main bearings, connecting rods and crossheads, which comprise the "running gear".

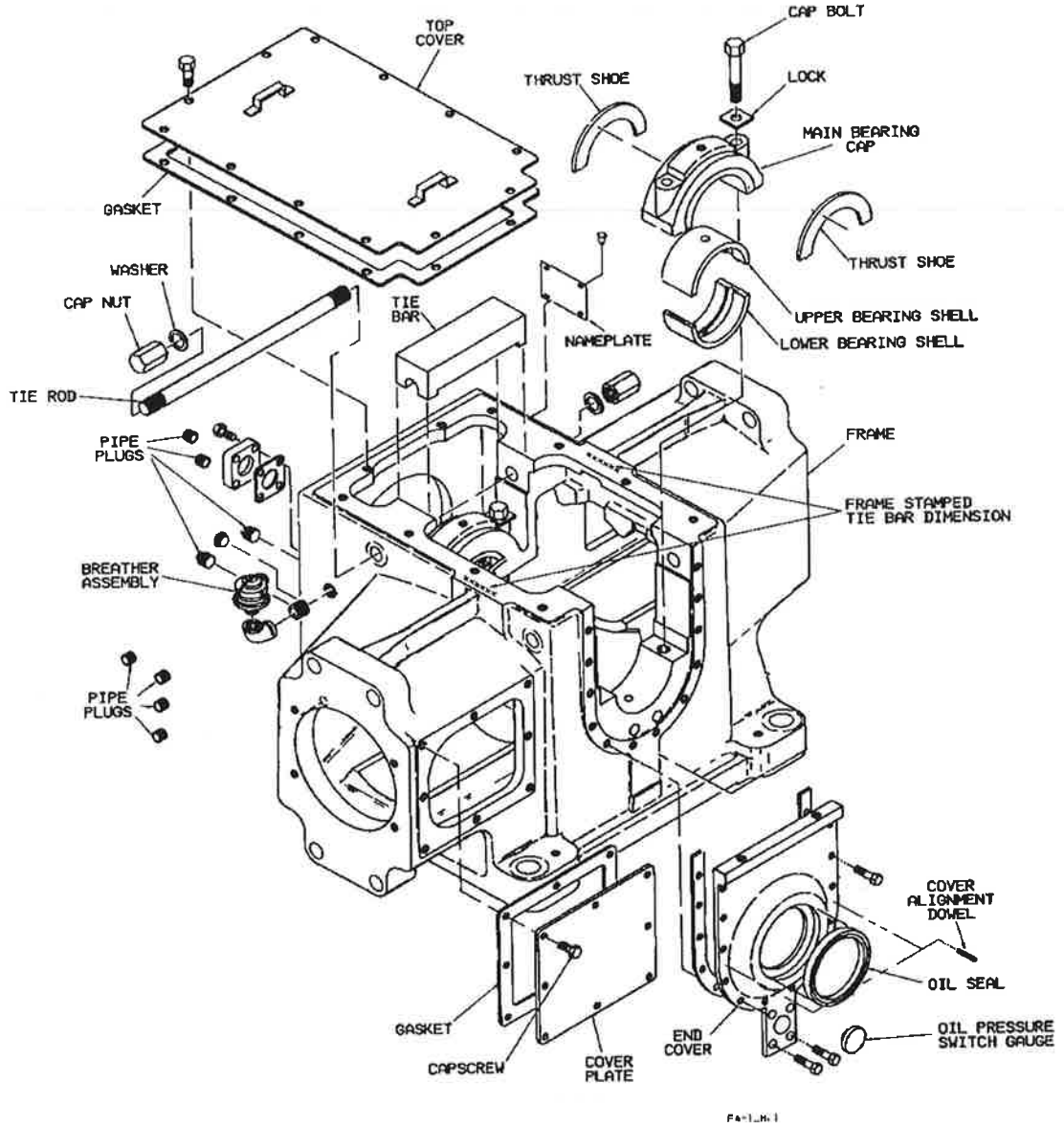


FIGURE 4-1. TYPICAL HOS FRAME

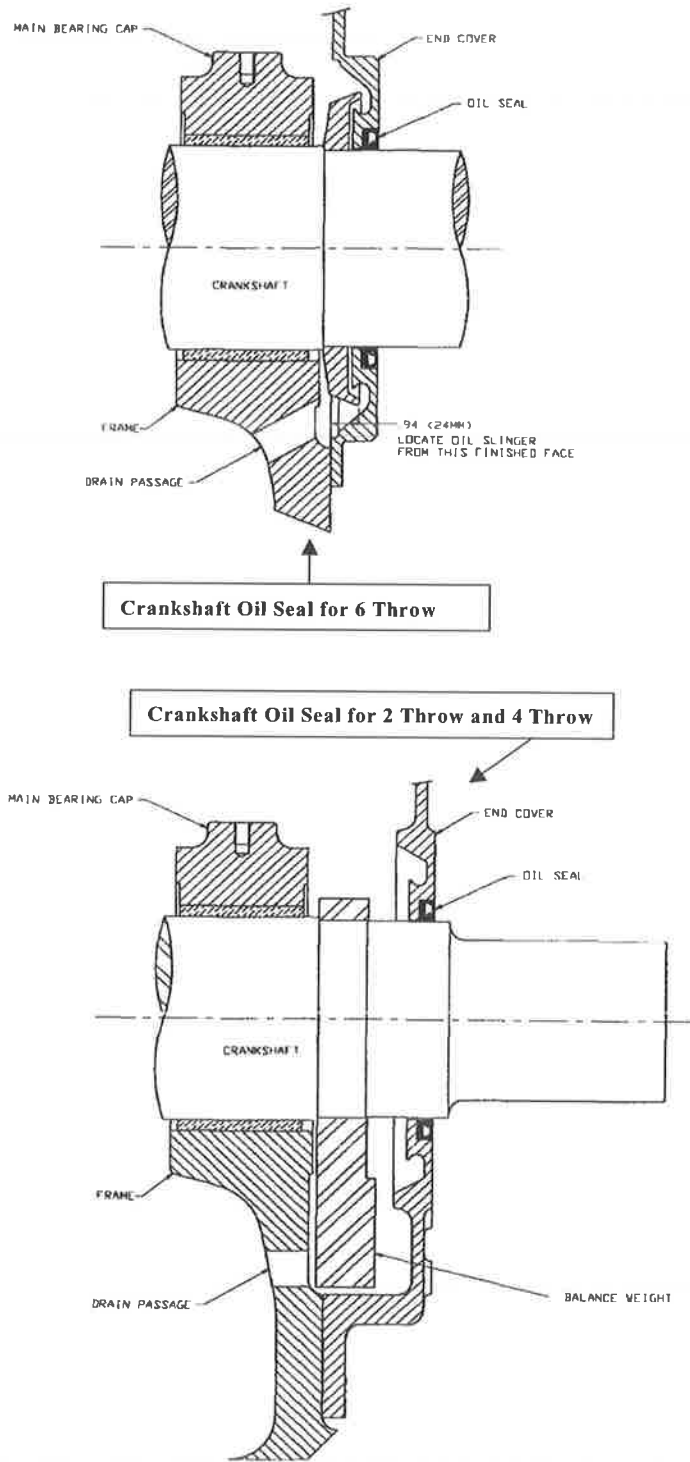


FIGURE 4-2. CRANKSHAFT OIL SEAL

#### 4-4. CRANKSHAFT

The crankshaft is a single-piece, heavy steel forging and is designed to avoid torsional criticals within the operating speed range. There is a separate crank throw to carry the connecting rod for each compressor cylinder. Oil holes are drilled in the shaft from the main journals to the adjacent crank pins so that lubricating oil under pressure at the main bearings is fed to the connecting rod bearings. It is essential to the proper lubrication of the compressor that the oil passages in the crankshaft are kept clear of any obstruction. They should be inspected during any compressor overhaul for sludge or other obstructions.

#### 4-5. CRANKSHAFT OIL SEAL

The crankshaft oil seal, located at the drive end of the unit as shown in Figure 4-2. A correctly installed oil seal should require little or no attention.

### **▲ CAUTION**

**Should leakage occur past the crankshaft oil seal, do not, under any circumstances, reduce the bearing oil pressure in an effort to control the leakage. Reduced oil pressure can result in serious compressor damage, which might not be immediately apparent.**

*The following procedure is recommended to properly install the crankshaft oil seal:*

1. Install the front cover gasket on the frame. Install front cover by sliding it over the alignment dowels. Secure the cover by tightening the capscrews to their proper torque value.
2. Coat the oil seal with grease on only that portion that contacts the crankshaft. Orient the seal so that the seal lips are pointing toward the frame and then press the seal into the recess in the end cover.

#### 4-6. ACCESSORY EQUIPMENT

Items not manufactured by Dresser-Rand Company include the lubricator, oil cooler, drive engine or motor, coupling, filters, coolers, scrubbers and control devices. Additional equipment supplied by the packager of the compressor must be supported by accessory literature supplied by the various manufacturers of the components. This literature, generally including engine or drive motor manufacturer's bulletins, coupling manufacturer's bulletins and control panel manuals, is found in the overall manual prepared by the packager for the complete compressor package.

#### 4-7. MAIN BEARINGS

Main bearing arrangement is shown in Figure 4-3. The main bearings are horizontally split precision aluminum shells that are accurately sized to fit the bearing caps and the support saddles in the frame.

Whenever a main bearing cap is removed from the machine, it is important that it is returned to its original position in the frame or serious damage can result. The bearing caps are match-stamped in an off center location to agree with the nearest stamping on the top of the frame partition. Always check the stamping on a bearing cap when installing it to be sure that it matches the nearest stamping on the frame partition.

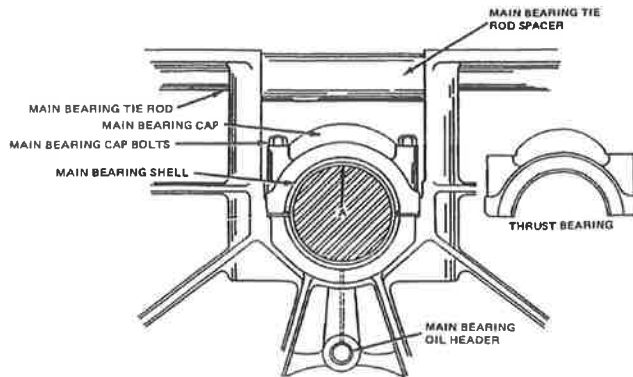


FIGURE 4-3. MAIN BEARING ARRANGEMENT

### 4-7.1. Checking Bearing Clearance

The clearance of each main bearing can be determined by the use of Plastigage® at point "A" shown in Figure 4-3. Lay a piece of Plastigage® across the crankshaft journal, install cap and torque to specifications. Remove the cap and measure the Plastigage® to ensure you have proper clearance. Refer to CHAPTER 5, GENERAL DATA & SPECIFICATIONS, which gives the bearing clearance limits of machines as originally built. Remove Plastigage® from crankshaft and/or bearing before reassembly. These clearance limits, although only guidelines, can be helpful in determining when a bearing requires replacement. The only proper way to determine if a bearing replacement is required is to perform a visual check. It should be noted, however, that a bearing will give much longer service when the proper oil clearance is maintained. After a bearing change always recheck the actual bearing-to-shaft clearance with Plastigage® before operating the machine.

Plastigage® is the preferred method of checking bearing clearances. If Plastigage® is not available, another acceptable method is doing a lift check.

Mount a dial indicator on top of the connecting rod as close to the center of the split line as possible. Lift the connecting rod up until the clearance is removed, and note the dial indicator reading. Ensure that the crankshaft does not rotate while checking bearing clearances using the lift check method.

### 4-7.2. Replacing a Main Bearing

If replacement of a main bearing becomes necessary, use these recommended steps:

#### **▲ CAUTION**

Be certain the main driver is blocked out so that there is no possibility of the driver starting. In addition, a warning sign bearing the legend "WORK IN PROGRESS - DO NOT START" must be attached to the starting equipment.

1. Remove the top covers from the frame.
2. Loosen all frame spacer tie rods.
3. Remove the frame spacer and tie rod that corresponds to the bearing being serviced.
4. Remove the capscrews from each side of the main bearing cap.
5. Install a 1/2-inch eyebolt into the tapped hole in the top of the bearing cap. Carefully remove the bearing cap and upper bearing half.
6. Remove the lower half of the bearing by rotating it 180°. If the lower shell cannot be pushed out by hand, use a copper or soft metal "roll-out" plug in the crankshaft and "roll out" the lower shell. The plug is placed in the oil hole in the crankshaft so that it protrudes about 1/4-inch (6 mm) from the shaft; it must be flanged to prevent it from dropping into the oil hole.

### SERVICE NOTE

If more than one adjacent lower shell is removed; blocking must support the crankshaft. Always support the crankshaft on two cylinder frames.

7. Replacement bearing shells must fit the support saddle and bearing cap perfectly so that they will be uniformly supported at all points. An imperfect fit, burrs, nicks or dirt between the shells and support saddle or cap will result in stress concentration due to flexing of the shell and subsequent premature failure of the bearing.

### ⚠ CAUTION

**Never scrape the bore nor file or attempt to build up the ends of these precision bearing shells. To do so will result in a ruined bearing and possible major damage to the crankshaft.**

8. Place a lock plate under the head of each bearing cap bolt and tighten the bolts evenly to the torque value specified in CHAPTER 5, GENERAL DATA & SPECIFICATIONS. Bend the edge of the lock against the flat on the head of each cap bolt.
9. Check the installed bearing clearance with Plastigage® as described in Paragraph 4-7.1. before continuing with further assembly.
10. When one or more replacement bearings are installed, check the crankshaft alignment by checking for clearance under the bottom of the crankshaft journal at each main bearing. A 0.0015 inch (0.04 mm) feeler should not start. Any bearings found to be low must be replaced.
11. Replace the main bearing tie rod and spacer, using Teflon® pipe thread sealer under the nut heads and on the tie rod threads. The spacer is sized for an interference fit with the frame opening. Position the tie rod in the frame and spacer so that it is centered with respect to the frame. Place a washer over each end of the tie rod and then assemble and snug up the cap nuts evenly. Tighten one of the nuts until the measured distance in the spacer opening is not less than, and no more than 0.002 inch (0.05 mm) greater than, the dimension stamped in the frame adjacent to the spacer. See Figure 4-1 for stamping location.

12. Install the frame top cover and any other parts that may have been removed.

### 4-7.3. Bearing Crush

Bearing crush is the difference in height between the bearing and its housing at the parting line. This crush is actually an interference fit between the bearing and its housing. It is necessary to assure full contact between the bearing and housing to prevent flexing of the bearing shell and to aid in transferring heat from the bearing. Because both bearings and housings are precision-made parts, there is no reason to measure the bearing crush in the field. If a problem with bearing crush is suspected, contact your Dresser-Rand customer service representative.

### NOTE

Bearing *crush* has no relation to bearing *clearance* and it is important that the two are not confused.

### 4-7.4. Checking Crankshaft Thrust

End thrust of the crankshaft is limited by bronze shoes fastened to the faces of two of the main bearing caps. On two-cylinder frames, there is a main bearing at each end of the frame, and the thrust shoes are attached to the inboard faces of the bearing caps; the shoes bear against the thrust collars of the number 1 and number 2 crank webs. On the four- and six-cylinder frames, the thrust shoes are bolted to the faces of the second and third main bearing caps from the drive end of the unit; the shoes bear against the thrust collars of the number 2 and number 3 crank webs, counting from the driver end.

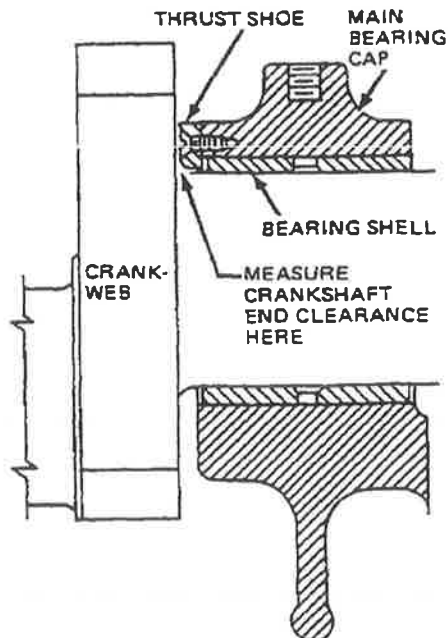


FIGURE 4-4. CRANKSHAFT THRUST ARRANGEMENT



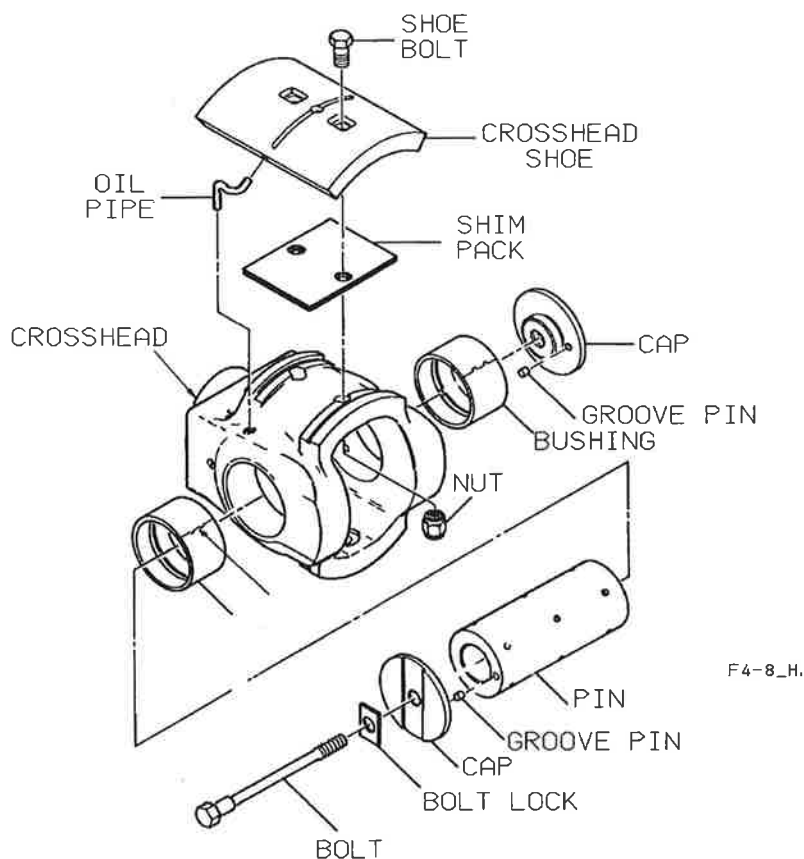
Crankshaft end thrust, or end play, is totally controlled by the position of the driver unit, whether it is a motor or a gas engine. The thrust shoes cannot in any way "control" the end thrust and the shoes are installed primarily to position the shaft axially in the frame. Normally, end thrust is negligible if the compressor and driver have been properly installed.

**▲ CAUTION**

**If wear on the thrust surfaces is observed, the only way to correct it is moving the driver. If this isn't done, serious damage to the compressor crankshaft or frame can result.**

The compressor is originally built with a total crankshaft thrust clearance within the limits given in CHAPTER 5, GENERAL DATA & SPECIFICATIONS. The clearance can be measured by totaling the feeler clearances taken between each thrust shoe and the adjacent crank web (Figure 4-4). The manufacturing process controls the thrust and cannot be field adjusted.

**4-8. CROSSHEAD / CONNECTING ROD ASSEMBLY**



**Figure 4-5. Crosshead**

### 4-8.1 Crosshead

The compressor crosshead, Figure 4-5, is a box type with shim-adjustable shoes. The crosshead pin is full floating and is carried on two steel-backed bronze bushings that are shrunk into the crosshead. A single steel-backed bronze bushing is shrunk into the eye of the connecting rod. The compressor piston rod screws into the crosshead and is secured by a crosshead locknut.

### 4-8.2 Connecting Rods

The compressor connecting rods are made of forged steel and incorporate a one-piece, shrink-fitted bronze bushing with a light babbitted coating in the small end and two-piece bearing shells in the large (crankpin) end. The rods are rifle drilled from the connecting rod journal bearing-end to the crosshead pin-end, providing a passageway for the lubricating oil between the two points.

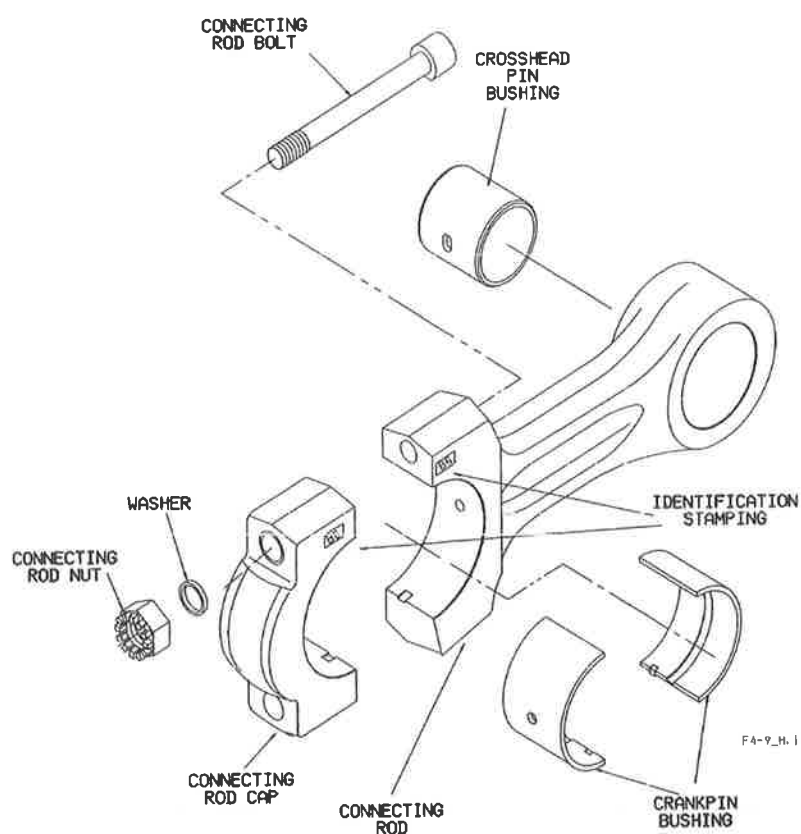


Figure 4-6. Connecting Rod & Bearing Assembly

### 4-8.3 Connecting Rod Bearings

The connecting rod bearing is a split steel-backed bronze design with a babbitt overlay. See Figure 4-6, which shows the assembled position of the bearing in the connecting rod. This is a precision bearing, which requires no adjustment. If the bearing-to-shaft clearance becomes excessive and the bearing is noisy, the bearing shells must be replaced.

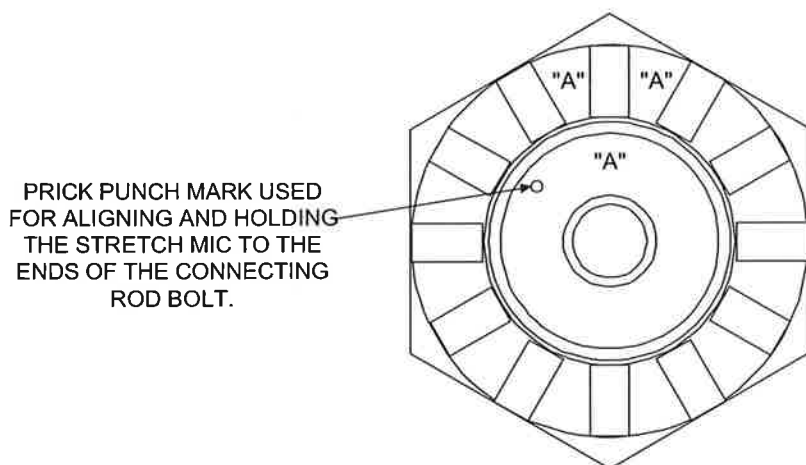
When the connecting rod cap is removed from the rod, it must be reassembled in exactly the same position it held during factory assembly or serious damage to the machine can result. The cap and its rod are stamped with identical letter and number markings as shown in Figure 4-6.

**NOTE**

While checking bearing clearances with Plastigage® make sure crankshaft does not rotate.

At the factory the bolts are stretched per specifications in CHAPTER 5, GENERAL DATA AND SPECIFICATIONS. Once the proper stretch has been achieved, the end of the bolt and the face of the nut are stamped with three corresponding letters. (See Figure 4 -7).

If a new connecting rod is being installed or if the existing components become mixed up during disassembly, please use the following bolt stretch procedure. The following procedure may be done while the connecting rod is installed in the frame, but the preferred method is with the connecting rod on a workbench.



"A" REPRESENTS THE ALIGNMENT MARK THAT IS PUNCHED INTO THE END OF THE CONNECTING ROD NUT. IT IS NOT NECESSARILY A LETTER, IT MAY BE A PUNCH MARK OR A NUMBER.

**Figure 4-7. Identification of Connecting Rod Bolt Markings**

**A. Stretch Micrometer Procedure**

**NOTE**

Before removing connecting rod nuts make note of the match mark stampings on the face of the nut and the end of the bolt as shown in Figure 4-7. Ensure all components (nuts, washers, bolts) are reassembled in the same position as they were removed. It is extremely important that these components are not mixed up. If this happens refer to the connecting rod bolt stretch procedure.

## Maintenance

1. Prior to assembly, thoroughly degrease with solvent and dry all contact surfaces of rod, nut and washer.
2. Thoroughly lubricate bolt threads with an anti-seize lubricant after placing it in the hole.

### NOTE

When using anti-seize lubricants, care should be taken not to use excessive amounts. Excessive amounts could contaminate oil samples.

3. Lubricate the contact surface between the nut face and the washer with anti-seize. The surface between the washer face and rod must remain dry, so washer does not rotate.
4. Bolts should be prick (center) punched on each end, before assembly, to ensure that micrometer reading is taken in the same place before and after elongation.
5. The micrometer reading of the bolt length should be taken before the nut is tightened (see Figure 4-8). This dimension should be recorded for future reference. (This should be done on both bolts prior to any tightening.)
6. Bolts shall be tightened in a cross pattern ensuring that all bolts are tightened in equal increments.
7. Each nut should be tightened in small increments until the micrometer reading indicates the bolt has been elongated (stretched) the specified amount. For proper stretch dimensions refer to CHAPTER 5, GENERAL DATA & SPECIFICATIONS.
8. After proper elongation (stretch) is attained the face of the nut and the end of the bolt should be match marked as shown in Figure 4-7.

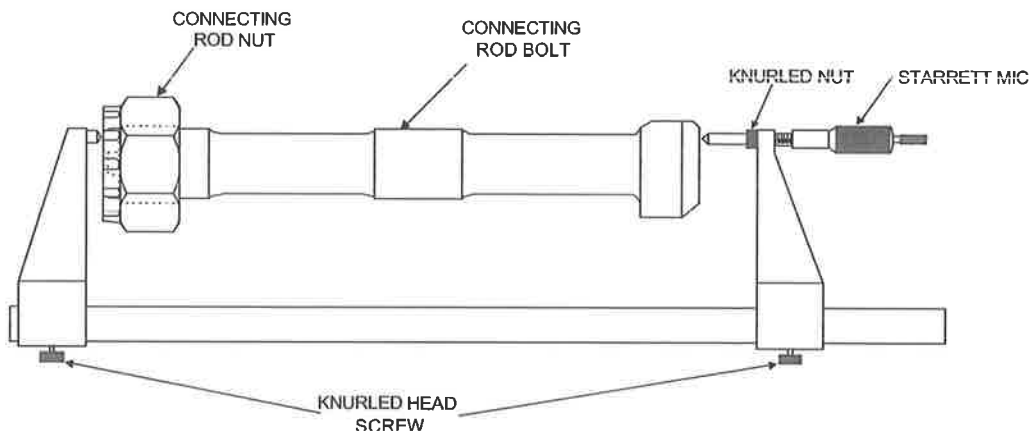


Figure 4-8. Stretch Micrometer

Connecting rod bearing-to-shaft clearance can be checked by using Plastigage®. Lay a piece of Plastigage® across the crankshaft journal, install cap and tighten to connecting rod bolt stretching procedure. Remove the cap and measure the Plastigage® to ensure you have proper clearance. The assembly clearance specifications are given in the list of part fits and tolerances in CHAPTER 5, GENERAL DATA & SPECIFICATIONS. Remove Plastigage® from crankshaft and/or bearing before reassembly.

### 4-8.4. Replacing Connecting Rod Bearings

1. Remove the frame top cover that will give access to the connecting rod.

### **▲WARNING**

**Before barring the unit over, the operator must ensure that the driver will not start either by grounding the ignition and closing the fuel gas valve on gas engine-driven units or by ensuring that power cannot be turned on with electric motor-driven units. Failure to heed this WARNING can result in a fatal accident if the unit rolls over unexpectedly.**

2. Rotate the crankshaft to place the connecting rod in a convenient position to remove the cap.

### **NOTE**

Before removing connecting rod nuts make note of the match mark stampings on the face of the nut and the end of the bolt as shown in Figure 4-7. Ensure all components (nuts, washers, bolts) are reassembled in the same position as they were removed. It is extremely important that these components are not mixed up. If this happens refer to the connecting rod bolt stretch procedure.

3. Pull the cotter pins and remove the nuts and washers from the connecting rod bolts.
4. Carefully lift the connecting rod cap and cap bearing half out of the frame.
5. Support the connecting rod and then rotate the crankshaft to move the crankpin away from the rod so that the rod bearing half can be removed.
6. Clean the replacement bearing shells, being certain that the oil holes and grooves are clear, and also clean the bore in the connecting rod and cap before assembling the new bearing. It is essential that there be no dirt or foreign particles between the bearing shells and the rod, and that the shells fit their housing perfectly so that they are supported uniformly at all points. It is normally not required to check bearing crush since these are precision made and inspected parts. If a bearing crush problem is suspected, contact your Dresser-Rand service representative.
7. Install the bearing shell halves in the rod and cap. Each shell half has a tab on its outer edge at the parting line. The tabs fit into slots which are machined into the rod and cap and accurately position each shell half and lock the bearings to prevent rotation in the bore.

## Maintenance

8. Assemble the rod and cap on the crankpin. Work carefully to assure correct assembly and to prevent damaging the parts.
9. Tighten the nuts on the connecting rod bolts uniformly until the bolts are elongated (stretched) the amount given in CHAPTER 5, GENERAL DATA & SPECIFICATIONS. Bolt elongation is determined by measuring the length of the bolt both before and after tightening.
10. Check the connecting rod bearing-to-crankpin clearance as described previously.
11. Insert and bend a cotter pin to lock each nut on the rod bolt. When it is necessary to reposition the nut to install the cotter pin, always turn the nut in the tightening direction.
12. Check to be sure no tools have been left inside the frame and replace the top cover on the frame.

### 4-8.5. Crossheads and Pins

The conventional crosshead, figure 4-6, is the box type with shim adjustable shoes. The crosshead pin is full floating and is carried on two steel-backed bronze bushings that are shrunk into the crosshead. A single steel-backed bronze bushing is shrunk into the eye of the connecting rod. The compressor piston rod screws into the crosshead and is secured by a crosshead jam nut.

Normal running clearance of the crosshead in the guide is specified in CHAPTER 5.

### 4-8.6. Removing Crosshead and Connecting Rod

The connecting rod should be removed from the frame if it is necessary to replace the crosshead pin bushing that is shrunk into the small end of the rod. To remove the connecting rod:

1. Remove the top frame cover, tie bar(s), and frame extension cover that will give access to the connecting rod.

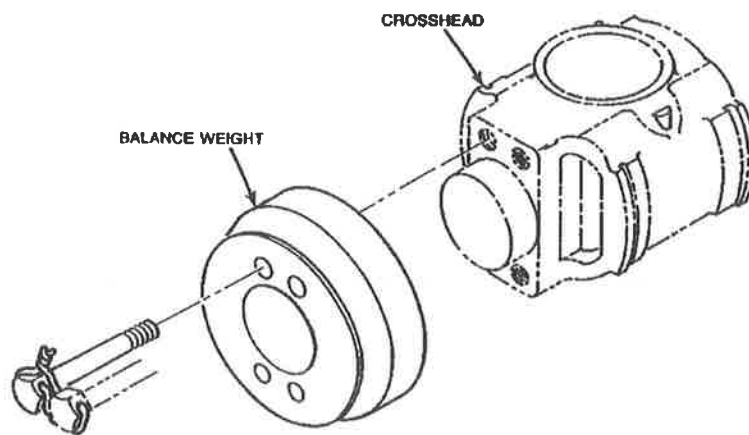
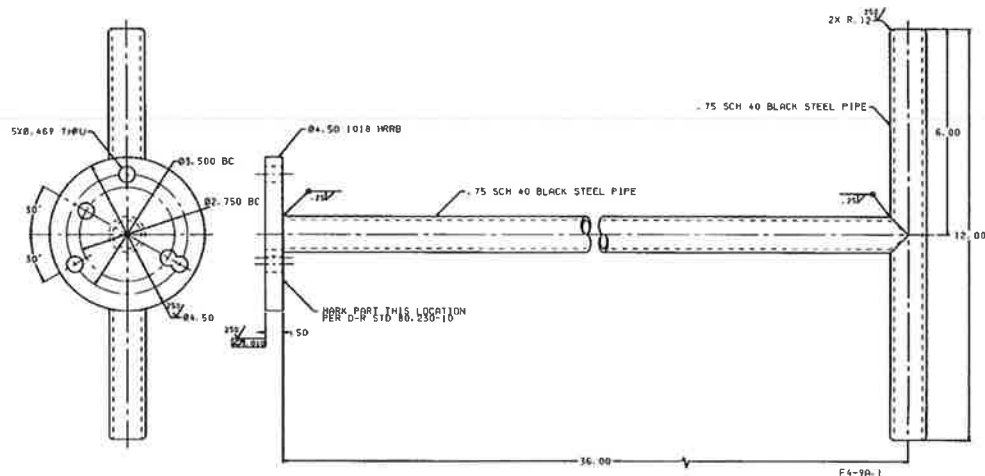


Figure 4-9. Lockwire Crosshead Balance Weights as Shown

2. All crosshead balance weights must be removed from the nose of the crosshead by removing the lockwire and cap bolts. (See Figure 4-9.)
3. Unscrew the piston rod from the crosshead using a strap wrench or a piston removal tool as shown in Figure 4-10. As the piston rod thread disengages from the crosshead, unscrew the crosshead jam nut and remove balance weights (if required) and lay them aside. Pull the piston rod away from the crosshead being careful not to pull the threads into the scraper rings.



**Figure 4-10. Piston Removal Tool**

4. Remove the crosshead pin bolt lock and unscrew the crosshead pin bolt. The pin end caps are doweled to the pin. Remove the pin end caps. A steel chisel of appropriate length wedged between the bottom of the crosshead extension and pin bolt slot will aid in removing the pin bolt.
5. Use pieces of 2 X 4 lumber to wedge the crosshead end of the connecting rod upward enough to take the weight of the rod off the pin. Block the rod and remove the pin.
6. Rotate the crosshead 90° in the guide to place it on its side and remove the crosshead from the frame.
7. Immediately mark the crosshead to identify which cylinder it is associated with and which face is positioned at the top.
8. Bar the compressor over until the cylinder is at mid-stroke and the connecting rod being worked on is positioned at the top of the frame. Break the connecting rod cap bolts loose.

### **⚠ WARNING**

**Before barring the unit over, the operator must insure the driver will not start; either by grounding the ignition and closing the fuel gas valve on engine driven units, or by insuring that power cannot be turned on with electric motor driven units. Failure to heed this WARNING can result in a fatal accident if the unit rolls over unexpectedly.**

### NOTE

Before removing connecting rod nuts make note of the match mark stampings on the face of the nut and the end of the bolt as shown in Figure 4-7. Ensure all components (nuts, washers, bolts) are reassembled in the same position as they were removed. It is extremely important that these components are not mixed up. If this happens refer to the connecting rod bolt stretch procedure.

9. Remove the connecting rod cap.
10. Move the connecting rod and crankshaft to gain space for removing the rod. Ensure the crosshead guides are protected from damage. Ease the large end of the connecting rod past the crankshaft with care to prevent damage to the crosshead guide or the crankpin. Continue to rotate the crankshaft until the webs are positioned such that the small end of the connecting rod will pass.

#### 4-8.7. Replacing Small End Bushing

The small end bushing-to-crosshead pin clearance can be checked by comparing micrometer measurements of the pin O.D. and bushing I.D. The bushing is non-adjustable; it must be replaced with a new one when the clearance becomes excessive or if the bushing is otherwise defective.

1. Press or machine the old bushing out of the connecting rod. If a machining operation is used, be careful not to cut into the connecting rod.
2. Clean the rod and check to make sure it is not bent or twisted. Maximum allowable bend and/or twist is 0.003 inch (0.076 mm).

### **⚠ WARNING**

**Always use liquid nitrogen in a well ventilated area and protect the eyes and skin from contact. Improper use may result in frostbite, respiratory ailments or asphyxia.**

3. The replacement bushing must be chilled (using liquid nitrogen) to reduce its outer dimension sufficiently so that it can be pressed into the eye of the connecting rod without applying an appreciable amount of force. The back of the bushing and connecting rod eye must be wiped clean before installing the bushing.

### **⚠ CAUTION**

**There is a hole in the connecting rod bushing, which must align with the rifle-drilled hole in the rod to ensure sufficient lubrication of the crosshead. If the hole is not aligned properly, the crosshead bushings will be quickly destroyed.**



4. Use an insertion tool as shown in Figure 4-11 to press the chilled bushing into the rod. The tool will aid in keeping the bushing square as it enters the rod. Do not allow the bushing to warm up during this procedure. Excessive force on these thin-walled bushings will cause distortion.

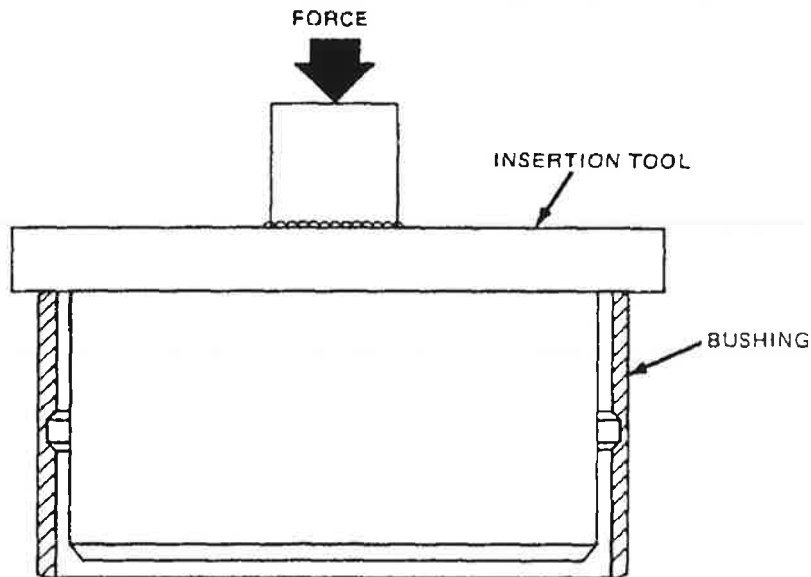


Figure 4-11. Bushing Insertion Tool

5. Be sure to align the hole in the bushing with the rifle-drilled hole in the rod. Check the pin-to-bushing clearance of the new parts. Refer to CHAPTER 5, GENERAL DATA & SPECIFICATIONS for assembly fits and tolerances.
6. Install the connecting rod in the compressor using the reverse of the removal procedure. Be sure the rifle-drilled oil passage in the rod is clear of any obstruction before installing the rod. Refer to the appropriate instructions when assembling the rod on the crankshaft and when installing the crosshead pin.
7. If new parts are being used, check for sufficient side clearance between the connecting rod and adjacent crank webs. This clearance can be measured with feelers and compared with the listed assembly clearance limits. As a final check of proper connecting rod installation, it is suggested that the unit be barred through one complete revolution while watching the connecting rod to see that it runs true on the crankpin. Replace the top cover on the frame.

### ⚠ CAUTION

The connecting rod bolts must be kept tight at all times. If they are allowed to loosen, broken bolts and considerable damage will occur. If these connecting rod bolts have been allowed to run in a loosened conditioned, as noted upon inspection, they should be replaced to prevent future fatigue failure no matter what their visual appearance. New bolts must be securely tightened to the proper torque specified in CHAPTER 5, GENERAL DATA & SPECIFICATIONS.

### 4-8-8. Replacing Crosshead Pin and Bushing

To replace the crosshead bushings, the crosshead must be removed from the machine as previously described.

1. Use a puller to remove the shrink fitted bushings from the crosshead. It is also possible to drive out the bushings.

#### CAUTION

**There is a hole drilled in each crosshead pin bushing. This hole must align with the oil hole in the crosshead to ensure adequate lubrication of the crosshead shoes. Improper installation will result in a scored crosshead guide and ruined shoes.**

2. Clean the bore in the crosshead and wipe off the replacement bushings. Chill the bushings in liquid nitrogen to reduce the diameters so they can be pressed into the crosshead without applying appreciable force. Insert the bushings into the bore. When inserting the bushing use a tool as shown in Figure 4-9 to keep the bushing square to the bore. Do not allow the bushing to warm up. Excessive insertion force on these thin wall bushings will cause distortion. Bushings must be flush with the edge of the crosshead.

#### WARNING

**Always use liquid nitrogen in a well ventilated area and protect the eyes and skin from contact. Improper use may result in frostbite, respiratory ailments or asphyxia.**

3. Mic the I.D. of the bushing and the O.D. of the crosshead pin. Refer to CHAPTER 5, GENERAL DATA & SPECIFICATIONS for the proper clearance.
4. Install the crosshead into the crosshead guide using the opposite procedure as previously described for removal in Paragraph 4-8.6.
5. Oil the crosshead pin and slide it into place in the crosshead and connecting rod. Assemble the end covers (the end covers are doweled to the pin) and replace the bolt to fasten the covers to the pin.
6. Check to see that the lock is in place under the head of the bolt and then tighten the bolt to the torque given in CHAPTER 5, GENERAL DATA & SPECIFICATIONS. Bend up the lock tabs to secure the bolt.
7. Remove any blocking device used and replace the frame extension cover.

### 4-8.9. Crosshead Shoe Replacement and Piston Rod Runout Adjustment

The crosshead shoes are fitted at the factory with the clearance listed in CHAPTER 5, GENERAL DATA & SPECIFICATIONS between the top shoe and upper crosshead guide. However, this clearance as well as the compressor piston rod alignment must be checked before starting a new unit and also after any replacement of compressor cylinder, piston, piston rod or crosshead shoes. Adjustment or replacement of the crosshead shoes is indicated when the shoes become noisy or when the compressor piston rod runout exceeds the specified limits.

With the compressor cylinder correctly installed and the piston rod crosshead locknut tightened, check the crosshead to be sure it is resting squarely on the lower guide. Do this by checking for clearance under the bottom crosshead shoe; a 0.0015 inch (0.04 mm) feeler should not enter between the center of the bottom shoe and guide at either end of the shoe. Measure the clearance between the top shoe and the upper guide at all four corners. Record these clearances for later reference.

The compressor piston rod runout (alignment) must be checked before starting a new unit or after any replacement of compressor cylinder, piston, piston rod or crosshead. Be sure the crosshead locknut has been properly tightened against the crosshead before checking the piston rod runout.

One of the primary reasons to keep rod runout within limits is to keep the rod running true through the piston rod packing, thus ensuring the longest possible packing life with the least leakage.

Piston rod runout is usually checked with the unit "cold". Vertical rod runout under these conditions is mainly influenced by the crosshead-to-crosshead guide cold clearance and the compressor piston-to-cylinder bore clearance. Because the compressor piston "grows" as it heats up during operation, it is normal to see a cold vertical runout much larger than what it will be when the unit is operating.

Runout limits are given in Table 4-1. All runout figures assume that the piston end of the rod is "low" to compensate for thermal growth of the piston. After running for four hours under full load and temperature conditions, check the "hot" runout. Runout should be as close to zero as possible.

There is no adjustment for horizontal piston rod runout, and it should not exceed 0.003 inch (0.08 mm) if everything is fitted properly.

**Factors that can influence piston rod runout are as follows:**

- A. Lack of proper supports, particularly on larger cylinders where excessive cylinder "droop" can occur.
- B. Excessive piping strain on the cylinder, or distorted cylinder supports pulling the cylinder out of alignment.
- C. Cylinder-to-frame joint burrs or debris in the joint, causing the cylinder to be misaligned.
- D. Excessive piston or cylinder bore wear. This can be checked by measuring the piston and bore with the appropriate micrometers.
- E. Worn crosshead shoes. Crosshead shoes are adjustable on conventional crossheads only and may be shimmed if worn.

**Table 4-1. Normal Cold Vertical Piston Rod Runout**

Cylinder Bore Diameter (Inches)	Approximate Cold Runout (Inches)
4.75 – 8.00	0.0000 - 0.0020
9.50 – 11.50	0.0005 - 0.0025
13.00 - 15.00	0.0015 - 0.0035
17.50 – 20.50	0.0025 - 0.0055
23.00 – 26.50	0.0040 – 0.0065

## Maintenance

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- F. A worn (or bent) piston rod. Check rod diameters along the full length of the rod if this is suspected. Also, check for bending. A worn or bent rod should be replaced.
- G. A crosshead jam nut not seating squarely against the crosshead nose. Improperly machined parts or debris can cause this situation.

### A. Crosshead Shoe Replacement

- 1. To remove the crosshead shoes pull the crosshead pin and remove the crosshead as described in Paragraph 4-8.6.

#### NOTE

Ensure the shims, which are removed, are reinstalled in the same position. It is recommended (but not required) that all lock nuts be replaced after initial use.

- 2. Remove the lock nuts, which secure the shoes to the crosshead.
- 3. Install new crosshead shoes and torque to the proper specifications listed in CHAPTER 5, GENERAL DATA & SPECIFICATIONS.
- 4. Mic the I.D. of the crosshead guide and the O.D. of the crosshead to ensure you have the proper running clearances per CHAPTER 5, GENERAL DATA & SPECIFICATIONS.
- 5. Reinstall the crosshead into the crosshead guide.

### B. Piston Rod Runout Adjustment

***The following instructions describe the recommended procedure for checking and adjusting the compressor piston rod runout:***

- 1. Mount a dial indicator in the distance piece so that it will read on the top of the piston rod. Be sure the indicator is securely mounted and depress the indicator button, rotating the pointer one revolution on the dial to preload the indicator. Set the dial to the zero mark.
- 2. Bar the compressor through 180°, starting from the maximum outboard stroke. *The largest reading seen during this 180° traverse to the inboard stroke position, whether plus or minus, is the total runout and is to be recorded on the frame record card using the proper sign (±) for the number.* In order to check the accuracy of the reading, continue to bar the compressor an additional 180° (in the same direction of rotation) to the maximum outboard stroke position. The dial indicator should now be pointing to zero; if not, the indicator has moved.

#### SERVICE NOTE

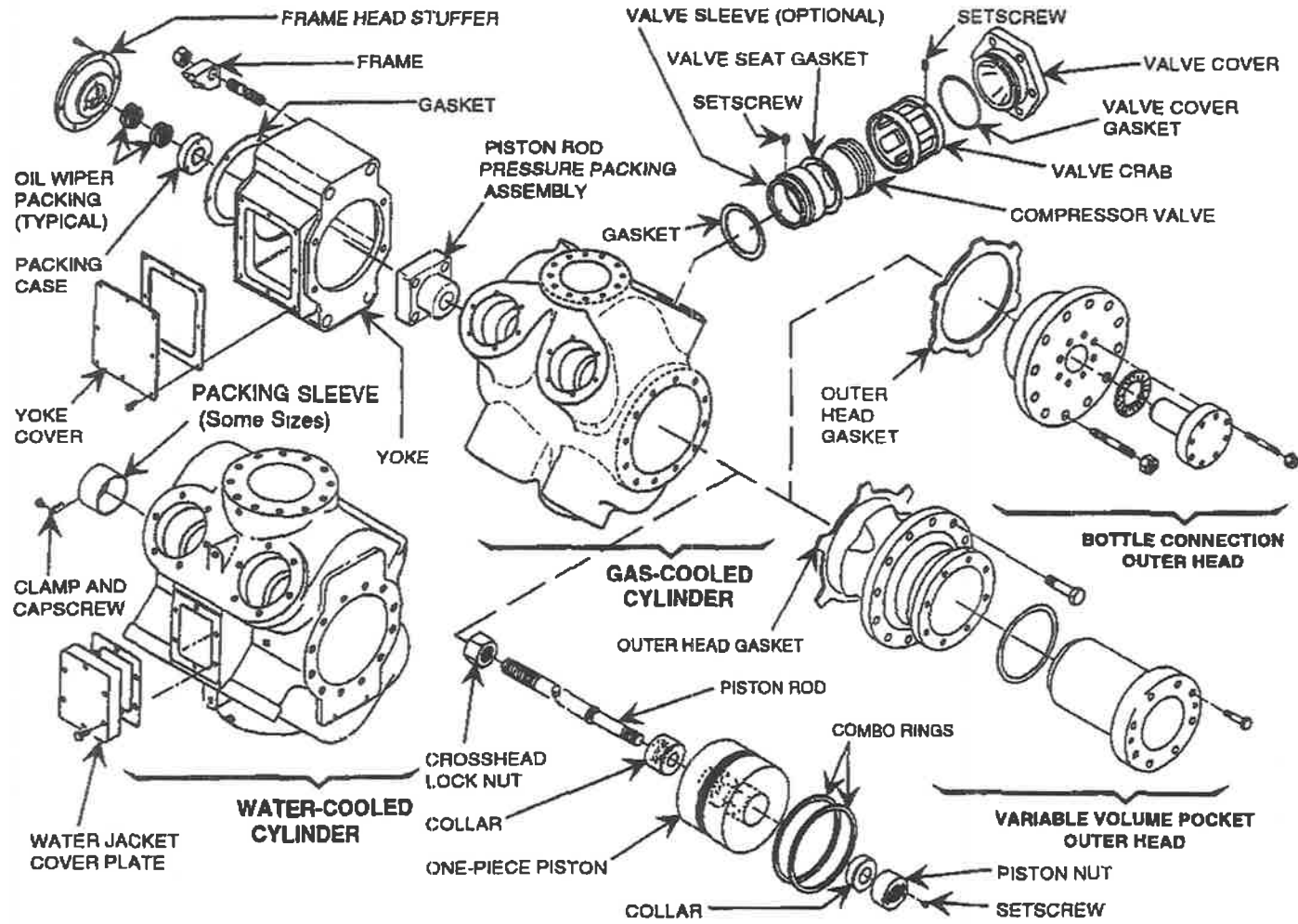
If the indicator needle "jumps" at the extreme ends of the stroke it is an indication of either a loose crosshead jam nut or a nut face that is not square to the crosshead nose.

3. The piston rod runout is adjusted in the vertical direction by adding or removing shims between the crosshead and its bottom shoe. If the piston rod is high at the piston end, shims must be added under the bottom shoe. If the rod is high at the crosshead end, shims must be removed from under the bottom shoe. If there is some confusion as to which end of the rod is high, a machinist's level can be placed on the piston rod to tell whether the crosshead must be raised or lowered. Always remember that the shim thickness removed or added to one shoe must then be either added or removed from the other shoe if the required top shoe-to-guide clearance is to be maintained.
4. Since the piston rod runout is initially checked and adjusted with the parts cold, the rod should normally be set slightly lower at the piston end to compensate for piston expansion when running at design load and temperature conditions. The amount the piston is set lower than the crosshead is determined by both the size and material of the piston. (Larger piston sizes should be set slightly lower to compensate for increased expansion.) **See Table 4-1.**
5. It is necessary to remove the shim from under the crosshead shoe to adjust the shim thickness. To remove the shoe, pull the crosshead pin as described in the instructions which follow; the crosshead shoe bolt nuts can then be removed and the crosshead rotated 90° in its guides to allow the shoe to be removed through the side inspection opening in the frame extension. Take off the shim and add or remove laminations as required. Generally, adding or removing one shim lamination will change the indicated rod runout about 0.001 inch (0.03 mm); therefore, to raise the indicated rod runout 0.002 inch (0.05 mm) at the crosshead end, it would be necessary to add two laminations to the shim used under the bottom shoe. Always remove or add a like number of laminations to the upper shoe to maintain the required top shoe-to-guide clearance.
6. Re-check the piston rod runout with a dial indicator, as described in Steps 1 and 2, after each shoe adjustment. Always check rod runout with the piston rod crosshead jam nut firmly tightened as a loose nut can alter the runout reading.
7. After setting the rod runout initially, and before operating the compressor, check that there is running clearance between the piston rod and piston rod packing glands.
8. There is no adjustment for horizontal piston rod runout. It is important, however, that the rod runout is checked in the horizontal direction by arranging the dial indicator to read on the side of the rod. If the horizontal indicated rod runout exceeds 0.003 inch (0.08 mm), the cause must be located and corrected. Check the cylinder, yoke and frame mating surfaces for dirt, nicks or burrs. Another possible cause of misalignment is an improperly tightened crosshead locknut or a nut that is not seating squarely against the crosshead. The possibility of cylinder supports or piping pulling the cylinder out of alignment should also be explored.
9. Both the piston rod alignment and the crosshead top shoe-to-guide clearance should be checked after operating the compressor for at least four hours under full load and temperature conditions. These checks must be made immediately after shutting down before the parts have had a chance to cool. Piston rod runout should be as close to zero as possible and must not exceed the limits given in Table 4-1 in any plane. The minimum acceptable clearance between the top crosshead shoe and guide with the parts at operating temperature is given in CHAPTER 5, GENERAL DATA & SPECIFICATIONS. If it is necessary to remove the shims to obtain this minimum clearance, be sure they are removed from under the top shoe. Record the hot clearance for future reference.

### 4-9. COMPRESSOR CYLINDERS

A wide variety of cylinder types are used on the 6-inch stroke HOS compressor. These can be divided into two major families – water cooled and gas cooled. Examples of these two families of cylinder are illustrated in Figure 4-12.

Figure 4-12. Typical HOS Cylinders



Water-cooled cylinders are available in standard bore sizes from 4-3/4 inches to 26-1/2 inches in diameter in cast iron, while gas-cooled cylinders with bores ranging from 6 inches to 15 inches in diameter are available in nodular iron as standard. (The cylinder line-up is shown in Table 4-3.)

### **⚠ WARNING**

**All precautionary measures specified by the Occupational Safety and Health Act of 1970 (OSHA) must be complied with when storing, handling, or using solvents.**

The cylinder bores, valves, valve passages, piston rod packings and any regulation equipment supplied should be inspected at regular intervals (refer to the routine maintenance schedule in Chapter 3), and any accumulations of foreign matter should be removed. Valves must be dismantled, soaked in safety solvent and physically brushed to soften and remove any deposits; a light scraping usually will suffice to clean the cylinder valve passages.

Dresser-Rand Type PF valves are used as standard in HOS cylinders. Detailed instructions for servicing the valves can be found in this chapter, Paragraph 4-16.4.

With water-cooled cylinders, mud will be deposited in the cylinder jackets, water heads and packing cooling sleeves if the circulating coolant (usually a mixture of 50-50 ethylene glycol and water) is dirty. This will eventually obstruct the flow of coolant unless care is used to prevent such an accumulation. Clogged passages will interfere with proper cooling, which will result in possible damage to the cylinder, pistons and packing.

The cylinder water jacket cover plate or hand hole covers (depending on design) should be removed occasionally and the water jackets and passages inspected. If any mud deposit is found, clean it out thoroughly and flush the jackets with water.

Piston and ring clearances for standard water-cooled and gas-cooled HOS cylinders are given in Table 4-3. Clearances for non-standard bore diameter cylinders will be given in a separate addendum sheet prepared for your unit. *The specified clearance limits are those to which the parts are originally assembled.* Varying operating conditions at different installations make it generally impractical to specify maximum acceptable clearances. Careful observation by the operator and good judgment by the mechanic are often the most effective means of determining when clearances have become excessive and adjustment or replacement of parts is required.

Before doing any maintenance work on the cylinders, closely observe the minimum safety precautions described previously in Paragraph 4-2. ***To protect personnel, it is imperative that all pressure be bled from the cylinder passages before attempting to open the cylinder.***

Also, before servicing the cylinders, review the Parts List illustrations thoroughly to become familiar with the particular assemblies involved. There may be slight design differences on a particular assembly that can require a modification to the recommended maintenance procedures.

#### **4-9.1. Removing and Installing Compressor Cylinders**

The compressor cylinder can be opened and the various cylinder components serviced as described in the maintenance instructions that follow. If the complete cylinder is to be removed from the compressor frame, it is first necessary to disconnect all piping from the cylinder, as applicable. Also, the compressor piston rod assembly should be removed from the cylinder as explained in the instructions, which follow. To remove the

## Maintenance

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cylinder from the frame, support the weight of the cylinder with rigging from an overhead hoist, or other means, and then unbolt the cylinder from the main frame and carefully lower the cylinder assembly to the floor.

Normally, the cylinders are mounted on the compressor frame when it is shipped to the installation site. However, in some instances, usually because of shipping and packaging restrictions, the cylinder is shipped separately and must be installed at the compressor site. Refer to the installation plans prepared for the compressor to determine the position in which each cylinder is to be mounted.

Before doing any maintenance work on the cylinders, closely observe the minimum safety precautions described previously in Paragraph 4-2. **To protect personnel, it is imperative that all pressure be bled from the cylinder passages before attempting to open the cylinder.**

Also, before servicing the cylinders, review the Parts List illustrations thoroughly to become familiar with the particular assemblies involved. There may be slight design differences on a particular assembly that can require a modification to the recommended maintenance procedures.

The compressor cylinder can be opened and the various cylinder components serviced as described in the maintenance instructions that follow.

### A. Removing Compressor Cylinder

***Remove the compressor cylinder from the compressor frame as follows:***

1. If the complete cylinder is to be removed from the compressor frame, it is first necessary to disconnect all of the gas, oil, water and control piping from the cylinder, as applicable.
2. The compressor piston and rod should next be removed from the cylinder as explained in the instructions which follow in Paragraph 4-9.3.
3. To remove the cylinder from the frame, support the weight of the cylinder with rigging from an overhead hoist, or other means, then unbolt the cylinder yoke from the main frame and carefully lower the cylinder assembly to the floor.

### NOTE

Cylinders must be returned to their original locations on the frame. Never change cylinder mounting locations without first consulting the nearest Dresser-Rand office.

Instructions for installing and aligning the compressor cylinder are described below. Install one cylinder at a time on the unit. Where supports are used, insert leveling screws in the support bases being sure the threads are greased and free in their holes.

### B. Installing Compressor Cylinder

***Install and align the cylinder on the compressor frame as follows:***

1. Thoroughly clean the mating surfaces on the cylinder and yoke. Coat both surfaces with gasket shellac, but do not use a gasket.



**NOTE**

Mating surfaces must be checked for flatness. Flatness of both mating components should be within .002".

2. Using capscrews, bolt the cylinder and yoke together. Insert the four cylinder-to-frame tie rods through the yokes and into the cylinder.
3. Thoroughly clean the mating surfaces on the frame extension and yoke. Coat both surfaces with gasket shellac, but do not use a gasket.
4. Mount the cylinder and yoke assembly on the frame. The cylinder yoke is centered on the frame extension by a shoulder which fits closely into the frame extension bore. Support the cylinder and then snug down the two top tie rod nuts.
5. Clean the gasket surface for the inlet (flange) on top of the cylinder and place a level on this surface parallel to the crankshaft. Rotate the cylinder until the gasket surface is level with the top of the frame; then, secure the cylinder.
6. Depending on the particular compressor, the cylinder may be equipped with a yoke support, or outer end support, or a combination of both. With either support location, the support must be adjusted so that it is supporting the weight of the cylinder but not placing an upward strain on the cylinder-to-frame bolting. The following procedure is recommended when an outer end support is used:
  - A. Loosen the cylinder-to-frame tie rod nuts and capscrews, leaving the two top tie rod nuts snugged down lightly.
  - B. Raise the cylinder with the support leveling setscrews until a 0.0015 inch (0.04 mm) feeler gauge can just be started at the bottom cylinder-to-frame joint.
  - C. Lower the cylinder to just close the joint, then tighten the cylinder to frame tie rod nuts using a torque wrench to obtain 40,000 PSI (276 Mpa) pre-stress. See CHAPTER 5, GENERAL DATA & SPECIFICATIONS for torque value.
7. Remove the outer head from the cylinder. Using a machinist's level having a cross level, check that the cylinder bore in the piston travel area is level. Locate the cause of any misalignment. **Do not use the support leveling setscrews to force the cylinder into alignment.**
8. Check the level of the crosshead guide. The cylinder bore and the crosshead guide need not be perfectly level, but both should be in the same plane. Do not use the cylinder inlet (or discharge) connection as an alternate to the cylinder bore. If the crosshead guides are level but one or more cylinders is not, the most likely cause is dirt or raised material in the joint where the cylinder fits the yoke or where the yoke mates with the frame extension.

Assembly of the compressor cylinders, including installation of valves and rod, piston rod packing, alignment of the piston rod and adjustment of piston and clearances, is completed by following the appropriate assembly procedures outlined in this manual.

**4-9.2. Disassembly and Assembly of Pistons & Piston Rods**

1. Observe all possible safety precautions as described previously in Paragraph 4-2.

2. Block the crosshead by jamming wooden blocks between the crosshead and frame extension to prevent twisting the crosshead and/or connecting rod when removing the locknut.
3. Loosen the crosshead locknut on the piston rod.
4. Remove the piston rod pressure packing and oil scraper rings as explained later in these instructions in Paragraphs 4-13. and 4-14. Always remove the packing rings before pulling or installing the piston rod; never slide these rings over the end of the rod.

### CAUTION

**Never use a pipe wrench on the piston rod. Take every precaution to avoid scratching or nicking the piston rod surface. Even a slight nick in the rod can ruin the packing rings.**

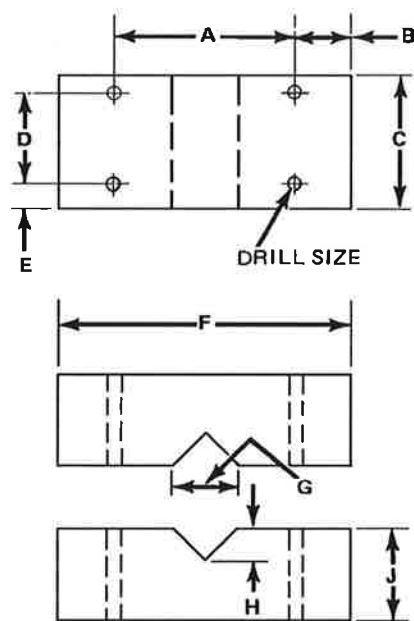
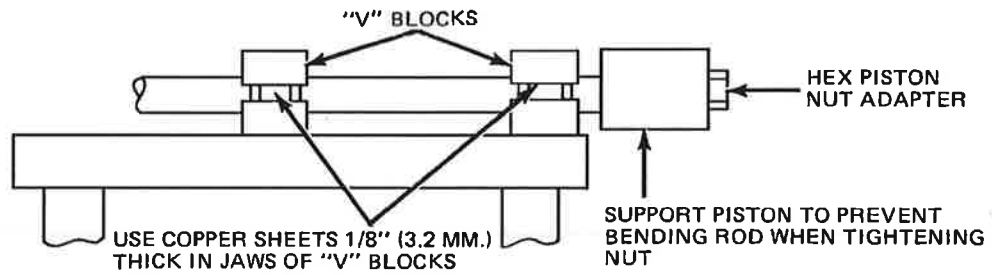
5. Remove the outer head and then unscrew the piston rod from the crosshead using a strap wrench or piston removal tool (Figure 4-10).
6. Pull the piston and rod assembly through the outer end of the cylinder. Be careful to support the piston until the rod is clear to prevent bending or scratching it. Mark the assembly so that it can be installed in the same cylinder.
7. If the packing cup and gland assemblies are removed from the cylinder at this time, be sure the parts are marked or tagged to facilitate proper reassembly.
8. Set the piston and rod in a safe place and protect the finished surfaces from damage. If the piston and rod are not integral, and if the piston is to be separated from the piston rod, refer to piston & rod disassembly and reassembly steps.

#### **A. Piston and Rod Disassembly**

1. Install the piston rod assembly in a clamping fixture as shown in Figure 4-13 or a similar device that will keep the piston rod from turning while loosening and/or tightening the piston rod nut. Use a soft bearing material next to the rod surface to prevent scoring or scratching.
2. Remove the piston nut locking setscrew. Remove the piston rod nut using the wrench adapter provided. If available, a suitable size impact wrench is ideal for loosening the nut. If necessary to sledge or use a cheater on the wrench, support the piston to prevent bending of the piston rod.
3. Remove the piston from the rod.

#### **B. Piston and Rod Assembly**

1. To assemble a piston and rod, install the rod in a clamping fixture as shown in Figure 4-13.
2. Inspect the mating surfaces of the piston rod collar, piston faces and piston rod nut for dirt, burrs and general condition. Clean up the parts as required.



"V" BLOCKS  
MATL.-STEEL

DIMENSION TABLE (INCHES)										DRILL
ROD SIZE	A	B	C	D	E	F	G	H	J	SIZE
UP TO 2-1/4"	3-1/2	1-3/4	6	4	1	7	2-1/8	5/8	2-1/2	3/4
2-1/4" & LARGER	8	2-1/2	6	4	1	13	5-1/2	1-3/4	4	1-1/8

DIMENSION TABLE (CENTIMETERS)										DRILL
ROD SIZE	A	B	C	D	E	F	G	H	J	SIZE
UP TO 5.7 cm	8.9	4.5	15.2	10.2	2.5	17.8	5.4	1.6	6.4	1.9
5.7 cm & LARGER	20.3	6.4	15.2	10.2	2.5	33.0	14.0	4.5	10.2	2.9

Figure 4-13. Suggested Piston Rod Clamping Fixture

## Maintenance

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3. Place the collar on the rod and check the mating surfaces between the rod shoulder and collar by "blueing" to assure that at least 75% bearing contact is made. Repeat for collar contact on piston. Check that the mating area is uniform completely around the circumference and across the mating face. Lap the faces, if necessary, using a valve grinding compound. Remove all traces of compound using soap and water.

### SERVICE NOTE

With step cylinders, both an inboard and outboard piston and piston spacer as well as piston collars and nut must be blued to 75% contact in the appropriate order.

4. Check the mating surface between the piston nut and the piston for adequate contact as in Step 3. If the bearing area is insufficient, check the squareness of the nut face with the nut threads. Scrape or lap faces, if necessary, using valve grinding compound until adequate bearing area is obtained. Remove all traces of compound using soap and water.
5. Coat the piston rod and piston nut threads with a suitable anti-galling compound, such as **Felpro C-100** (distributed by Felpro, Inc., Skokie, IL 60776) or **Jet Lube #20** (distributed by Marlon Supply Co., 5016 Edgewood Rd., Crystal Lake, IL 60014). Apply a thin film on the face of the piston nut and piston. Tighten the nut to 150 ft. lb. (203 NAM) to ensure adequate metal-to-metal contact.
6. Scribe a line (A) through the centerline of the rod and extend it out onto the piston as shown in Figure 4-14.
7. Refer to Table 4-2 to determine the number of degrees the nut must be turned with relation to the piston rod. *The use of torque is strongly discouraged because of the variations obtained with small changes in lubrication and surface condition of the mating parts.*
8. Measure from the original scribe line (A) the number of degrees that the piston nut must be turned. Prick punch point (B) on the piston and scribe a line through this point (B) and the centerline of the piston rod.
9. Install the piston nut adapter. Mark the adapter (or socket, if an impact wrench is used) adjacent to the first scribe line (A) as in Figure 4-14.
10. Tighten the piston nut until the mark on the adapter (or socket) coincides with the second scribe line (B).

### SERVICE NOTE

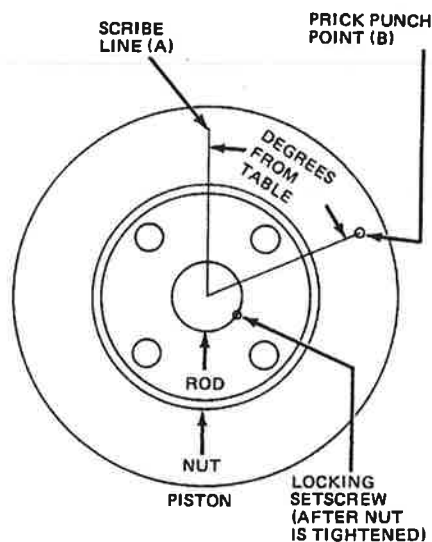
With the wrench socket on the adapter, it will be impossible to see the scribe mark on the piston nut. It is essential that the scribe marks between the piston rod and nut line up. It is therefore recommended that the scribe mark on the socket be turned slightly beyond the second scribe mark on the piston, as the piston may rotate slightly on the rod due to friction.

11. If a new piston, piston rod or piston nut is being installed, tighten the assembly at least twice to the full pre-stress as described in Steps 6 through 10. Then, loosen the assembly again and repeat Steps 18 through 23 (for at least the third time) to secure the piston on the rod.

**NOTE**

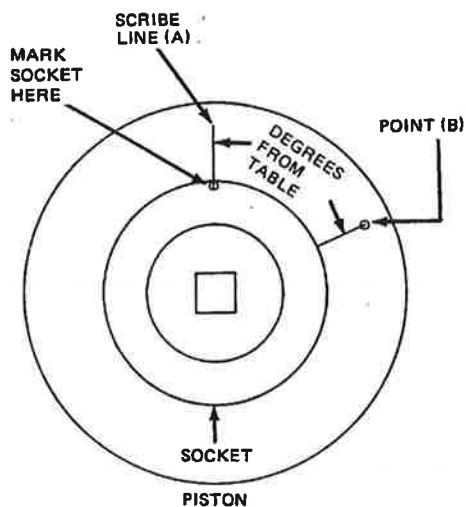
It is anticipated that the piston will go beyond the original scribe mark; therefore, it is imperative to re-scribe each time the nut is tightened.

12. After completing the piston nut tightening procedure, drill and tap the piston rod and nut for the locking setscrew. (Facing the end of the piston, half of the tapped hole should be in the piston rod and half in the nut.)



SEE TABLE 4-2 FOR TIGHTENING ANGLE

TP-1826



TP-1827

Figure 4-14. Marking Piston Nut and Adapter or Socket

**Table 4-2. Piston Nut Tightening Angles for Standard Cylinders**

Tightening Angle	Cylinder Size	Configuration
40°	9.5", 10.5", 11.5" & 13"	Two Valves per Corner Cast Iron Piston
45°	6.0" Lined, 7.0" & 8.0"	One Valve per Corner Slant Design
45°	All 15", 17.5" & 20.5"	Cast Aluminum Pistons Smaller Sizes
50°	All 23" & 26"	Cast Aluminum Pistons Larger Sizes
60°	4.75", 5.0" Lined & 6.0"	Cast Iron Billet
70°	6.0" F.S.	Forged Steel Billet
120°	Step Pistons	Step (Tandem) Cylinder

Note: Table 4-2 covers both water-cooled and gas-cooled designs.

13. Lock the piston nut to the rod using the setscrew.

**NOTE**

Some piston tightening angles are found printed on the piston parts lists. If there is a discrepancy between this chart and any such figure, use the figure on the parts list.

This completes the assembly of the compressor piston and rod. Install the piston and rod into the cylinder as outlined in the following steps.

**4-10. INSTALLING PISTON ROD AND ADJUSTING END CLEARANCE**

When adjusting piston end clearance, it is desirable to have more clearance at the outer end than at the frame end. This is because expansion from operating heat tends to increase the frame end clearance and decrease the outer end clearance. For this reason, when setting piston end clearance, the outer end is usually given about 50% more lineal clearance than the frame end. Specific end clearances are shown on the cylinder nameplate. Standard HOS cylinder clearance is as follows:

**Frame End = 0.042-0.062 inch (1.06-1.57 mm)**

**Outer End = 0.084-0.124 inch (2.13-3.15 mm)**

### **⚠ WARNING**

**Before barring the unit over, the operator must ensure that the driver will not start - either by grounding the ignition and closing the fuel gas valve on engine driven units - or by ensuring that the power cannot be turned on with electric motor driven units. Failure to heed this WARNING can result in a fatal accident if the unit rolls over unexpectedly.**

The piston end clearance, after having been correctly set at the time of installation, should rarely require adjustment. It should, however, be checked occasionally as follows: To measure the end clearance, first remove the cylinder indicator plugs for each end. When the machine is cold, find the exact clearance by barring over the compressor until the piston is at the innermost end of its stroke. Using feeler gauges, measure the distance between the face of the piston and the inboard cylinder head. Note this measurement and then bar the compressor 180° to bring the piston to the outermost end of its stroke. Again using feeler gauges, measure the clearance between the face of the piston and the outboard cylinder head. Note any difference in the clearances and then screw the piston rod in or out of the crosshead to make the clearance about 50% more at the outer end than at the frame end.

If it is necessary to change the clearance at either end, loosen the locknut on the piston rod at the crosshead. Turn the piston rod in or out of the crosshead as required. Each quarter turn of the rod changes the end clearance by 0.031 inch (0.79 mm). After proper clearance in the cylinder is established, tighten the crosshead locknut on the piston rod, as described later in the following steps.

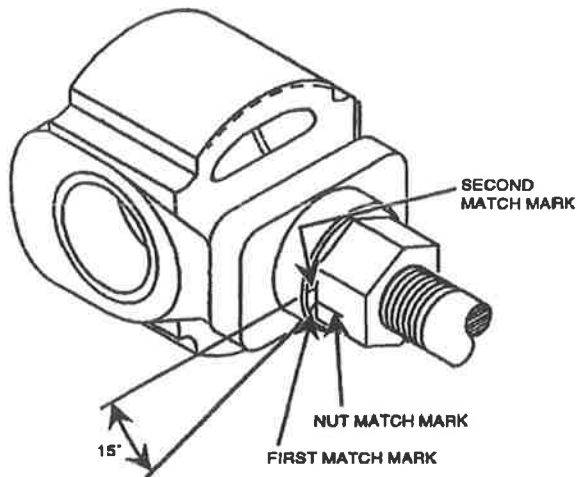
1. Place an entering sleeve onto the end of the piston rod to protect the packing. Coat piston rod and sleeve with oil, then push the piston assembly into the cylinder.
2. Remove the entering sleeve.

### **⚠ CAUTION**

**Never use a pipe wrench on the piston rod. Take every precaution to avoid scratching or nicking the piston rod surface. Even a slight nick in the rod can ruin the packing rings.**

3. Install jam nut on the piston rod and balance weights (if required) making sure the machined surface will contact the crosshead.
4. Screw the piston rod into the crosshead until the required piston frame end clearance is obtained. (Refer to the instructions above for a discussion of the piston end clearance.) A strap wrench or a piston installation/removal tool ( see Figure 4-10) should be used to screw the piston rod into the crosshead. Snug the piston rod locknut against the crosshead, but do not tighten it at this time. Check to see that there is some clearance between the piston rod and the connecting rod in the crosshead.
5. Check the seating surfaces between the crosshead and lock nut by "blueing" to ensure that at least 80% seating contact is made. Check that seating area is uniform completely around the circumference and across the seating face. If the seating is insufficient, check the squareness of the nut face with the nut threads. Scrape or lap the faces, if necessary, using a grinding compound until adequate seating area is obtained. Remove all traces of compound using soap and water.

6. Tighten the crosshead lock nut as follows:
  - A. The crosshead should be blocked between the crosshead and frame extension to prevent twisting the crosshead and/or connecting rod during tightening. A wooden block may be used.
  - B. Coat the rod and nut threads with a suitable anti-galling compound or extreme pressure lubricant. Apply a thin film on the seating faces of the nut and crosshead. Tighten the nut to approximately 150-ft. lb. (203 N m) to ensure good metal-to-metal contact.
  - C. Refer to Figure 4-15. Match mark a flat on the nut with the face of the crosshead using a punch, scribe, or other suitable instrument. To mark the proper nut-tightening angle, measure clockwise 15 degrees from the first mark using a protractor and make a second mark on the crosshead face.
  - D. Tighten the lock nut until the first mark (on the nut flat) is aligned with the second mark (on the crosshead face).



**Figure 4-15. Marking Crosshead and Crosshead Lock Nut Tightening Angle**

7. Check the rod runout and adjust as required in Paragraph 4-8.9.
8. Install the outer head assembly onto the cylinder and tighten to the specified torque. Check the piston end clearance at each end of the stroke as described in instructions above.

### 4-11. INSPECTION / MAINTENANCE OF CYLINDER BORES

1. Place the cylinder in a clean work area and wipe the bore with clean rags. It may be necessary to use a safety solvent to remove some deposits.

## **WARNING**

All precautionary measures specified by the Occupational Safety and Health Act of 1970 (OSHA) must be complied with when storing, handling, or using solvents.



2. Shine a light down the cylinder bore and visually inspect for scratches, gouges and nicks.
3. Using an internal micrometer, measure each bore at its frame end, center portion and outer end at the limits of piston travel, taking measurements 90° apart. Comparing the measurements will give figures for taper (end-to-end in the same bore position) and out-of-round (same bore position but 90° apart) for each bore. Maximum allowable taper is 0.0005 inch (0.013 mm) per inch (25 mm) of stroke. Maximum allowable out-of-round is 0.0005 inch (0.013 mm) per inch (25 mm) of bore diameter for TFE or thermoplastic rings.
4. A bore not worn to the limits (above) may be cleaned up using a glaze breaker or a rigid portable hone and new piston rings may be fitted. See "Honing", later in this section, for a procedure.

**NOTE**

Generally, standard rings may be used in cylinders worn up to the limits shown in Table 4-3. For cylinders with bore diameters greater than specified, oversize piston rings should be used. The bore must be round. Oversize rings are not the cure for an out-of-round or tapered bore condition. When ordering oversize rings, furnish Dresser-Rand with the cylinder bore measurements. Rings ordered through Dresser-Rand will be tagged, indicating the proper side and end gap clearances. Use Table 4-3, as a guide to determine what the maximum bore should be before oversize piston rings are required.

**Table 4-3. Cylinder Reconditioning Data**

Original Cylinder Size (Inches)  Nominal Bore Diameter	Maximum Bore Diameter Increase (Inches) Allowed  Before Oversize Rings Required
4.75	0.015
6.000	0.018
7.000	0.021
8.000	0.024
9.500	0.029
10.500	0.032
11.500	0.035
13.000	0.039
15.000 – 26.500	0.048

NOTE: Inch-to-millimeter conversion-multiply inches by 25.4 to obtain millimeters.

**A. Honing**

In all cases where a bore is being field reconditioned, it is important to achieve a surface finish at least as good as the factory finish to ensure adequate ring seating and longevity. Hone the cylinder bore to restore surface finish. Bores should be at least 32 RMS Ra (0.8 um). Honing will polish scratches and remove burrs, and will often restore a cylinder bore after minor scuffing. This can be achieved using a glaze breaker or hone, finishing with extra fine hone stones. A crosshatch pattern can be used if desired. ALWAYS WASH GRIT FROM HONING OUT OF THE BORE USING SOAP AND HOT WATER

### NOTE

The major difference between a glaze breaker and a cylinder hone is that the glaze breaker will follow the contour of the cylinder. If the bore is out-of-round, the glaze breaker will only clean it up; it will not "true up" the bore. The hone, on the other hand, will true up a slightly out-of-round or tapered cylinder bore, although it too tends to follow the existing bore contour.

## 4-12. NON-METALLIC COMBINATION PISTON & RIDER RINGS

These segmented, non-metallic combination piston/rider rings function as both piston and rider rings. They are used as a standard on all HOS cylinders except the 26- and 26.5-inch (660 and 673 mm), which uses glass - molydisulphide-filled Teflon® piston rings with band-type riders made of the same material.

The combination piston and rider rings will hold the piston away from the cylinder bore during operation, thus preventing piston-to-cylinder bore contact and the resultant scoring and wear. To promote long ring life, cylinder bore surface finish is to be maintained at 32 Ra (0.8 micrometer).

Standard size rings may be used in oversized cylinder bores up to 0.003 inch (0.08 mm) for each inch (25.4 mm) of bore diameter up to and including 0.045 inch (1.14 mm) maximum oversize. For cylinders with bore diameters greater than specified for nominal bore size, oversized piston rings should be used. Remember that the bore must be round. Oversize rings will not correct or compensate for out-of-round or tapered bore conditions.

### 4-12.1. Handling Instructions

These piston rings are fragile (when compared to metallic parts) and can be easily damaged by careless handling. Always use care during storage, handling, installation and removal.

During long shutdowns (over six months), the pistons and rods should be removed from the compressor; coat the piston and rod assembly with a rust preventative that meets Military Specification MIL-C-16173 latest revision. The rings are to be removed from the piston and stored flat. No special covering or rust preventative is required. Do not lay the piston and rod assembly down with rings installed.

### 4-12.2. Establishing Ring Wear Rate

The combination piston/rider rings may wear more rapidly than other rings because of the functions they are designed to perform. (These are sealing of the cylinder bore, and the prevention of piston to cylinder bore contact.) Operating and maintenance personnel must take this factor into consideration when scheduling inspections and normal part replacement.

As wear occurs, piston rod runout will eventually exceed allowable limits. If oversized rings are installed in an oversized bore the ring wear factor is more critical because the rod drop will be increased by one-half the total oversize. For example, if the bore is 0.026 inch oversize (0.66 mm) the rod will drop an additional 0.013 inch (0.33 mm) before the bottom clearance or ring radial thickness indicates replacement is required. Therefore, the operator must keep in mind that the rings must be replaced when their original radial thickness is reduced by one-half of the original (new radial) thickness. Also, note the clearance between the piston rod and packing housing. DO NOT allow these items to come into contact with each other

Because of the many variables involved, it is impossible to accurately predict the rate of wear. (Some of the variables are pressure, temperature, lubrication or lack thereof, piston weight, gas type, gas wetness, gas cleanliness and cylinder bore finish.)

### ▲ CAUTION

To prevent scoring of the cylinder bore, piston or the piston rod, the amount of ring wear (clearance between the piston and cylinder bore) must be checked on a regular basis. This action will tell the operator if wear is excessive, allowing replacement before damage is done.

The importance of frequently checking ring wear rate cannot be over-emphasized. The rate of wear must be determined so that a replacement schedule can be established. Measurement of the piston to cylinder bore clearance ("A", Figure 4-16) should be taken at intervals of 10, 100, 250, 500 and 1000 hours. Record these numbers for future reference, or plot a simple wear versus time curve that will indicate both the rate of wear and the approximate number of hours running time before the combination rings need to be replaced.

### NOTE

When plotted, the wear rate curve will usually show a relatively rapid rate of wear during the first few hours of operation. As the rings wear, the curve should flatten out.

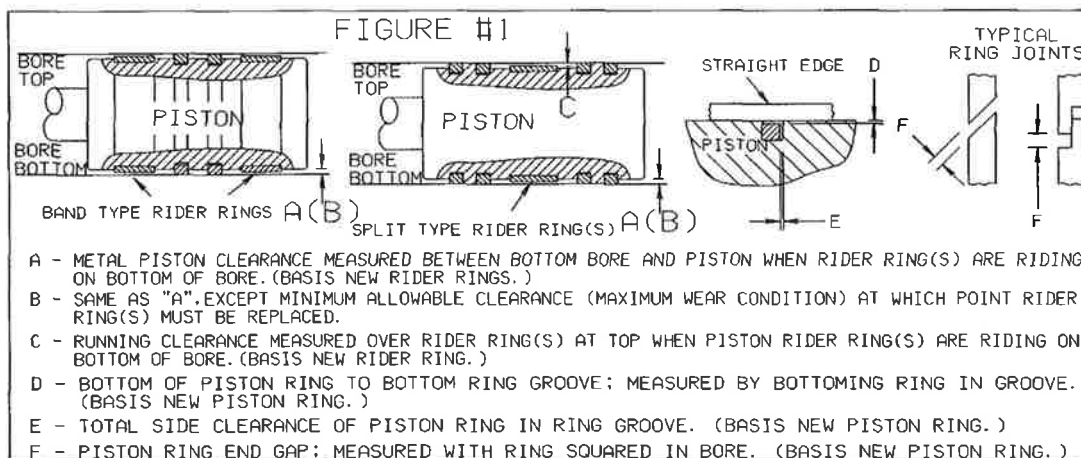


Figure 4-16. Points for Checking Clearance  
(See Table 4-4 For Dimensions)

#### 4-12.3. Replacing Rings

Rings are replaced when the bottom piston to cylinder bore clearance ("B" Figure 4-16) has been reduced to the minimum allowable clearance or if the original radial thickness of the rings has been reduced by one-half.

### ▲ WARNING

Never measure piston-to-cylinder bore clearance through a valve opening; always remove the outer head. Refer to the appropriate instructions to remove and install the outer head. Failure to comply with this warning may result in severe personal injury caused by compressor roll.

## Maintenance

### 4-12.4. Installing Rings

The rings must be assembled in the piston grooves as the piston is slid into the cylinder bore. These rings will extend beyond the piston's outside diameter when installed. After the piston is installed, measure the bottom clearance between the piston and cylinder bore (see "A" Figure 4-16). This is the point of reference from which the amount of wear will be determined.

**Table 4-4. Piston and Ring Clearance for Standard HOS Cylinders**

Nominal Cylinder Size (Inches)	G/C <sup>1</sup>	W/C <sup>2</sup>	Piston Mat'l.	Groove Width (In.) +0.001 -0.000	"C" Running Clear.(In.) Top-New Rings	"E" Side Clear.(In.) Between Ring & Groove	Total <sup>3</sup> Ring End Gap New Parts (In.)
4.75		X	CI	0.500	0.029/0.040	0.009/0.013	0.033/0.053
6.00	X	X	CI	0.500	0.012/0.026	0.009/0.013	0.042/0.062
7.00	X	X	CI	0.625	0.014/0.028	0.011/0.015	0.049/0.069
8.00	X	X	CI	0.500	0.017/0.031	0.009/0.013	0.056/0.080
9.50	X	X	CI	0.625	0.020/0.034	0.011/0.015	0.067/0.095
10.50	X	X	CI	0.625	0.021/0.035	0.011/0.015	0.074/0.105
11.50	X	X	CI	0.625	0.023/0.037	0.011/0.015	0.081/0.115
13.00	X	X	CI	0.500	0.026/0.040	0.009/0.013	0.091/0.130
15.00	X	X	AL	0.623	0.041/0.056	0.007/0.011	0.105/0.150
17.50		X	AL	0.623	0.050/0.065	0.007/0.011	0.123/0.175
20.50		X	AL	0.623	0.057/0.072	0.007/0.011	0.144/0.205
23.00		X	AL	0.623	0.065/0.080	0.007/0.011	0.161/0.230
26.00		X	AL	0.623	0.070/0.085	0.007/0.011	0.182/0.260
26.50		X	AL	0.623	0.071/0.086	0.007/0.011	0.186/0.265

**NOTES FOR TABLE:**

<sup>1</sup> = Gas cooled

<sup>2</sup> = Water cooled

<sup>3</sup> = For TFE rings, end gaps are as follows:

Min = .017 x Nominal Bore

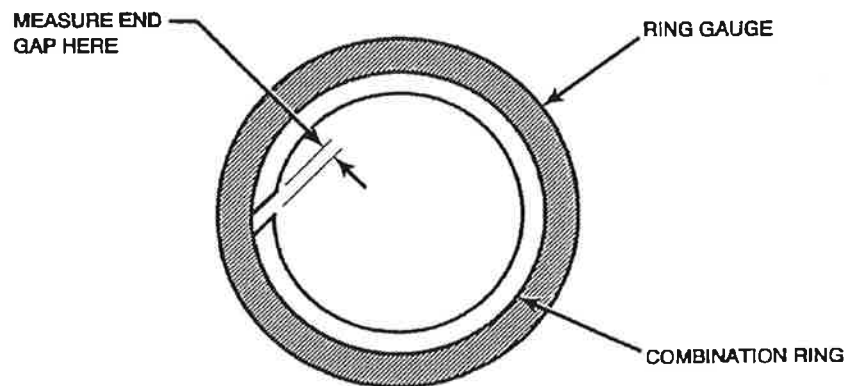
Max = .020 x Nominal Bore

Multiply clearance dimension by 25.4 to obtain (soft converted) metric dimension.

- CI = Cast Iron; AL = Aluminum
- Metric groove width tolerance is +0.025/-0.000 mm.  
(A 0.500" width is 12.7 mm; a 0.625" width is 15.88 mm.)
- Dimensions Refer to Figure 4-15. All dimensions are for new parts.

**To install the rings, follow these steps. Clearances are listed in Table 4-4.**

1. Check the ring part number against the parts list to ensure the correct parts are being installed.
2. Manufacture a ring gauge that has the same nominal inside diameter as the cylinder bore. Insert the rings, measure and record total ring end gap clearance; see Figure 4-17.
3. Measure radial thickness of the rings. Record this dimension for future reference.
4. Be sure the piston ring grooves are clean and smooth.
5. Install the packing entering sleeve on the piston rod.
6. Push the piston into the cylinder until the innermost groove is just outside the cylinder.



**Figure 4-17. Taking End Gap Clearance**

7. Make, from thin shim stock, a tool to hold the ring segments in the piston grooves.
8. Place the ring segments into the piston grooves and take side clearance as shown in "E" Figure 4-16; record these clearances.
9. LIFT the piston slightly and push it into the cylinder until the cylinder bore holds the ring segments in place. Remove the shim stock.
10. Measure the clearance between the ring and cylinder bore at "C" Figure 4-16. Repeat Steps 8 and 9 until all rings have been installed.
11. After all rings are in place, push the piston all the way into the cylinder; remove the entering sleeve and connect the piston rod to the crosshead and install the outer head following the appropriate instructions.

### 4-12.5. Breaking-in Combination Rings

Full pressures normally can be applied to the rings when they are initially placed in service. However, on new or overhauled units, consideration of the break-in requirements of the compressor "running gear" must also be considered. Always watch operating temperatures for indications of overheating, especially during break-in. Refer to CHAPTER 3, OPERATION AND TROUBLESHOOTING. If possible (pump-to-point systems only) set the cylinder lubricator feed rate to provide maximum delivery during the break-in period. At the end of the break-in period, the feed rate can be reduced to normal.

### 4-13. PISTON ROD PRESSURE PACKING

Generally, all piston rods are packed with floating type packing (see Figure 4- 18). There is no adjustment or take-up for this type of packing. Tighten the flange stud nuts evenly and squarely to obtain even crushing of the gasket at the bottom of the stuffer; this will prevent cocking of the packing cups and ensure their being perpendicular with respect to the piston rod.

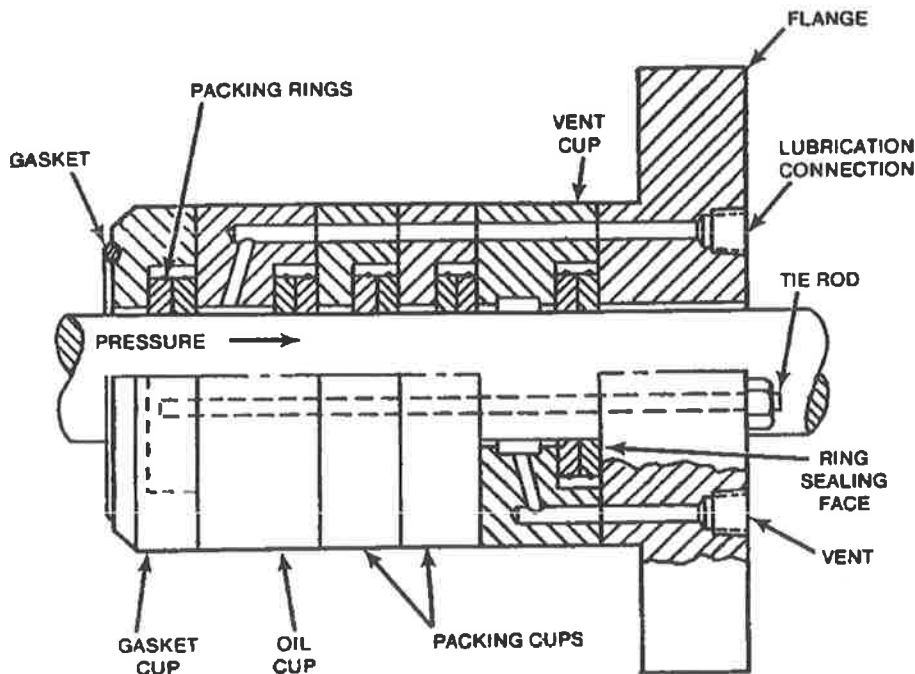


Figure 4-18. Piston Rod Pressure Packing Typical Construction

#### 4-13.1. Packing Rings

The packing rings are the most important part of the packing. They seal the pressure, take the normal wear and must be serviced and lubricated. When sludge and carbon from poor or incorrect lubricating oil have fouled them, they must be cleaned. When the rings (except backup rings) have worn so that no end clearance exists between the segments, the rings should be replaced. The rings are the working parts in any packing set and it is they that require the most attention. Usually these rings have a long life, but it is a good policy to have a set of replacement rings on hand to meet emergencies. Replacement rings may be ordered in sets, without ordering the flange or cups.

Packing ring material and type of packing is supplied to suit each application. While it is possible that special, non-standard packing may be encountered in the field, Dresser-Rand currently supplies only three basic types of packing, based on the pressure application. These are as follows:

### **Type I. 1750 PSI (12 Mpa) Packing**

*This type packing is used on 4.75-inch, 6.00-inch, 7.00-inch and 8.00-inch water-cooled cylinders and on 6.00-inch, 7.00-inch and 8.00-inch gas-cooled cylinders.*

- 1- Zero end gap, cast-iron pressure breaker (P-ring)
- 4- Sealing single-acting rings, glass - graphite-filled TFE with metallic back-up ring
- 1- Flange end double-acting packing ring, glass - graphite-filled TFE.

### **Type II. 1150 PSI (7.9 Mpa) Packing**

*This type packing is used on 9.50-inch and 10.50-inch water-cooled and gas-cooled cylinders. No P-ring is used.*

- 4- Sealing single-acting rings, glass - graphite-filled TFE with metallic back-up ring
- 1- Flange end double-acting packing ring, glass - graphite-filled TFE

### **Type III. 775 PSI (5.3 Mpa) Packing**

*This type packing is used on 11.50-inch, 13.00-inch, 15.00-inch, 17.50-inch, 20.50-inch, 23.00-inch and 26.00/26.50-inch water-cooled cylinders and on 11.50-inch, 13.00-inch and 15.00-inch gas-cooled cylinders. No P-ring is used.*

- 3- Sealing single-acting rings, glass - graphite-filled TFE with metallic back-up ring
- 1- Flange end double-acting packing ring, glass - graphite-filled TFE

The TFE ring joints are cut tangent to a diameter slightly smaller than the rod size. These joint surfaces seal, so they must be in good condition. On some rings, the pressure side will have radial notches.

These notches must face toward the pressure when installed. The metallic backup ring is designed to remove heat from the rod and prevent extrusion of the TFE rings. The backup ring has radial joints, which butt, when the ring is assembled on the rod, leaving the ring slightly larger than the rod. No end clearance should exist at the joints, which would permit the ring to pressure-load the rod. The joints must be smooth and butt squarely to prevent leakage.

The outside edges only of any pair of rings should have approximately 1/16-inch (1.6 mm) radius and are normally furnished this way. Do not radius the mating (inside) edges of any pair of rings. The faces of the rings are usually lettered or numbered on each segment of each ring for easy identification and assembly. These identification letters or numbers must face toward the pressure. The depth of the cup in each packing flange and the axial width of each packing ring or ring pair should be measured using depth and outside micrometers, or a straightedge and feelers.

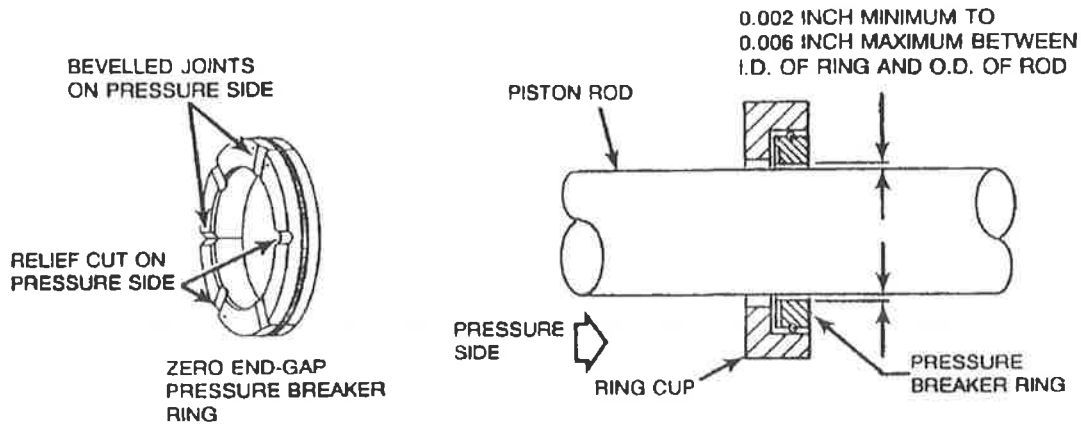


Figure 4-19. Zero End Gap Pressure Breaker

The pressure breaker, Figure 4-19, is installed in the first packing cup that faces the pressure. Its purpose is to slow down, or "break", the effects of gas pressure without totally sealing. The type pressure breaker used is "zero end gap" type design which has zero gap at the joints and a 0.002-0.006 inch (0.05-0.15 mm) clearance on diameter over the rod. This ring has pressure relief cuts in the face that is towards the pressure. It is important that this newer design is not confused with the old-type pressure breaker that had a significant end gap at the ring joints.

Both single acting (Figure 4-20) and double acting (Figure 4-21) rings are free to float (move axially and vertically with the piston rod) in their respective cups.

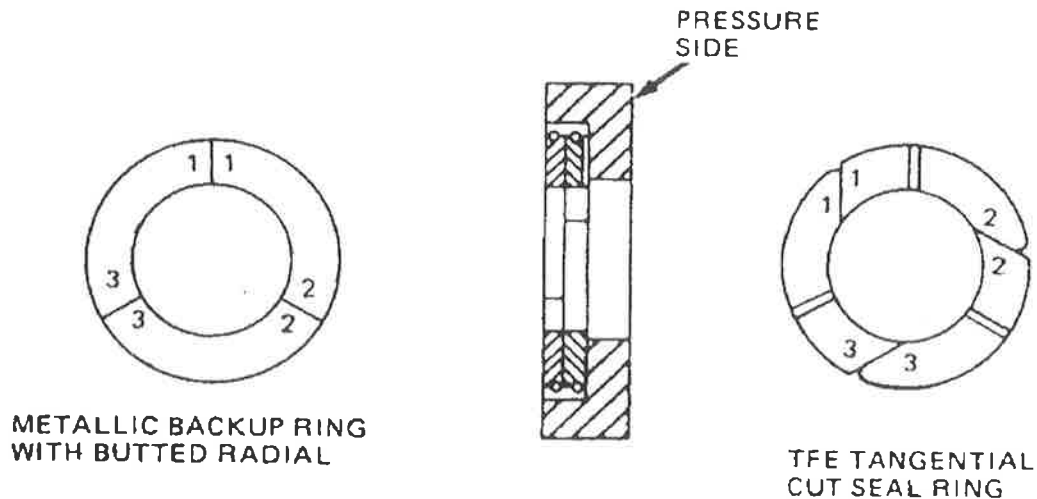
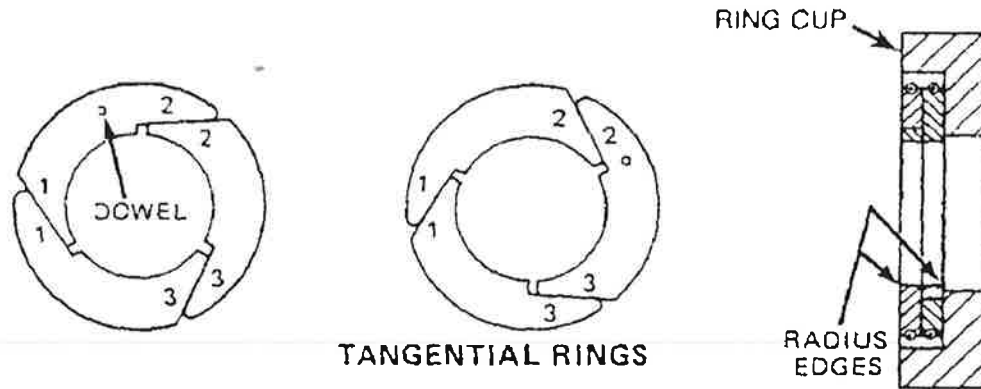


Figure 4-20. Single-Acting TFE Ring with Metallic Back-Up





**DOUBLE ACTING RINGS - ONE PAIR OF RINGS CONSISTS OF TWO TANGENTIAL CUT RINGS (WITH SPRINGS).**

Figure 4-21. Double-Acting Sealing Rings, Tangentially Cut

Clearance should be as listed in Table 4-4. *If the measured clearance is outside of the limits shown, refer the problem to the Dresser-Rand Gas Field Compressors Customer Service Group Tulsa, OK before remachining either packing rings or flange cups.*

Table 4-4. Packing Clearances

Ring Material	Axial Clearance Cast-Iron Cups Inch (mm)	Axial Clearance Steel Cups Inch (mm)	Maximum Radial Clearance Inch (mm)
Filled TFE	0.011 - 0.015 (0.28 - 0.38)	0.020 - 0.024 (0.51 - 0.61)	0.060 (1.5)

**NOTE**

The total radial clearance for the metallic back-up rings used with 16A11 single-acting sealing rings should be 0.010-inch (0.25 mm) maximum without regard to piston rod diameter.

**4-13.2. Packing Gasket**

Next in importance to the packing rings is the end gasket. Keep gasket surfaces clean and dry. No matter how perfectly the packing rings seal around the rod, if the end gasket leaks, the pressure forces the gas to bypass the rings by leaking around the case into the area between the case and the bore and then to the atmosphere. The packing flange stud nuts must be tightened evenly to ensure a proper seal of the gasket at the front end of the packing and to ensure closure of the ground joints on the packing. The packing rings have been given sufficient side clearance so that normal tightening will not pinch the rings in their grooves.

After a short period of operation, soft gaskets should be retightened to take up any additional deformation caused by the working pressure on the packing.

Spare gaskets should be carried in stock and a new gasket installed each time a packing is disassembled. This prevents forced shutdowns due to leaks occurring after the cylinder is pressurized.

### 4-13.3. Packing Cases

The cases are made up of cup-like sections. The joints are ground or lapped. Each contacting surface must be cleaned of dirt and lint and inspected for scratches and burrs before assembling. The mating surfaces must occasionally be lapped to maintain a tight seal. To do this, lap the cup to a surface plate after making sure that the surface plate is in good condition. On packing assemblies that are designed for internal water cooling, small O-rings are used between the cups. See the instructions, which follow concerning proper installation of these seal rings.

### 4-13.4. Installing the Packing

The packing should not be installed until the unit is ready to start, since the rings may corrode the piston rod where they rest on it. The cup sections are held together by tie rods which are screwed into tapped holes in the nose piece (end cup) of the packing, and are held on the outer end by nuts on the face of the flange. Become acquainted with the construction of the packing you are about to install. Learn how it will go into the cylinder, and know the proper location of each cup and ring set. Note the location of vent cups, oil cups and cooling water cups and gaskets, if used. Pay particular attention to the rings located in each cup and know how they are assembled and which side faces the pressure. Before any packing is taken apart, it is recommended that each cup and the flange be stamped in numerical sequence so they can be reassembled in their original positions.

1. If the compressor piston and rod have previously been installed in the cylinder, remove the locking dowel (if so fitted), disconnect the piston rod from the crosshead and move the crosshead away from the rod. If the oil scraper packing was previously installed, disassemble and remove the scraper rings as described in instructions, which follow.

### **⚠ WARNING**

**All precautionary measures specified by the Occupational Safety and Health Act of 1970 (OSHA) must be complied with when storing, handling, or using solvents.**

2. After marking the outside of the packing cups (on a non-critical surface) in numerical sequence as discussed previously, disassemble the packing cups and rings; be careful not to lose any gaskets, ring segments or garter springs. Lay the packing components on a clean surface in the order removed. Clean all parts with a safety solvent. Be sure that there is no dirt, chips or other foreign matter in the oil or vent passages that can be carried into the packing during operation or obstruct the flow of oil into the packing.
3. Thoroughly clean the piston rod and packing cavity in the frame end of the cylinder. Make certain that the piston rod is not scratched, nicked or otherwise marred where it will operate in the packing.

4. On older cylinders where an external packing cooling sleeve is used, the sleeve should be removed, inspected and flushed out whenever the packing is being serviced. The sleeve is removed as follows:
  - A. Remove the packing following the reverse of the installation procedure.
  - B. Disconnect the cooling water piping and remove the two clamps which attach the sleeve to the cylinder.
  - C. The sleeve can now be removed and inspected.
  - D. Flush the sleeve with clean water for several minutes. Dry the sleeve and replace it into the cylinder.
  - E. Reconnect the cooling water piping and turn on the cooling water. Check for leaks.
5. The packing cups should be disassembled and the rings taken apart when the packing is installed (this also applies when the packing is being removed or when it is necessary to pull the piston rod). It is not a recommended practice to attempt to slide the packing rings over the end of the piston rod, unless an entering sleeve is used, because the rod threads can nick or otherwise damage the rings.
6. New packings come assembled with the correct type of rings in their proper grooves and in proper relation to one another. All rings must be reassembled in their original positions or they will not function correctly. Refer to the previous instructions in Paragraph 4-13.
7. Slide the end cup (or nose cone) over the end of the piston rod and assemble its packing ring(s) over the rod by first fastening the garter spring around the rod and then inserting the ring segments, one at a time, under the spring. Be sure the rings are assembled exactly in their original positions with all segments in correct relation to each other and with the correct side facing the pressure. Be sure dowels and dowel holes are lined up between ring pairs; then, lubricate the rings generously with oil and slide them into their cups.
8. Continue with each packing cup and ring arrangement in sequence, sliding the cups together over the tie rods. Slide the flange into position and tighten the tie rod nuts. Be certain all of the cups are evenly centered around the piston rod.

### NOTE

For packings having O-rings between the cups, as is the case with water-cooled packing assemblies, be sure that the O-rings are correctly located in their grooves before tightening the tie rod nuts. A thin coating of grease on the O-rings aids in keeping them in the grooves prior to tightening the assembly.

As the O-rings can be easily damaged, it is a good practice to carry sufficient spare sets and to replace them each time the packing is dismantled.

9. Make certain the gasket on the end cup is in good condition and clean; then, oil the rod (if lubricated packing is being used) and slide the packing assembly into place in the frame end of the cylinder. Center the packing with respect to the piston rod and then assemble and tighten the packing flange stud nuts evenly to assure the end gasket is evenly compressed. If this gasket is not properly seated, leakage can occur around the end cup.

10. Recheck the gap between the piston rod and packing flange at several points around the circumference of the rod; the possibility of the rod dropping slightly because of piston ring wear must be given due consideration.

### CAUTION

**Should the rod contact the packing flange or cups during operation, damage to the rod is almost certain to result.**

11. The packing rings are free to float in their cups (assuming they have proper side clearance) regardless of stud tightening forces and the packing cups are designed to transmit uniform stud pressure through the joints without deflection. Like any gasketed joints, the packing stud nuts must be periodically tightened.
12. Install the oil scraper rings per Paragraph 4-14 and connect the piston rod at the crosshead per Paragraph 4-10.
13. When the machine is started, oil the packing rings and piston rod generously until the rings wear in. The packing may leak slightly while creating a satisfactory fit with the rod; however, the packing should not blow oil profusely during break-in. Should severe leakage (blowing) occur, the compressor must be immediately shut down and the packing dismantled to determine the cause. Abnormal leakage can also be caused by dirt or chips cutting the rings, an improper grade (or too much) lubricating oil in the sump, or inadequate side clearance of the rings in their cups.

#### 4-13.5. Packing Operation and Maintenance

After installing a new packing or set of renewal rings, start the compressor up with no load in the same manner as breaking in a new unit. Feed two or three times the usual amount of oil to the packing while it is wearing in. The oil that works out along the rod, or through the packing vent, should be checked frequently.

If the oil remains clear, it is a good indication that the packing is wearing in properly. During break-in of higher pressure packings (over 1000 PSIG or 6900 kPa), the oil normally will become darker and show some wear particles; however, the oil should not become black. Should the oil become black (indicating premature wear), or should blow-by be excessive, the cause may be a too-rapid increase in the load or pressure on the packing. Often, by reducing the load slightly and running for a short time, the oil will clear up to the point where the load can be increased again.

Because there are many variables (such as temperature, pressure, type of lubricant, material, gases being handled, etc.), there are no hard and fast rules for allowable rate of increase in pressure while breaking in a new packing. With filled Teflon® packing rings, the break-in time is normally much shorter than with metallic rings. Often, the break-in time with this ring material is a matter of minutes, and the load may be increased rapidly. Watch piston rod and packing temperatures carefully to avoid excessive heat buildup in the packing during rapid break-in.

During operation, the packing leakage may become progressively worse over a period of time. This indicates the packing is faulty and it should be inspected as soon as possible. Operation of the unit with excessive packing leakage will result in abnormal wear of the packing rings or piston rods.

#### 4-13.6. Inspecting the Packing

Periodically, the packing should be removed for cleaning and inspection. In cleaning packing rings, wire edges may be found around the bore of the rings if considerable wear has occurred. Remove these wire edges with a file. However, do not break corners where any two surfaces of a packing ring match. In removing

the packing for cleaning, take care to avoid damage to the gasket or any surfaces that make pressure tight joints. Do not use a chisel or sharp instrument to open any joint (between packing cups) and do not disturb the bore of the rings except to remove the wire edges. Wash the springs clean of carbon and sludge. If they have lost their tension, replace them. Observe the clearance between the ends of the segments of the wearing rings. As long as some clearance is present, the rings may be used. However, when the rings have worn to the point where the ends butt, they should be replaced.

### 4-13.7. Replacing the Packing

In replacing the piston rod packing, take care to tighten the flange nuts evenly, while checking with feelers in the space between the rod and the packing flange. Make sure the clearance is equal all the way around the rod. Make sure the rod packing flange does not touch the piston rod, as the rod and the packing can be seriously damaged. When ordering parts or inquiring for additional information regarding packing, give the serial number stamped on the end of the case, along with the cylinder size and serial number.

## 4-14. PISTON ROD OIL SCRAPER RINGS

A stuffer is bolted to the frame end of the cylinder yoke; it contains a set of oil scraper rings, with flange, and prevents frame oil from being carried out of the frame along the piston rod. The rings also reduce the possibility of cylinder gases or cylinder lubricating oil entering the frame and possibly contaminating the frame lubricating oil.

Current stuffer and oil scraper ring arrangements are illustrated in Figure 4-22. Some distance pieces are equipped with a set of double-acting (Type BD) seal rings located in the gland closest to the cylinder. For those applications requiring a purged distance piece (2) standard sets of (3) 3RWS rings are used. This helps to seal the distance piece.

### CAUTION

**Metallic oil scraper rings must be disassembled and the rings taken apart when they are being removed or installed. Do not attempt to slide the rings over the end of the piston rod because the threads can nick the rings and permanently damage them.**

Before starting for the first time, wipe out the stuffers and clean the piston rods. Take care to keep a smooth bearing on the rod, as nicks or dents in the rings or scores on the rod will prevent a tight seal.

Oil scraper rings normally require little attention except for periodic cleaning, as determined by the operating conditions. Inspect the rings for wear by checking the end clearance after slipping the rings over a mandrel the same diameter as the piston rod. When the rings have worn sufficiently to butt the ends, it is best to replace them.

Renewal oil scraper rings are furnished in sets. The ring segments are usually numbered and adjacent segments must match. With the current design shown in Figure 4-22, the radially cut grooves on the scraper rings should face the cylinder and the flat faces of the rings should face the crosshead. The packing rings can face either direction.

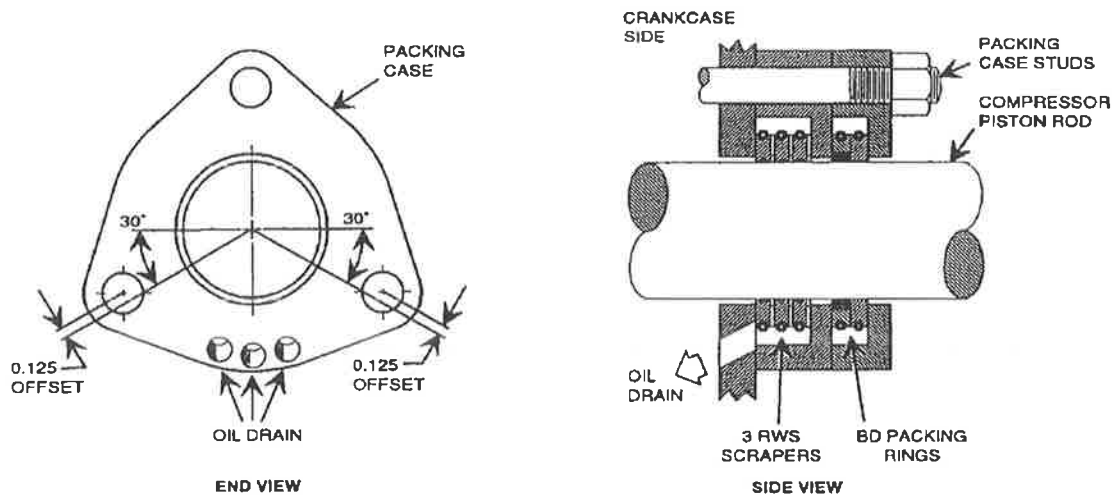


Figure 4-22. Piston Rod Oil Scraper Packing

Use the following steps to install replacement oil scraper rings in the unit:

1. Unscrew the piston rod from the crosshead, back the crosshead away from the rod and remove the stuffer from the yoke.

### ⚠ WARNING

All precautionary measures specified by the Occupational Safety and Health Act of 1970 (OSHA) must be complied with when storing, handling, or using solvents.

2. Disassemble the rings and lay the parts on a clean surface. Note the identification marking on each segment of each ring. Clean the parts thoroughly with a safety solvent.
3. Make certain that the piston rod is clean and free of nicks or burrs; if found, these should be carefully removed with a file and the rod polished using a fine emery cloth.
4. Clean the stuffer thoroughly and install it in the yoke. Be sure a gasket is placed between the stuffer and yoke mounting surfaces. Bolt the stuffer securely in place.
5. Place the ring flange on the piston rod and then assemble the oil scraper rings over the rod; the flat sides of the rings face the crosshead. First fasten the garter springs around the rod, then place the ring segments under the springs, making sure to match the segments according to the letters or numbers stamped on them.
6. Move the flange into position over the rings. The flange is designed to provide 0.002 to 0.004 inch (0.05 to 0.10 mm) total end clearance for the scraper rings. Check this clearance before securing the flange. If the clearance is insufficient for the rings to "float" on the rod, they will not function properly. Make sure the drain holes in the flange are at the bottom, then attach the flange to the stuffer; tighten the flange capscrews evenly. Check to be sure the flange is centered around the

piston rod; avoid any possibility of the rod touching the flange or stuffer as the rod, flange and rings may be damaged if this happens.

7. Liberally oil the scraper rings before starting the compressor when new rings have been installed. The oil from within the frame will then keep the rings lubricated during normal operation and subsequent starts.

**WARNING**

Before barring the unit over, the operator must ensure that the driver will not start—either by grounding the ignition and closing the fuel gas valve on engine driven units—or by ensuring that the power cannot be turned on with electric motor driven units. Failure to heed this WARNING can result in a fatal accident if the unit rolls over unexpectedly.

**SERVICE NOTE**

When the compressor is shut down for a long period and the piston rod packing and the oil scraper rings are not removed, bar over the compressor once every 24 hours to distribute any oil held in the packing and to prevent localized corrosion of the rods.

**4-15. BALANCE CYLINDER (If Used)**

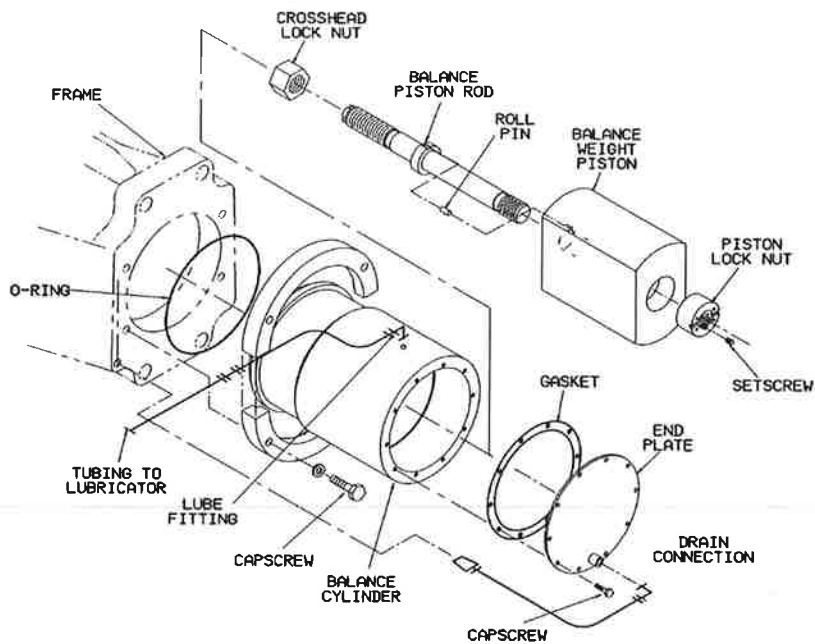


Figure 4-23. Balance Cylinder

A balance cylinder (Figure 4-23) is supplied on those compressors where less than a full complement of cylinders is required (for example, a four-throw unit using only three cylinders). The balance cylinder mounts directly on the frame extension and utilizes a piston rod and balance piston that are similar to a conventional compressor piston and rod for disassembly and assembly purposes.

To remove the balance cylinder, disconnect lube supply and drain piping. Take out the capscrews that hold the end cover in place, then remove the cover to expose the cylinder bore. Unscrew the balance piston rod from the crosshead and pull the piston and rod out through the bore. Take off the cylinder to frame stud nuts and remove the cylinder. Replacement of the balance cylinder is the reverse of the removal steps.

### 4-16. COMPRESSOR VALVES

The "PF" valve, a high speed plate valve of Dresser-Rand design, is used as the standard valve in HOS cylinders. These instructions cover only the PF valve; if other valves are used, supplemental instructions must be consulted. The valve is furnished in two styles; one style has a metal valve plate with two damping plates that is assembled as shown in Figures 4-24 and 4-25. The other style has a plastic valve plate with one damping plate as shown in Figures 4-26 and 4-27. Both valve styles contain a seat, stop plate, damping plate(s), ring guide, damping springs, closing springs and valve plate. The valve is held together by a center stud and nut arrangement. A gasket is used under the stop plate on inlet valves and the valve seat on discharge valves where they seat in the cylinder gas passage, preventing gas leakage past the valve.

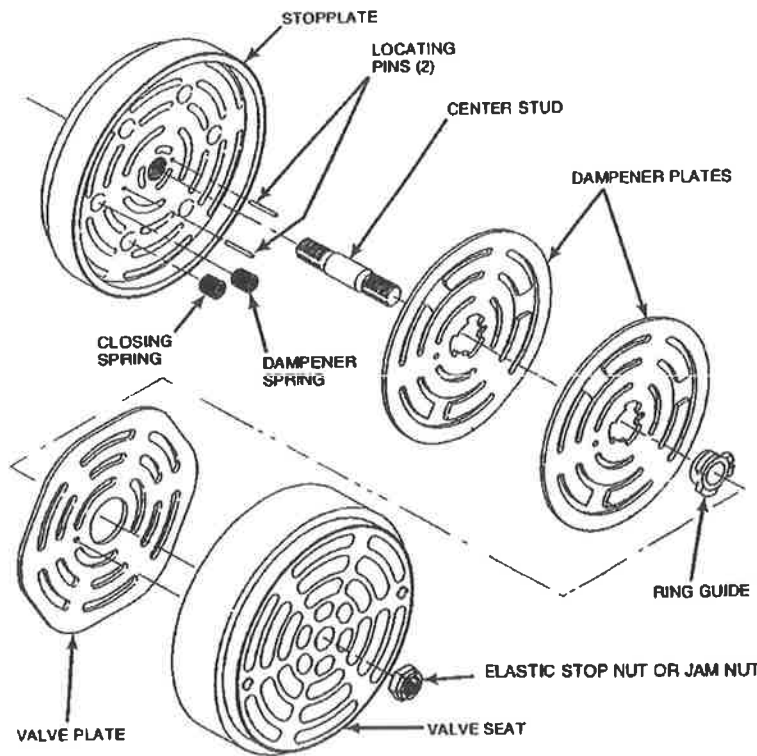


Figure 4-24. Typical "PF" Inlet Valve With Metal Valve Plate



#### 4-16.1. Description of Operation

A compressor valve acts as a check valve in the inlet and discharge passages to the cylinder bore. The inlet valve allows the gas to enter the cylinder on the suction stroke and then closes to prevent back flow of the gas into the inlet gas passage on the discharge stroke. The discharge valve opens to allow gas to leave the cylinder on the discharge stroke and then closes to prevent the gas in the discharge passage from re-entering the cylinder on the suction stroke.

Compressor valves are opened by differential pressure across the valve. The damping and valve plates move off their seat and are guided into the stop plate recess by the guide ring when opening. Damping springs and damping plate(s) prevent slamming of the valve plate against the valve stop plate when the valve opens. As the piston nears the end of its stroke, pressure across the valve starts to equalize. At this point, the springs start to move the damping plate(s) away from stop plate and the valve plate toward the seat. This is done to prevent the parts from slamming against the seat as the piston changes its direction. If slamming were allowed to happen, severe damage would result to the valve. A combination of spring load and differential pressure will hold the inlet valve closed on the discharge stroke and the discharge valve closed on the suction stroke.

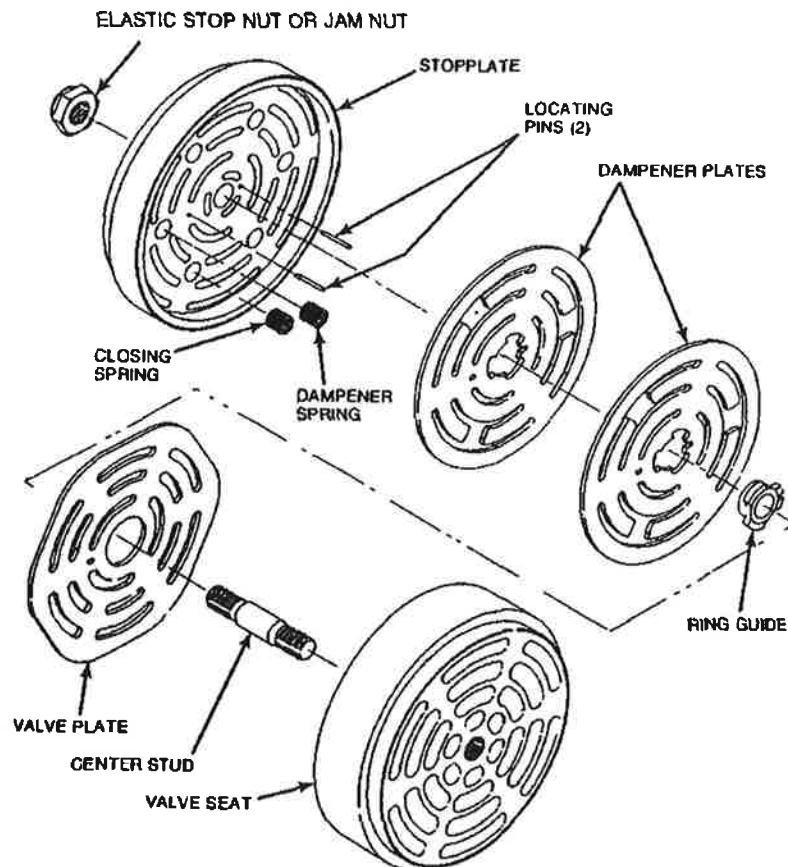


Figure 4-25. Typical "PF" Discharge Valve with Metal Valve Plate

## 4-16.2. Valve Maintenance Recommendations

1. To obtain maximum efficiency from a compressor cylinder, the inlet and discharge valves must be clean and tight. The valves and cylinder gas passages must be periodically examined and thoroughly cleaned wherever dirt is evident. Operating experience will dictate both the length of time between valve inspections and the valve maintenance cycle. At start-up, check the valves during break-in at least once, then one week after start-up, or more frequently if the gas being handled is known to be dirty. If the valves are found to be particularly dirty, locate and eliminate the cause. See item 2 for a suggested MINIMUM maintenance schedule.
2. We recommend the following valve inspection and maintenance schedule as a MINIMUM:
  - Prior to initial start-up and EVERY TIME valve or unloader maintenance is performed.
  - At least ONCE during the break-in period.
  - One week after start-up (including after valve or unloader maintenance or after overhauls).
  - Once a month thereafter for three months.
  - Once every three months thereafter for a full year.
  - Once each year thereafter, or as conditions dictate.
3. The center setscrews used with unloaders, and all other valve fasteners, particularly the stud nuts that secure the valve cover, MUST be properly tightened to the torque values given in this form. DO NOT USE AN IMPACT WRENCH ON VALVE FASTENERS.

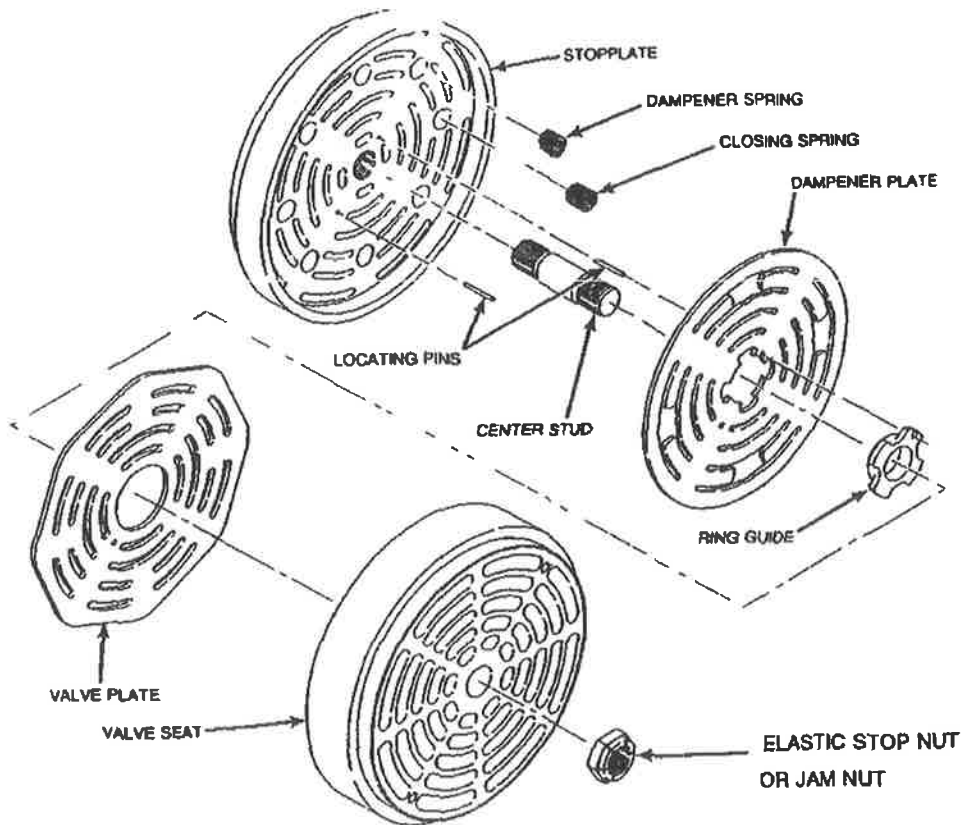


Figure 4-26. Typical "PF" Inlet Valve with Plastic Valve Plate

4. Never attempt to tighten fasteners on a compressor cylinder, including the valve or unloader setscrews, while the compressor is running or with the cylinder pressurized. This practice is extremely hazardous, and can result in a life-threatening accident should a stud or bolt break during the tightening process.
5. Always make sure there is no residual gas pressure in the cylinder bore or passages before removing valve or unloader covers.
6. Venting of hazardous gases must be performed in accordance with established safety practices at the installation site.
7. The importance of keeping accurate valve maintenance records cannot be overemphasized. Record all valve failures, the cylinder and location on that cylinder, the type of damage and any other data that may be helpful in finding a trend.

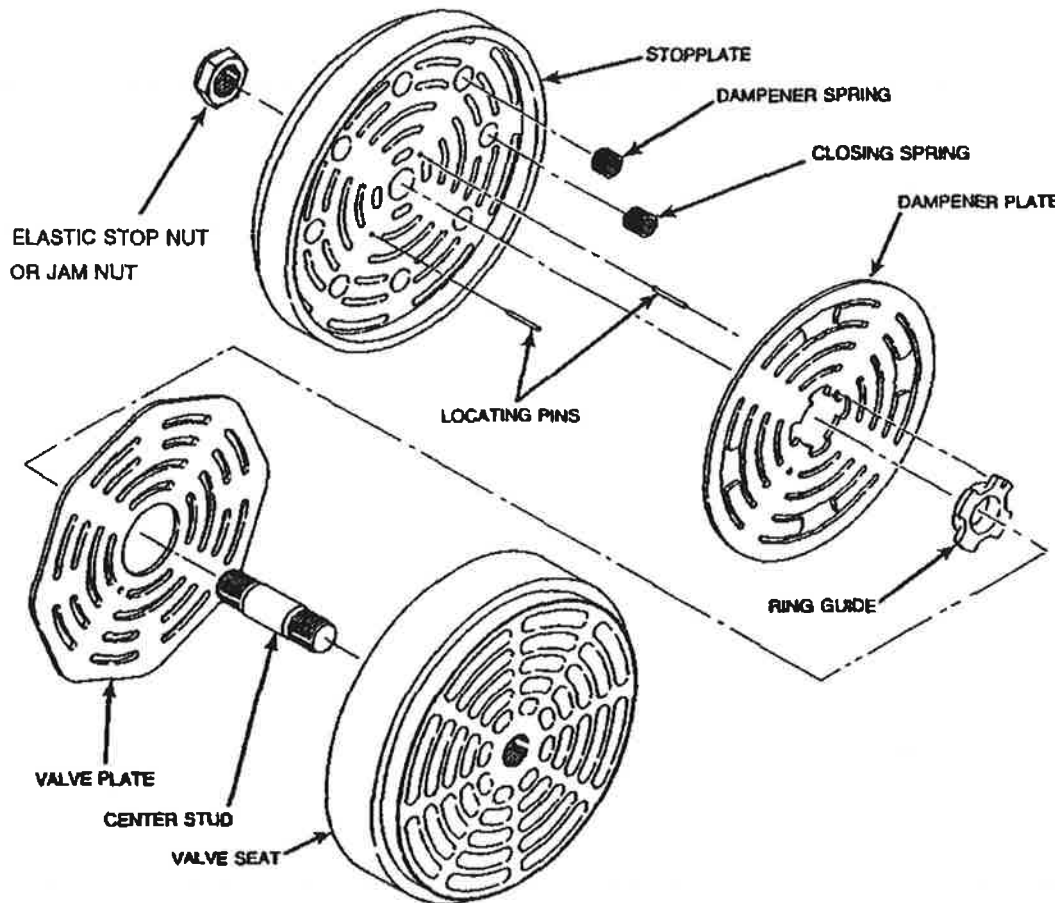


Figure 4-27. Typical "PF" Discharge Valve with Plastic Valve Plate

8. To eliminate dirt found in the compressor valves, a suitable intake filter or scrubber should be installed and properly maintained. Experience will dictate the filter or scrubber maintenance cycle.

9. Cylinder lube oil in excess of the amount required to properly lubricate the cylinder bore and valves is detrimental to valve life. The oil feed rate of the cylinder lubricator (with pump-to-point systems) can be reduced to eliminate excess lubrication based on the condition of the cylinder gas passages, valves and cylinder bore. On inspection, the valve should have a greasy appearance, but not have oil droplets showing. Shortened valve life often results from using an oil with improper viscosity or poor quality, or delivery at the improper feed rate. Recommendations for selecting a cylinder lubricating oil are given in CHAPTER 2, LUBRICATION; these recommendations should be reviewed with a reputable oil supplier to determine the best oil for a particular application.
10. All compressor valves should be inspected for leakage (which may result in abnormally high temperatures). In addition, the cylinder cooling water system (if used) should be examined for general cleanliness and obstructions to ensure the proper quantity of coolant at the required temperature is available. Periodic cleaning of the cylinder water passages may be required.
11. Liquids in the gas stream can wash or dilute cylinder bore lubricating oils, causing rapid wear and early failure of the valve (and cylinder) parts. A slug of liquid can cause a failure of the valve channels or plates or, in severe cases, the valve seat. Some "wetness" in the gas stream often can be dealt with by the selection of a suitable lubricating oil. With very wet applications, adequate separators should be located close to the cylinders. Also, it is important that the cylinder inlet piping be arranged without low spots where liquid can accumulate.
12. Mark or tag valves with the following minimum information as they are being removed from the cylinder. This information will be useful when troubleshooting valve problems and will help prevent the intermixing of valve parts, when more than one valve is disassembled.
  - Compressor Serial Number....
  - Cylinder Serial Number....
  - Inlet or Discharge Valve....
  - Cylinder location - Frame or Outer end....
  - Hours of Operation.
13. The reconditioning procedures given in these instructions are valid only when genuine Dresser-Rand parts are used.
14. Carefully check the part number of new parts against those in the parts list.
15. Never change valve lift.
16. The valve seat may be reconditioned following instructions later in this chapter.
17. A new valve plate must be used if the valve seat has been reconditioned.
18. Never turn the valve or damping plate(s) over; always replace them and recondition the seat.
19. When handling assemblies or parts, take care not to contaminate the items.

**⚠ WARNING**

Observe the safety precautions (Paragraph 4-2) before attempting to remove a compressor valve. It is particularly important that **ALL PRESSURE** is released from the cylinder passages and piping before pulling valve covers. **CAREFULLY CRACKING OPEN** drain valves on inlet and discharge manifolds is a good method to determine if any pressure exists in the cylinder bore, cylinder passages and piping; **INJURY TO PERSONNEL CAN OCCUR IF THESE PRECAUTIONS ARE NOT STRICTLY OBSERVED**. Whenever compressor valves are removed, it is extremely important that the inlet and discharge valves be correctly reinstalled in the cylinder. Incorrect assembly can cause an extremely hazardous condition which can result in severe damage to the compressor and **INJURY OR DEATH TO THE OPERATING PERSONNEL**.

**4-16.3. Removing the Valves - O-Ring Valve Cover**

The current standard valve cover design used with HOS cylinders is the O-ring cover design, illustrated in Figure 4-28. *Only the O-ring cover design is covered by these instructions.*

**⚠ WARNING**

With the O-ring body seal used on this type valve cover, any pressure that may be left in the cylinder will not be released when the cover nuts are loosened, but will remain under the cover trapped by the O-ring. To prevent the possibility of the valve cover being "blown off" by residual pressure when the cover nuts are removed, two longer studs are required to permit the safe removal of the cover. These studs are either present (they are double-nutted if factory supplied) or should be fabricated at the site. **FAILURE TO OBSERVE THE FOLLOWING VALVE REMOVAL STEPS CLOSELY CAN RESULT IN POSSIBLE PROPERTY DAMAGE, INJURY TO THE MAINTENANCE PERSONNEL OR DEATH.**

1. Mark or tag the valves and valve holes as the valves are removed to ensure that they are returned to their original locations.
2. Locate the two longer studs; these are diametrically opposed across the valve cover bolt pattern. If such studs are not installed, fabricate two studs and install them (with nuts) 180 degrees apart before removing or loosening any other stud nuts. Evenly loosen the valve cover stud nuts; note that two nuts are used on the two longer factory-installed studs used with each valve cover.
3. Remove only those nuts on the short valve cover studs. At this point, the nuts on the long studs are securing the valve cover.
4. Equally loosen the nuts on the long studs two turns at a time. As the stud nuts are loosened, it may be necessary to tighten down the valve cover jackscrews (if equipped) or to carefully pry under the valve cover to keep the cover in contact with the stud nuts. (This will prevent sudden loosening or blowing off of the valve cover when the O-ring breaks free of the valve passage, caused by any residual pressure.) As the O-ring is pulled free of the valve passage, any residual pressure will be safely vented.

5. Remove the valve cover.

### SERVICE NOTE

A retaining setscrew in the side of the valve cage is used to hold the valve and cage in a valve hole located in the bottom half of the cylinder. However, care still must be exercised when removing the valve cover so that the valve does not fall out should the setscrew not hold.

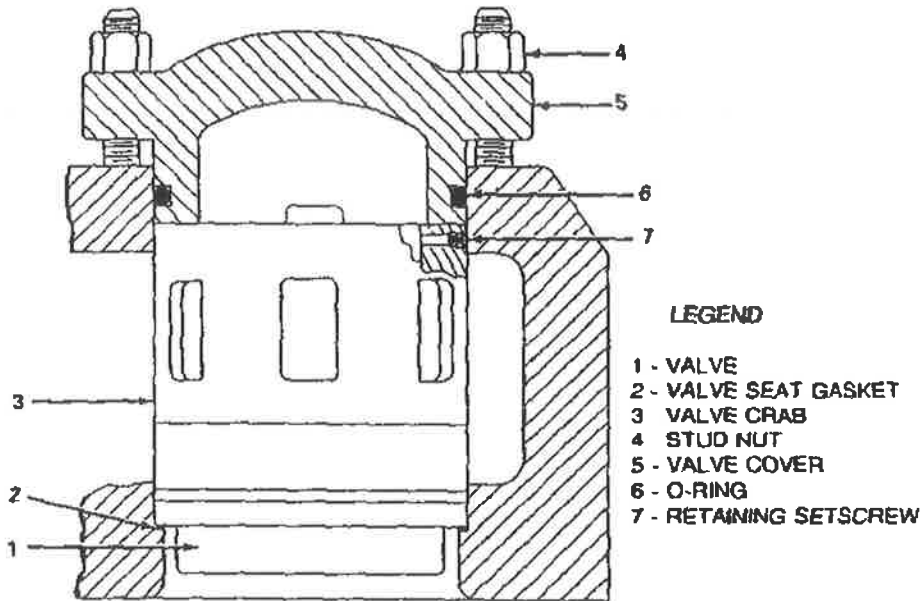


Figure 4-28. O-Ring Seal Type Valve Cover Arrangement

6. Larger valves have two tapped holes in the discharge seat, or inlet stop plate, on the face toward the cylinder bore. To simplify valve removal when the valve is located in the bottom half of the cylinder, first remove the top valve that is located 180 degrees opposite the bottom valve being removed; then, working through the top valve port, (with the compressor piston must be positioned so that it does not interfere with this operation) screw a threaded rod into the tapped hole in the bottom valve. The valve and cage assembly then can be supported from above while the valve cover and valve is removed.
7. Loosen the retaining setscrew from any valve cage so equipped, then remove the valve cage and valve from the cylinder. Remove the valve seat gasket that is located under the valve. This gasket should not be reused; install a new gasket when installing the valve. Most valves are attached to the valve cage with two capscrews or machinescrews to facilitate handling; remove these fasteners to separate.

### SERVICE NOTE

If the compressor valve is stuck in the cylinder, it can be jarred free by striking edgewise on the valve crab with a wood block or soft metal bar (to prevent damage to the cage or valve). Do not use a hammer on the cage.

#### 4-16.4 Disassembling & Servicing the Valve

### ▲ CAUTION

Care must be taken when disassembling these valves to ensure that the damping and valve plate closing springs do not become mixed. Failure to follow this caution will result in incorrect loading of the various plates, resulting in premature valve failure. Even when the valves are of the same type (inlet or discharge) and of the same size, the components of the various valves must not be mixed. This is because each valve has established its own wear pattern and sealing surface which will not function in another valve. Failure to follow this caution will result in valve leakage and premature valve failure.

1. Place the valve in a valve holder. (Figure 4-29 shows a suggested valve holder.)

### ▲ CAUTION

If the valve must be held in a vise, do not clamp the valve tightly enough to cause distortion. Distorting the valve will render it useless.

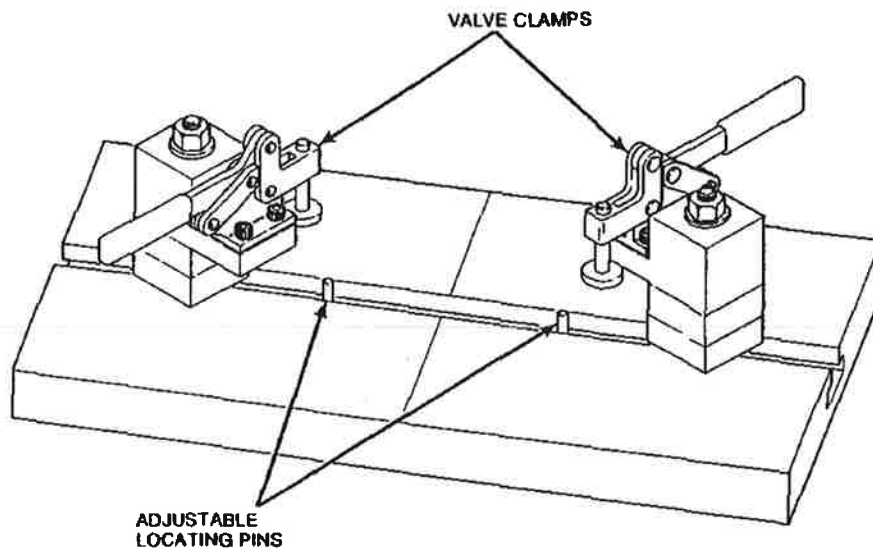


Figure 4-29. Suggested Valve Holder

## Maintenance

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2. Remove the stud nut that fastens the valve together. DO NOT allow the stop plate to turn in relation to the valve seat; to do so may shear the locating pins.

### NOTE

The closing and damping springs can be of the same height and wire diameter (load), but more often they will be of different height and wire diameter, resulting in different loads.

3. Very carefully, separate the stop plate and valve seat. Note the position of all valve internals; do not allow them to become mixed. Remove the closing springs and place them in a separate location; do the same with the damping springs.

### ⚠ WARNING

**All precautionary measures specified by the Occupational Safety and Health Act of 190 (OSHA) must be complied with when storing, handling or using solvents.**

4. Clean the parts. (Soaking the valve parts overnight in safety solvent followed by a stiff brushing or light scraping will aid in the removal of carbon.) Brush the parts with a soft wire brush to remove deposits, but use a soft bristle brush on all seating surfaces.
5. Rinse the parts in clean solvent; dry thoroughly using clean, dry compressed air.
6. Inspect the valve and damping plate(s) for cracks, nicks, warpage, wear steps, leakage paths and other signs of defects. On the valve plate there will be annular rings worn in by the valve seat, these are normal. [Replace the valve plate if the ring depth is greater than 0.010 inch (0.25 mm) on plastic plates OR 0.005 inch (0.13 mm) for metal plates.] Check the rings for uniformity of contact; any dull or uneven contact is an indication of improper seating. Do not grind or invert valve plates to obtain a new seating surface; replace them.
7. Examine the valve seat for cracks, nicks, burrs, scoring, steps, leakage paths and other signs of defects. The valve plate seating area (rings) on the valve seat should be very bright and evenly polished. Check the rings for uniformity of contact; any dull or uneven contact is an indication of improper seating.
8. Valve seats can be machined to correct for wear or minor defects to the seating surfaces. Refacing operations are described in later instructions. Excessively worn or damaged seats must be replaced.

### ⚠ CAUTION

**When rebuilding a valve, always renew the seating surfaces. That is, provide a new valve plate when a new or reconditioned valve seat is used. Likewise, when a new valve plate is used a new or refaced valve seat must be provided. Failure to follow this caution will result in leakage and early valve failure.**



9. Check valve springs for cracks, pits or set (set is determined by measuring free height of a used spring against a new one). Also, check for weakness by comparing the used spring against a new one with the same part number.
10. Examine the stop plate for wear and damage.

#### 4-16.5. Refacing Valve Seats

Valve seats which have become worn or damaged can be refaced provided that certain dimensional limits are not exceeded; these limits are given in subsequent instructions.

On discharge valves, the center stud is screwed into the valve seat. Around the center stud shank, there is a recess in the seat (see Figure 4-30) which is approximately 0.080 inch (2 mm) larger in diameter than the shank diameter. This recess permits machining of the valve seat without removing the center stud. In some machining methods, it may be necessary to remove the center stud.

1. To remove the center stud, heat the valve to between 500° and 600°F (260° to 352°C); remove the stud while hot.
2. Using Loctite® "Chisel Gasket Remover", spray the residue left by the previously used Loctite® and wipe it off.

*A valve seat can be machined as indicated below without affecting the valve's performance (see Figure 4-30):*

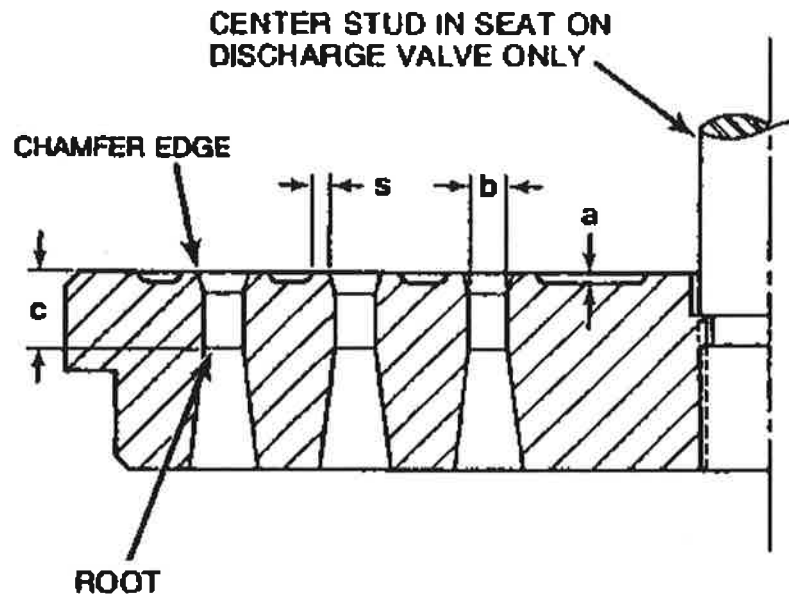


Figure 4-30. Valve Seat Rework Dimensions

TP-4265-A

## Maintenance

If the valve's outside diameter is less than 3 inches (76 mm), the seat rib root depth (c) of the innermost port cannot be less than 0.100 inch (2.54 mm). For valves with an outside diameter larger than 3 inches (76 mm), the rib root depth of the innermost port cannot be less than 0.188 inch (4.78 mm).

### ⚠ CAUTION

**The rib root depth (c) of the valve seat must not be machined to maintain the minimum depth. Do not increase diameter of ports (b). Machining the rib will weaken the valve seat. Also, be certain that any facing extends over the entire seating surface.**

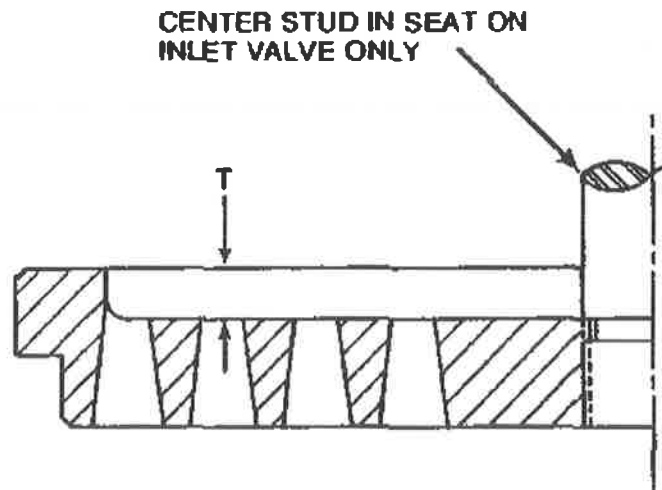
When facing the valve seat, the land width (s) is to be maintained at 0.025 to 0.050 inch (0.63 to 1.2 mm). If the land width exceeds this value, the mud grooves between ports (b) must be machined to obtain the original land width. In addition, the depth of the mud grooves (a) should be maintained at 0.031 inch (0.79 mm) and a full radius must be maintained where the mud groove meets the land. Moreover, a 0.005 to 0.015 inch (0.13 to 0.39 mm) chamfer edge must be maintained on each land.

#### 4-16.6. Reconditioning the Stop plate

Machining of the stop plate is usually not required during valve overhaul. If an inspection reveals minor damage to the stop plate, the defective part can be machined provided that certain dimensional limits are not exceeded; these limits are given in subsequent instructions.

### SERVICE NOTE

On suction valves, the center stud is screwed into the stop plate. In order to machine the counterbore, it may be necessary to remove the center stud.



TP-4266

Figure 4-31. Stop Plate Rework Dimensions

1. To remove the center stud heat the valve to between 500° and 600°F (260° to 352°C); remove the stud while hot.
2. Using Loctite® "Chisel Gasket Remover" spray the residue left by the previously used Loctite® and wipe it off.
3. If the locating pins are damaged, pull them out. If the locating pins cannot be pulled out, cut them off and drill out the remainder of the pin. Since the locating pins are held in by an interference fit, care must be taken not to drill the pin hole larger than its original diameter.

The stop plate can be reconditioned provided that the counterbore depth (T) is maintained (see Figure 4-31). If the counterbore depth is not maintained, the valve lift will be altered. The counterbore depth is equal to the guide ring height + 0.002 inch / - 0.000 inch (+0.05,-0.0 mm). Furthermore, spring hole depth must be maintained at original depth "0.010 inch ("0.26 mm), and the maximum removal from the stop plate is 0.031 inch (0.79 mm).

### 4-16.7. Assembling the Valve

#### SERVICE NOTE

When installing the center stud in the stop plate or seat, screw the stud in only until it is flush with back side of the stop plate or seat. Furthermore, some center studs have a tapped hole or a longer threaded section on one side. This side of the center stud does not screw into the seat or stop plate.

1. If the center stud was removed, apply a light coat of Loctite® primer "T" to the threaded area. Apply a few drops of Loctite® #272 (item 27240) threadlocker and screw the stud into the valve seat or stop plate.
2. If removed, reinstall the locating pins.
3. Place the stop plate on a clean, flat surface with the locating pins up.
4. Place the valve springs into the spring holes in the stop plate. Ensure the springs are inserted into the same holes from which they were removed. (The damping springs must contact the damping plate(s) and the closing springs must contact the valve plate.) If new springs are being installed, refer to the parts list for identification.
5. Reinstall the damping plate(s). If the used plate(s) are being installed, ensure that they are the plate(s) removed from that valve. In valves with a metal valve plate, the damping plate with the smaller diameter is placed next to the stop plate.
6. Install the valve plate. If the used plate is being reinstalled, ensure that its seating surface matches the valve seat.
7. Insert the ring guide, with its nose down.
8. Fit the valve seat to the stop plate; orient the locating pins with the holes in the valve seat. Clean the internal threads of the nut and external threads of the center bolt, then apply anaerobic adhesive primer to the threads and allow it to dry for 5 minutes. Apply Loctite® #242 threadlocker (two drops only) to the external threads and install the nut finger tight. On discharge valves, it is necessary to carefully turn the valve over and install the nut.

### SERVICE NOTE

Some valves utilize a self-locking nut. It is not necessary to use Loctite® with this type nut.

9. Place the valve in a holding fixture. A typical fixture is shown in Figure 4-29.

### ⚠ CAUTION

**When tightening the center stud nut in Step 10, DO NOT allow the stop plate to rotate with relation to the valve seat. If this is allowed to happen, it may shear the locating pins.**

10. Torque the center stud nut to 25,000 PSI (172 Mpa) pre-stress, following the tightening instructions in CHAPTER 5, GENERAL DATA & SPECIFICATIONS.
11. Check for free movement of the valve plate by pushing on it with a piece of plastic or wood that will not scratch the valve plate.
12. Examine the valve seating surface in the cylinder. If it is marred, proceed as in Paragraph 4-16.8, Steps 1-A and 1-B.

#### 4-16.8. Installing the Valves - O-Ring Valve Cover

When removing an inlet valve from a location where an unloading device is being used in conjunction with the valve as a means of capacity regulation, refer to the applicable unloader instructions before removing the valve.

### ⚠ WARNING

**Whenever compressor valves are removed, it is extremely important that the inlet and discharge valves be correctly installed in the cylinder. Incorrect placement of the inlet and discharge valves in some cylinders which have no provision for polarization can cause an extremely hazardous condition. INSTALLING AN INLET VALVE IN A DISCHARGE VALVE HOLE, OR INSTALLING A DISCHARGE VALVE UPSIDE DOWN, CAN CAUSE A LIFE-THREATENING EXPLOSION. The type "PF" valve is always placed in the cylinder with the valve center bolt and nut located AWAY from the cylinder bore. Fasten the valve or unloader cage to the valve, when possible, to ensure the valve is not reversed at installation. IF IN DOUBT as to whether a valve is inlet or discharge or as to which cylinder holes receive an inlet or discharge valve, CHECK WITH YOUR SUPERVISOR.**

1. Prior to installing the valve, check to see that the seating surfaces on the valve assembly, valve cover and in the cylinder valve hole are smooth and clean. If any evidence of defective seating surfaces is found, use the following steps to ensure proper valve installation:

- A. Place lapping compound on the gasket seating surface of the valve and place the valve in the valve hole without using the seat gasket. Lap the valve and valve hole gasket surfaces to obtain at least 95% contact area, as evidenced by bluing or an equivalent method.
  - B. Remove the valve and clean both it and cylinder valve hole thoroughly with soap and water to remove all traces of the lapping compound. Solvent will not remove the lapping compound no matter how clean the surface appears to the eye.
2. Install a new valve seat gasket, then install the valve and cage in the cylinder valve hole. This task is made easier if these parts are fastened together with machinescrews and lockwashers before installation. Be certain the valve seats firmly on the ledge in the cylinder and rests squarely on the valve seat gasket.

### SERVICE NOTE

Valves and cages must be returned to the same valve holes from which they were removed. The threaded rod used to facilitate handling large valves, as described previously in the valve removal procedure, also may be used to assist in valve and cage installation.

3. On the bottom half of the cylinder, the valve and cage assembly is held in the valve hole by a retainer, normally a setscrew through the side of the valve cage on this valve design. Install the setscrew with an Allen wrench to hold the valve and cage in place until the valve cover can be installed.
4. Place a new O-ring in the valve cover body groove. A light coat of a silicone lubricant or other lubricant compatible with the O-ring material and process applied on the O-ring will facilitate its entry into the cylinder valve hole.

### **⚠**WARNING

**Torquing of the valve cover stud nuts is critical. Under torquing will result in loss of sealing capacity between the valve seat gasket and the valve seat and the possible loosening of the valve cover during operation with attendant process gas release. Over torquing will result in excessive stresses and loads being imparted to the valve, valve cage and cylinder seating ledge. It is imperative that when using the "Tightening Requirements" instructions in CHAPTER 5, GENERAL DATA & SPECIFICATIONS, the proper prestress column in the chart is selected as follows: find the maximum allowable working pressure (MAWP) as stamped on the cylinder nameplate and compare the pressure to those listed to obtain the correct pre-stress for the fastener. Go to the column headers in the torque table; then move down the column to the correct fastener size to obtain the torque.**

5. Place the valve cover over the valve hole. Watch the cover O-ring as it enters the valve hole to be sure it is not rolled out of its groove. Install the stud nuts.

### **⚠ WARNING**

**Never tighten the valve cover stud nuts while the compressor is in operation or pressure exists within the cylinder. A life-threatening release of gas or explosion can occur if a stud breaks during the tightening operation.**

6. Tighten the valve cover stud nuts alternately across the bolt circle to ensure that the cover is drawn down squarely. We require that this tightening progress in stages rather than to the full torque on the initial tightening. The required torques are listed in the in CHAPTER 5, GENERAL DATA & SPECIFICATIONS.
7. After all of the valves are installed, bar the compressor through at least one complete revolution to be certain there is no interference between moving parts.
8. The compressor now may be started in the normal manner.
9. After the cylinder has reached operating temperature and pressure, shut down the compressor and relieve all pressure in the cylinders. Check the tightness of the valve cover stud nuts. Torque the valve cover stud nuts as described previously.

### **⚠ WARNING**

**Use extreme caution when checking the valve covers. The discharge valve cover can experience temperatures in excess of 250°F (121°C). Touching a valve cover with an unprotected hand can cause severe burns. We recommend the use of a contact thermometer for checking temperature and a stethoscope for checking noises.**

10. At regular and frequent intervals (as established by operating experience) check the valve covers for looseness by using a stethoscope on the valve cover to listen for pounding or knocking of the valve cage against the cover while the compressor is operating. Any pounding or knocking indicates that the valve is loose. A loose valve may break apart and drop into the cylinder bore, causing serious damage to the compressor.

#### **4-17. REGULATION DEVICES**

Regulation devices can be of two basic types: the inlet valve unloader or the clearance pocket (either fixed volume or variable volume). Instructions for both basic types of device follow. ***These instructions cover the basic, current type regulation devices.*** Some design differences are to be expected due to operating requirements and these variants will undoubtedly be encountered in the field from time to time. Refer any questions regarding unloaders or clearance pockets to your nearest Dresser-Rand service representative.

### **⚠ WARNING**

**Regulation devices when activated or adjusted affect the performance of the compressor. Unloading sequences not initially approved or reviewed can lead to overloads, non-reversal, overheating, and/or valve reliability problems. Consult with a Dresser-Rand representative if such unloading sequences have not been approved.**

An **unloader** is used on a compressor cylinder inlet valve to render the valve inoperative as a way of unloading the cylinder for starting, or to control capacity of the compressor during operation. A typical inlet valve unloader, mounted on the standard O-ring cover, is shown in Figure 4-32. Some later unloaders have the plunger attached directly to the push rod and no return spring is used.

This unloader is "direct acting"; that is, operating pressure is applied to the top of the actuating piston to unload the end of the cylinder containing an unloader. (Reverse-acting unloaders also are available from Dresser-Rand.) In its normal position (when there is no operating pressure applied to the top of the actuating piston) the piston spring located under the actuating piston forces the piston and piston rod upwards; the plunger return spring moves the plunger assembly away from the valve plates. With pressure applied to the top of the actuating piston, the piston spring and plunger return spring are compressed allowing the plunger legs to hold the valve plates away from the valve seat. With the inlet valve being held open by the unloader, the gas admitted to the compressor cylinder on the suction stroke passes freely back through the open inlet valve on the discharge stroke without being compressed. An indicator is fitted to the underside of the actuating piston. When the unloader is actuated (cylinder end unloaded) the pin will protrude from the clearance hole in the lower housing cover. When the unloader is in its normal position (cylinder end loaded) the indicator pin is retracted.

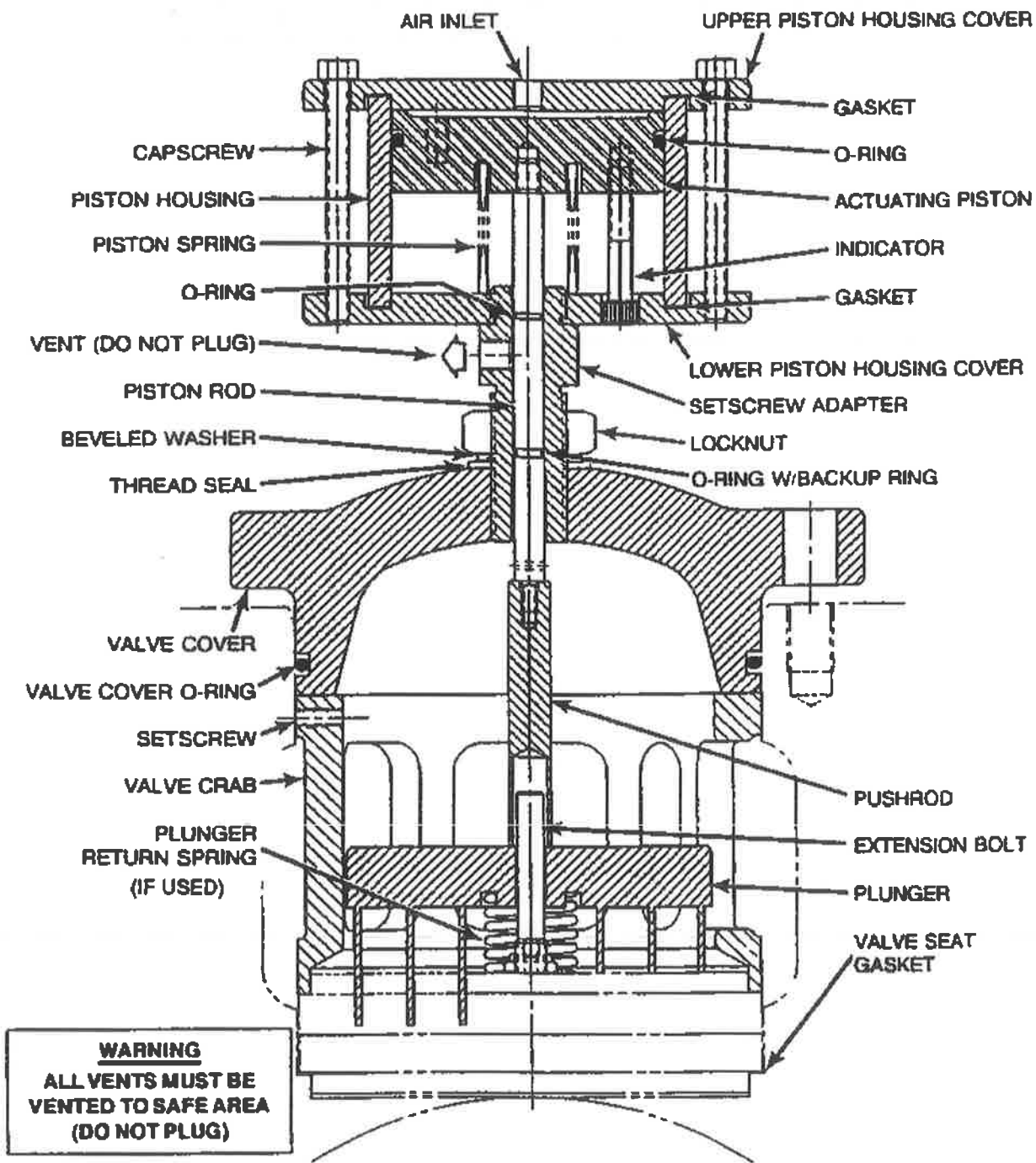
**Clearance pockets** (Paragraphs 4-17.2 and 4-17.3) are used on a compressor cylinder to add either a fixed volume, or a volume that is variable, to the cylinder's normal clearance volume. The pocket reduces the cylinder discharge capacity when it is in its normal deactivated (open) position. Fixed volume clearance pockets are operated by pneumatic pressure from an external source. **Variable volume pockets are generally operated manually by means of a handwheel or wrench, and may be adjusted ONLY when the machine is shut down.**

With a fixed volume, pneumatically-operated pocket, when operating pressure is applied to the top of the actuating piston the valve is forced closed, increasing the cylinder discharge capacity. In its normal position, with no operating pressure applied to the actuating piston, the clearance valve is held in the open position by the return spring. A variable volume pocket is positioned by turning the piston rod (to which is attached a piston riding in a cylinder) in a clockwise direction to reduce volume or a counterclockwise direction to increase volume.

In its open position, the clearance pocket adds the volume of the clearance pocket to the end of the cylinder in which it is installed. By adding volume to a cylinder end, a reduced quantity of gas is discharged during the compression stroke because part of the gas being compressed is passed into the added volume of the pocket instead of out through the discharge valves. On the expansion portion of the stroke, the gas in the added volume pocket expands into the cylinder. As with the inlet valve unloader, an indicator rod is extended with pneumatic pockets when the clearance valve is in the open (volume added) position. When the device is actuated, closing the clearance pocket valve (no volume added), the indicator rod is retracted. Manual pockets generally are equipped with some type of scale to allow determination of how much of the pocket is open.

### 4-17.1. Inlet Valve Unloaders

The inlet valve unloader is operated by pneumatic pressure applied to the top of an actuating piston. The actuating piston is located outside of the cylinder inlet passage in a separate housing, as shown in Figure 4-32, which is mounted on the setscrew adapter as shown in the illustration. The setscrew adapter is hollow so that actuating piston motion can be transmitted by the piston rod via a pushrod to a plunger mechanism located inside the valve cage. The plunger utilizes "legs" to force the valve plates off the valve seat to mechanically hold the inlet valve open.



TP-4524

Figure 4-32. Inlet Valve Unloader with O-Ring Valve Cover



An O-ring seal is installed around the actuating piston to seal against the leakage of operating pressure past the piston. Also, an O-ring and an O-ring/backup ring combination is installed on the piston rod to prevent process gas leakage past the rod. A vent is provided in the setscrew adapter, which prevents pressure buildup between the O-ring and O-ring/backup ring combination.

The internal components of the unloader assembly are held in the valve hole by the O-ring-type valve cover that presses against the valve cage. The internals consist of the valve cage, the plunger assembly, the return spring, the extension bolt, and the inlet valve. Some later models have the pushrod attached to the plunger and no plunger return spring is used. With these designs, the piston return spring pulls the pushrod and plunger away from the valve plates when operating pressure is released.

### **▲WARNING**

**If toxic, flammable, or narcotic gas is being compressed, observe applicable safety precautions.**

#### **A. Control and Vent Piping**

Operating pressure is applied to a 1/4-inch NPT tapped hole provided in the piston housing cover. Drawings are furnished to show the arrangement of factory supplied piping and controls. Recommended piping arrangements are usually furnished when the piping is being done by others.

### **▲WARNING**

**The vent opening in the setscrew adapter must always be left open to assure safe and effective operation of the unloader. When the process gas is toxic, flammable, or in any other way objectionable in the compressor building, the vent must be piped so that any leakage can be carried away. Vent tubing must not be less than 3/8-inch (9.5 mm) O.D. and, if combined with other vent systems, there must not be any back pressure or vacuum in this piping.**

#### **B. Unloader Cleanliness**

1. The inlet valve unloader must be clean and tight to operate satisfactorily. The unloader should be examined during normally scheduled valve maintenance and/or inspection cycles. O-rings used in the unloader must be replaced during these maintenance/ inspection cycles. Always lubricate new O-rings. The use of a silicone type lubricant, or other lubricant, that is compatible with the O-ring material and the process is recommended.

### **▲WARNING**

**All precautionary measures specified by the Occupational Safety and Health Act of 1970 (OSHA) must be complied with when storing, handling, or using solvents.**

## Maintenance

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2. To thoroughly clean the unloader assembly, it must be completely dismantled. Soaking the unloader parts in a safety solvent, followed by a stiff brushing or light scraping, will aid in removal of foreign material. Brush the parts carefully with a soft wire brush, but use a bristle brush for all seating surfaces. Blow away all loose particles with compressed air. All components must be thoroughly dried before reassembly.

### C. Removing Operator, Unloader and Valve Assembly

#### **⚠ WARNING**

**Before performing any service on the unloader, including removal of the upper housing cover for inspection purposes, be certain there is no pressure in the compressor cylinder bore or passages.**

1. Shut off and vent the operating pressure to the unloader.
2. Depressurize and vent the compressor cylinder.
3. Disconnect the vent and operating pressure lines.

#### **⚠ WARNING**

**With the O-ring body seal used on this type valve cover, any pressure that may be left in the cylinder will not be released when the cover nuts are loosened, but will remain under the cover trapped by the O-ring. To prevent the possibility of the valve cover being "blown off" by residual pressure when the cover nuts are removed, two longer studs are required to permit the safe removal of the cover. These studs are either present (they are double-nutted if factory supplied) or should be fabricated at the site. FAILURE TO OBSERVE THE FOLLOWING VALVE REMOVAL STEPS CLOSELY CAN RESULT IN POSSIBLE PROPERTY DAMAGE, INJURY TO THE MAINTENANCE PERSONNEL OR DEATH.**

4. Evenly loosen the valve cover stud nuts; note that two nuts are used on the two longer studs used with each valve cover.
5. Remove only those nuts on the short valve cover studs.
6. Back off the nuts on the long studs evenly two turns at a time. As the stud nuts are loosened, it may be necessary to tighten down the cylinder cover jackscrews (if installed) or pry under the valve cover to keep the cover in contact with the stud nuts. (This will prevent sudden loosening of the valve cover when the O-ring breaks free of the valve passage, caused by any pressure present.) As the O-ring is pulled from the valve passage, any residual pressure will be safely vented from under the cover.
7. Remove the operator and the valve cover.
8. Loosen the cage setscrew, then pull the valve cage assembly, the unloader assembly and the inlet valve assembly from the valve hole.

**NOTE**

If two or more unloaders are removed; mark each one to be sure it is reinstalled into the same valve passage from which it was removed.

**D. Disassembling Cage and Plunger**

**SERVICE NOTE**

Some valve cages may be attached to the valve with two small machinescrews. If so, first remove the machinescrews.

1. Lift the valve cage off the inlet valve.
2. Remove the plunger assembly and the return spring (if present).
3. Thoroughly clean all pieces.
4. Service the Type PF inlet valve following the instructions in Paragraph 4-16 of this manual.

**SERVICE NOTE**

With some valves, it may be necessary to remove an extension bolt which is attached to the valve center stud in order to disassemble the valve. When unscrewing the extension bolt, be careful not to mar the surface of the bolt.

**E. Installing Valve, Cage and Plunger**

1. If the extension bolt has been removed, reassemble it to the valve first. Do this by cleaning the threads (internal and external), and applying primer for anaerobic adhesive. Allow the primer to dry for 5 minutes. Apply Loctite® #242 removable threadlocker (35272657) or equivalent. Screw the extension bolt into the valve.
2. Place the plunger return spring (if present) on the inlet valve over the extension bolt.
3. Set the plunger assembly over the extension bolt and onto the plunger; align the legs with the plates in the valve.
4. Lower the valve cage onto the inlet valve. Attach capscrew, if applicable.
5. Check for free movement of the plunger assembly.
6. Install a new valve seat gasket. Place the assembled inlet valve, valve cage, and plunger assembly into the cylinder valve hole. Secure the cage with the setscrew.

**F. Disassembling Unloader Cover and Operator**

1. Loosen the locknut on the setscrew adapter.

## Maintenance

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2. Separate the unloader cover from the operator and setscrew adapter.

### CAUTION

**Do not allow the actuating piston to rotate in the piston housing. Parts will be damaged by rotation.**

3. Unscrew the pushrod from the bottom of the actuating piston rod by using the hole at the base of the piston rod to secure the operator.
4. Remove and discard the Threadseal™, then remove the washer.
5. Separate the setscrew adapter from the operator. The setscrew adapter should have some drag on it, caused by the piston rod O-rings.
6. Loosen the six piston housing cover bolts gradually, allowing the housing covers to separate from the piston housing and relieve the spring pressure.
7. Remove the covers and gaskets. Clean the threads of the lower piston housing cover. Pull the piston spring, actuating piston with indicator and piston rod out of the piston housing. Remove and discard the piston and piston rod O-rings, and the backup ring.
8. The piston rod may be unscrewed from the actuating piston, if necessary, taking care not to mar the surfaces of the piston rod and piston. Use the two tapped holes on the top of the piston and the hole at the base of the piston rod to hold the piston and piston rod while turning.

### SERVICE NOTE

It is good maintenance practice to replace all O-rings, seals and gaskets during reassembly. Always lubricate the O-rings with a silicone lubricant or other lubricant compatible with the O-ring and process.

9. The indicator may be unscrewed from the actuating piston, taking care not to mar the surface of the piston.
10. If the piston rod was removed, clean the threads of the piston rod and the piston, then apply aerobic adhesive primer and allow it to dry for five minutes. Apply Loctite® #242 threadlocker (two drops) to the piston rod threads. Attach the piston rod to the piston.
11. Renew the O-rings and backup ring on the piston rod. (Note the order in which they are placed.) A single O-ring is installed in the top groove. Install the backup ring first and then an O-ring in the bottom groove. Make sure the O-rings and backup ring are lubricated with a lubricant compatible with the process gas.
12. Install a new piston O-ring and lubricate it with O-ring lubricant.
13. Insert the piston spring, actuating piston, and piston rod into the piston housing. Be sure that the O-ring is not rolled out of its groove when installing the actuating piston.
14. Clean the threads (both internal and external) of the piston housing cover bolts, then apply anaerobic adhesive primer and allow it to dry for five minutes. Apply Loctite® #242 threadlocker (two drops) to each bolt and with new piston housing cover gaskets in place, secure the piston housing covers to the piston housing. Tighten the housing cover bolts squarely by tightening gradually, in several stages, working back and forth across the bolt circle.

15. If the indicator was removed, clean the threads (internal and external) of the indicator, then apply anaerobic adhesive primer and allow to dry for five minutes. Apply Loctite® #242 threadlocker (two drops) to the indicator threads. Screw the indicator into the piston until the bottom of the indicator is flush with the lower piston housing cover.
16. Ensure that the setscrew adapter vent passage is clear.
17. Clean the threads of the setscrew adapter, then apply aerobic adhesive primer and allow to dry for five minutes. Apply Loctite® #242 (two drops) to the setscrew adapter threads. Slide the piston rod through the setscrew adapter and screw the setscrew adapter into the lower piston housing cover.
18. Ensure that the setscrew adapter has the locknut, beveled washer and Threadseal™ in place and in proper sequence. Insert the setscrew adapter into the unloader cover approximately 0.5 inch (12.7 mm) and tighten the locknut finger tight.

### CAUTION

**Do not allow the actuating piston to rotate in the piston housing. Parts will be damaged by rotation.**

19. Clean the threads (internal and external) of the piston rod and pushrod, and apply anaerobic adhesive primer. Allow it to dry for five minutes. Apply Loctite® #242 removable threadlocker (two drops) to the threads. Using the hole at the base of the piston rod to hold it steady, screw the pushrod into the piston rod.

### **G. Installing the Unloader**

1. Install a new O-ring onto the valve cover.
2. Install the assembled operator and valve cover assembly into the valve hole, sliding the pushrod over the extension bolt (loose fit).
3. Clean the threads (both internal and external) of the valve cover stud nuts or capscrews, then apply anaerobic adhesive primer and allow it to dry for five minutes. Apply Loctite® #242 threadlocker (two drops) to each capscrew. Tighten the valve cover squarely by tightening the capscrews gradually, in several stages, working back and forth across the stud circle.

### WARNING

**Valve cover stud nuts must be correctly tightened to the design pre-stress to ensure safe and efficient operation of the compressor. Refer to CHAPTER 5 of this manual for detailed tightening requirements.**

4. Adjust the stroke of the unloader.

### H. Adjusting the Stroke

1. Loosen the setscrew adapter locknut.
2. Slowly rotate the operator assembly clockwise until rotation is resisted without the locknut, washer, and Threadseal™ assembly contacting the valve cover.
3. Slowly rotate the operator assembly counterclockwise 1-1/2 turns if the suction valve lift is greater than 0.100 inch (2.54 mm), or 1 turn if the suction valve lift is less than or equal to 0.100 inch (2.54 mm).
4. Tighten the setscrew adapter locknut, pressing the washer and Threadseal™ firmly against the valve cover. Be sure not to rotate the operator, setscrew adapter assembly.
5. Connect operating pressure line and cycle unloader several times to ensure that free movement exists and that the unloader is functioning. Connect vent lines.

### 4-17.2. Variable Volume Clearance Pockets

The variable volume clearance pocket (Figure 4-33) is installed in the outer head of the compressor cylinder. Within the limits of pocket capacity, the exact amount of clearance volume can be added by turning the pocket's piston rod with a wrench. *The compressor MUST be shut down and the cylinders depressurized before making adjustments.*

The volume is changed by means of a movable piston, which is shown in Figure 4-33. The piston is sealed against leakage by two piston rings and is attached to the piston rod by a threaded connection between the piston and rod. The clearance volume is increased by loosening the jam nut and unscrewing the threaded rod, which will draw the piston outward away from the cylinder. Close control over cylinder capacity can be accomplished by setting the piston at some intermediate position between fully closed and fully open.

### A. Construction

There are two designs of the variable volume pocket. One has a bonnet with a long neck (illustrated in Figure 4-33), while the other has a flat bonnet (not illustrated). The long-necked version is equipped with special seals, shown in the detail in Figure 4-33, which are installed on each side of a lantern ring. This seal assembly is held in place by a flat washer and secured by a retaining ring. The flat-bonnet version is equipped with a simple soft gasket under the piston rod sealing nut. Passage in the bonnet neck is equipped with a grease fitting that allows the piston rod threads to be greased. In addition, there are two plugged openings in the pocket that allow accumulated liquids to be drained (lower hole) or a test gauge to be connected (upper hole).

### B. Maintenance

Periodic maintenance consists of applying a small amount of grease, compatible with the process gas, to the one grease fitting. It is suggested that the grease fitting be greased at least every three months.

The condition of the piston rings can be determined by periodic testing with a simple pressure gauge. With the compressor shut down and the cylinder vented, attach a test pressure gauge having a capacity at least a third higher than discharge pressure to the upper hole in the pocket. With the compressor again running, the gauge should read a steady pressure that falls somewhere between inlet and discharge pressure. A fluctuation of the gauge indicates that piston rings are leaking badly.

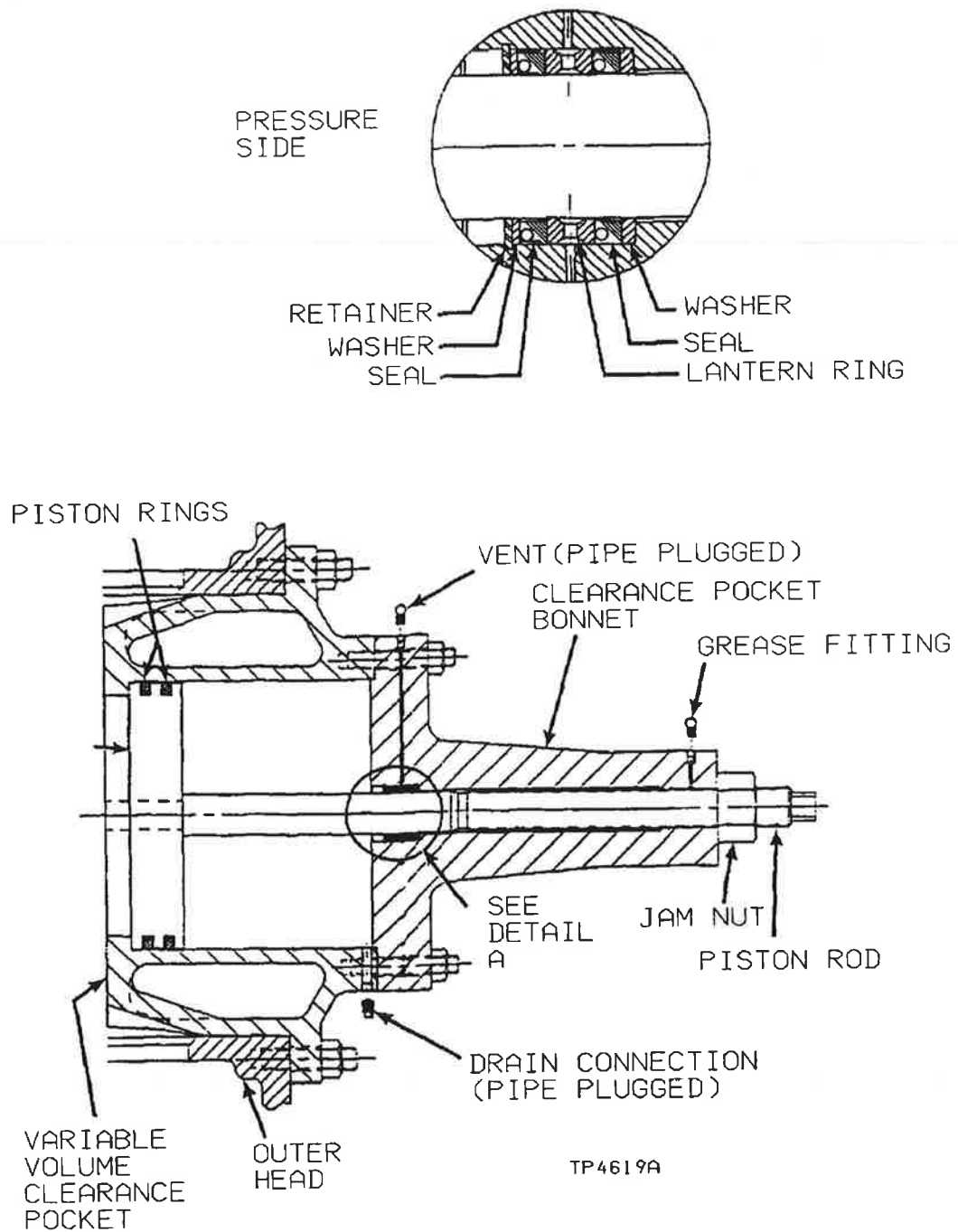


Figure 4-33. Current Design Variable Volume Clearance Pocket

*To remove and disassemble the pocket, use the following steps;*

1. **RELIEVE THE PRESSURE IN THE COMPRESSOR CYLINDER AND VENT THE CYLINDER.**
2. Loosen and remove the stud nuts that secure the flange to the outer head.
3. Pull the clearance pocket assembly from the outer head, keeping it level until the piston clears the bore. Be sure the assembly is fully supported at all times with a sling and hoist arrangement capable of taking the weight.
4. Clean and examine the components of the variable volume pocket. Pay particular attention to the piston rings.
5. On long-neck bonnet versions, remove the seal retaining ring by first prying one end out of the groove, then by winding the ring completely out.
6. Continue with seal removal process by removing the washer, then by pulling the seals and lantern using a shop-made wire hook.
7. Install new seals with the open cup side of the seals facing the pressure (towards the cylinder bore).
8. Install the washer and retaining ring, making sure the ring is tight in its groove.
9. Install new piston rings on the piston. Normally it is more practical to replace the rings than to attempt a judgement call on their condition. Stagger the ring end gaps.
10. Clean the gasket surfaces of the outer head and the flange.
11. Loosen the jam nut and unscrew the piston rod a few turns; this will ensure that the piston is not "bottomed" during installation. If this is a flat-bonnet version, replace the sealing gasket at this time.
12. Install a new flange gasket, then guide the piston into the outer head bore. Make sure the assembly is kept level during this operation to prevent damaging the piston rings.
13. Install the stud nuts and tighten them in a criss-cross fashion, and in several stages, to the 25,000 psi (172 MPa) level found on the standard torque chart for the proper size fastener. (This chart is found in CHAPTER 5, GENERAL DATA & SPECIFICATIONS of this manual.)
14. Adjust the piston to the desired position for operation. Make sure the jam nut is secure before starting up the compressor.

### **4-17.3. Fixed Volume Clearance Pockets**

The internal operating components of the clearance pocket are the indicator rod, actuating piston, piston rod, return spring, crossbar and clearance valve itself. The crossbar, return spring (if present), piston rod and clearance valve are assembled in the clearance valve sleeve which is in turn bolted to the valve cover. The actuating piston and indicator rod are located in the piston housing.



Piston rings are installed around the clearance valve sleeve to prevent leakage of process gas past the sleeve and clearance valve when the valve is seated. O-ring seals are used on the actuating piston and indicator rod to seal the leakage of operating pressure past the piston and rod. A gland seal arrangement is used to seal around the piston rod to prevent the leakage of process gas. Vent openings are provided in the valve cover and piston housing to vent the piston rod gland seal arrangement and the actuating piston housing.

When operating pressure from an outside control source is applied to the top of the actuating piston, the piston motion is transmitted through the piston rod to the clearance valve crossbar and to the clearance valve, closing the valve. (The clearance valve sleeve is slotted for the travel of the crossbar.) Piston rings in the valve sleeve prevent leakage past the clearance valve into the clearance pocket when the valve is in its closed position. When operating pressure is shut off and vented, the valve returns to its normal (open) position.

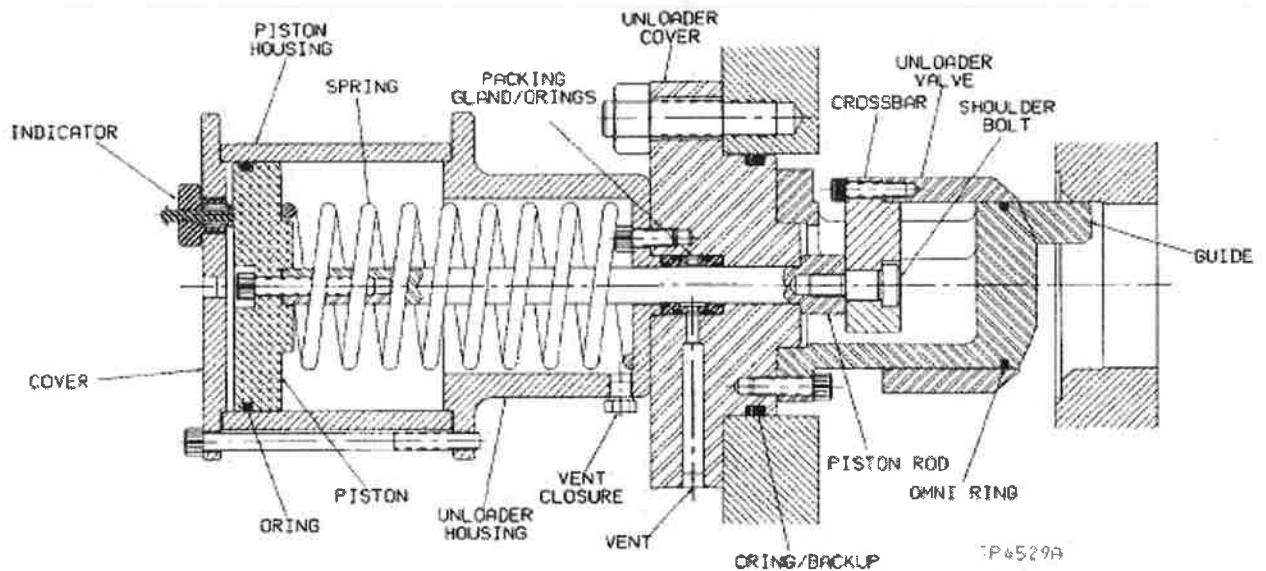


Figure 4-34. Typical Fixed Volume Clearance Pocket

**A. Control and Vent Piping**

Operating pressure is applied to a 1/4-inch NPT tapped hole provided in the piston housing cover. Drawings are furnished to show the arrangement of factory supplied piping and controls. Recommended piping arrangements are usually furnished when the piping is being done by others.

**▲WARNING**

The vent opening(s) in the clearance pocket must always be left open to assure safe and effective operation of the device. When the process gas is toxic, flammable, or in any other way objectionable in the compressor building, the vent must be piped so that any leakage can be carried away. Vent tubing must not be less than 3/8-inch (9.5 mm) O.D. and, if combined with other vent systems, there must not be any back pressure or vacuum in this piping.

### B. Clearance Pocket Cleanliness

1. The clearance pocket and valve assembly must be clean and tight to operate satisfactorily. The assembly should be examined during normal periodic maintenance inspections. O-rings and backup rings (if used) in the assembly must be replaced and lubricated periodically; it is suggested that this be accomplished during routine maintenance. The use of a silicone type lubricant or other lubricant that is compatible with the O-ring material and the process is recommended.

#### **⚠ WARNING**

**All precautionary measures specified by the Occupational Safety and Health Act of 1970 (OSHA) must be complied with when storing, handling, or using solvents.**

2. To thoroughly clean the assembly, it must be completely dismantled. Soaking the parts in a safety solvent, followed by a stiff brushing or light scraping, will aid in removal of foreign material. Brush the parts carefully with a soft wire brush, but use a bristle brush for all seating surfaces. Blow away all loose particles with compressed air. All components must be thoroughly dried before reassembly.

### C. Removing the Clearance Pocket Assembly

1. Shut down and vent ALL pressure from the unit.
2. Shut off and vent the operating pressure.
3. Disconnect the vent and operating pressure lines.
4. Mark or tag the clearance pockets before they are removed.

#### **⚠ WARNING**

**With the O-ring body seal used on this type valve cover, any pressure that may be left in the cylinder will not be released when the cover nuts are loosened, but will remain under the cover trapped by the O-ring. To prevent the possibility of the valve cover being "blown off" by residual pressure when the cover nuts are removed, two longer studs are required to permit the safe removal of the cover. These studs are either present (they are double-nutted if factory supplied) or should be fabricated at the site. FAILURE TO OBSERVE THE FOLLOWING VALVE REMOVAL STEPS CLOSELY CAN RESULT IN POSSIBLE PROPERTY DAMAGE, INJURY TO THE MAINTENANCE PERSONNEL OR DEATH.**

5. Evenly loosen the valve cover stud nuts; note that two nuts are used on the two longer studs used with each valve cover.
6. Remove only those nuts on the short valve cover studs.

7. Back off the nuts on the long studs evenly two turns at a time. As the stud nuts are loosened, it may be necessary to tighten down the cylinder cover jackscrews (if installed) or pry under the valve cover to keep the cover in contact with the stud nuts. (This will prevent sudden loosening of the valve cover when the O-ring breaks free of the valve passage, caused by any pressure present.) As the O-ring is pulled from the valve passage, existing pressure will be safely vented from under the cover.
8. Remove the assembly from the compressor.
9. Install temporary covers over the clearance pocket passage(s) to prevent entry of foreign objects.

### **D. Disassembling Actuating Piston Housing**

1. Remove the nuts that fasten the piston housing cover to the piston housing.
2. Carefully lift the piston cover over the indicator rod; remove and discard the cover gasket. Clean the gasket surfaces in preparation for reassembly.
3. Lift the piston housing off the valve cover.
4. Remove the actuating piston and indicator rod from the piston rod. (The piston rod can only be removed through the bottom of the body.) Remove and discard the actuating piston and indicator rod O-rings.

### **SERVICE NOTE**

It is good preventative maintenance practice to replace all O-rings and gaskets during reassembly. Always lubricate the O-rings with a silicone lubricant or other lubricant compatible with the O-ring and process.

### **E. Disassembling Clearance Valve Sleeve**

1. Remove the fasteners and the lockwasher that connect the valve sleeve to the valve cover and separate the two.
2. The piston rod may now be removed through the bottom of the valve cover.
3. Disassemble the crossbar by unscrewing the fasteners and lockwashers that fasten it to the clearance valve.
4. Pull the crossbar out of the sleeve.
5. Pull the clearance valve off the sleeve.
6. Remove and discard the piston rings if they are chipped, cracked, broken or stuck to their lands.
7. Remove and clean the return spring; check for cracks or other visible defects.

### **F. Servicing the Gland Seal**

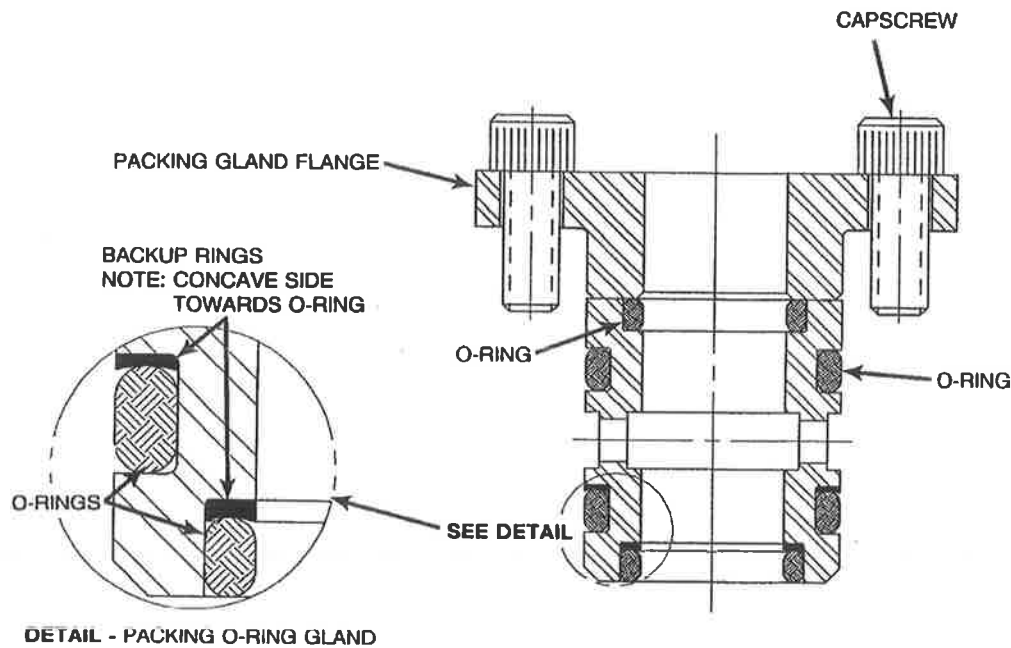
1. Remove the fasteners to permit removal of the gland seal. (See detail in Figure 4-35.)

## Maintenance

2. If necessary, use a shop-made wire hook to pull the gland seal from the body.
3. Remove and discard the O-rings and backup rings.

### SERVICE NOTE

It is good maintenance practice to replace all O-rings, backup rings, and gaskets during reassembly. Always lubricate the O-rings with a silicone lubricant or other lubricant compatible with the O-ring and process.



TP-4530

Figure 4-35. Gland Seal Detail

4. Renew the O-rings and backup rings on the gland seal. (Note the order in which they are placed.)  
O-rings are installed in the top inner and outer groove. Install a backup ring and then an O-ring in the bottom inner and outer grooves. (The concave surface of the backup ring faces toward the O-ring.)  
Make sure the O-rings and backup rings are lubricated with a lubricant compatible with the process gas.
5. Place the gland seal into the body; be careful not to roll or cut the O-rings.
6. Clean the threads (both internal and external) of the gland seal cap screws, then apply anaerobic adhesive primer and allow it to dry for five minutes. Apply Loctite® #242 threadlocker (two drops) to each cap screw; reattach the gland seal to the body.

7. Push the piston rod up through the gland seal.

### **G. Assembling Actuating Piston Housing**

1. If the piston rod was removed, clean the threads of the piston rod and the piston, then apply aerobic adhesive primer and allow it to dry for five minutes. Apply Loctite® #242 threadlocker (two drops) to the piston rod threads. Attach the piston rod to the piston.
2. Install new indicating rod and actuating piston O-rings and lubricate them with O-ring lubricant.
3. Insert the actuating piston and piston rod into the piston housing. Be sure that the O-ring is not rolled out of its groove when installing the actuating piston.
4. Clean the threads (both internal and external) of the piston housing cover bolts, then apply anaerobic adhesive primer and allow it to dry for five minutes. Apply Loctite® #242 threadlocker (two drops) to each bolt and with new piston housing cover gaskets in place, secure the piston housing covers to the piston housing. Tighten the housing cover bolts squarely by tightening gradually, in several stages, working back and forth across the bolt circle.
5. With a new cover gasket in place, reinstall the piston housing cover over the indicator rod; tighten the stud nuts evenly.

### **H. Assembling Clearance Valve Sleeve**

1. Inspect the valve sleeve piston ring lands, ensuring they are clean. The lands can be cleaned with a piece of carved hardwood. Do not use old rings to clean the lands because they may cut into the lands and grooves damaging the sleeve.
2. Fit new rings to the sleeve (if they are required). Stagger the butt ends of the rings 120 degrees.
3. While carefully compressing each piston ring, push the clearance valve over the piston rings and onto the valve sleeve. Do not push the clearance valve onto the valve sleeve far enough to block the slots in the sleeve.
4. Place the return spring (if used) into the valve sleeve. Some models do not require a return spring.
5. Insert the crossbar through slots in the valve sleeve. Fit the crossbar to the return spring then connect the crossbar to the clearance valve using the lockwashers and fasteners provided.
6. Connect the valve sleeve to the valve cover using the fasteners and lockwashers removed.

### **I. Installing Clearance Pocket Assembly**

1. Remove the temporary covers from the valve passage(s).
2. Install a new valve O-ring and backup ring seal around the valve cover. Place the unit in the clearance pocket and align the operating pressure and vent piping connections with the installed piping.
3. Reinstall the valve cover fasteners and hand tighten. Loosen all fasteners 1/4 turn.

## Maintenance

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4. Reconnect operating pressure and vent piping.
5. Apply operating pressure to the actuating port to seat the clearance valve. (This will align the clearance valve with the cylinder.)
6. Release the operating pressure.
7. Reapply operating pressure to the actuating port.

### **⚠ WARNING**

**Valve cover stud nuts must be correctly tightened to the design pre-stress to ensure safe and efficient operation of the compressor. Refer to CHAPTER 5, GENERAL DATA & SPECIFICATIONS of this manual for detailed tightening requirements.**

8. While operating pressure is still applied, make several passes working back and forth across the stud circle to ensure the valve cover is drawn down tightly and evenly.

**DRESSER-RAND**

**GENERAL DATA & SPECIFICATIONS**

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**HOS**  
**Chapter 5**

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<b>Paragraph</b>		<b>Page</b>
5-1.	GENERAL AND OPERATING DATA .....	5-2
5-2.	ASSEMBLY FITS AND CLEARANCES .....	5-4
5-3.	TIGHTENING REQUIREMENTS .....	5-6

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## General Data & Specifications

### 5-1. GENERAL AND OPERATING DATA

The specifications in this section apply to the standard 6-inch stroke HOS compressor, rated at 60,000 pounds (27 270 kg) rod load. Contact the nearest Dresser-Rand branch office when there is a question about any specification or recommendation in this manual.

**HOS Compressor General Data**

<b>Number of Throws</b>		2	4	6
<b>No. Main Bearings</b>		2	4	6
<b>Oil Sump Capacity</b>	<b>GAL.</b>	21	57	96
	<b>L.</b>	79	216	365
<b>Main Oil Pump Output @ 1000RPM</b>	<b>GPM</b>	40	70	110
	<b>LPM</b>	152	266	380
<b>Maximum Speed</b>		1200	1200	1200
<b>RPM</b>				
<b>Minimum Operating Speed</b>		500	500	500
<b>RPM</b>				

#### **Lubricating Oil:**

Normal Oil Pressure (at Header) ..... 50-65 PSIG (344-448 kPa)  
 Minimum Oil Pressure (at Header) ..... 40 PSIG (275 kPa)  
 Shutdown Oil Pressure (at Header) ..... 35 PSIG (240 kPa)  
 Minimum Start-up Oil Temperature (Electric Drive) ..... 80°F (27°C)  
 Minimum Load Oil Temperature (Engine and Electric Drives) ..... 90°F (32°C)  
 Normal Oil Operating Temperature ..... 150 to 170°F (66° to 77°C)\*\*

\*\*NOTE: Not to exceed 180° for continuous operation

#### **For units containing main bearing RTD's:**

Maximum Alarm Setting ..... 190°F (88°C)  
 Maximum Shutdown Setting ..... 200°F (93°C)

**Recommended minimum prelube capacity @ 35 psi (on electric motor driven machines only):**

<b>Frame Size</b>	<b>Gallons per Minute (GPM)</b>
2 Throw .....	15 GPM
4 Throw .....	25 GPM
6 Throw .....	50 GPM



***Water-Cooled Cylinders:***

Minimum Coolant Temperature (Outlet) .....	110°F (43°C)
Minimum Coolant Temperature (Inlet) .....	100°F (43°C)
Water-Cooled Packing [gpm (L/min)] per packing .....	2.5 (9.5)
Nominal Pressure .....	35 PSIG (241 kPa)
Maximum Pressure.....	75 PSIG (517 kPa)

***Distance Pieces:***

Maximum Internal Pressure.....	25 PSIG (172 kPa)
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**5-2. ASSEMBLY FITS AND CLEARANCES**

**Table 5-1. Running Gear Part Fits and Tolerances  
(ALL DIMENSIONS ARE GIVEN IN INCHES)**

<b>Location of Clearance or Fit</b>	<b>Original Clearance Micrometer</b>	<b>Original Clearance Feeler</b>
Main Bearing (Vertical-measured between top of crankshaft and main bearing shell) (Shim Type Aluminum)	0.008 to 0.011	0.007 to 0.010
Crankshaft Total Thrust	----	0.018 to 0.023
Connecting Rod Bearing to Crankpin (Diametral) (Shimless Steel-Backed Aluminum)	0.007 to 0.010	0.006 to 0.009
Total Side Clearance between Connecting Rod and Crank Webs	----	0.015 to 0.023
Crosshead Pin to Connecting Rod Bushing (Diametral)	0.002 to 0.006	0.001 to 0.005
Crosshead Pin Bushing to Connecting Rod (Interference)	(0.002 to 0.004)	----
Crosshead Shoe to Guide(Cold) 1 - piece 3 - piece Minimum (Hot)	0.013 to 0.018 0.017 to 0.022 -----	0.012 to 0.017 0.016 to 0.021 0.007
Main Bearing Tie Rod Spacer to Frame (Interference) [Spacer Length Less Opening Stamped on Frame]	(0.003 to 0.005)	----

**Table 5-1A. Running Gear Part Fits and Tolerances  
(ALL DIMENSIONS ARE GIVEN IN MILLIMETERS)**

Location of Clearance or Fit	Original Clearance Micrometer	Original Clearance Feeler
Main Bearing (Vertical-measured between top of crankshaft and main bearing shell)	0.20 to 0.28	0.18 to 0.25
Crankshaft Total Thrust	----	0.46 to 0.58
Connecting Rod Bearing to Crankpin (Diametral)	0.18 to 0.25	0.15 to 0.23
Total Side Clearance between Connecting Rod and Crank Webs	----	0.38 to 0.58
Crosshead Pin to Connecting Rod Bushing (Diametral)	0.05 to 0.15	0.025 to 0.13
Crosshead Pin Bushing to Connecting Rod (Interference)	(0.05 to 0.10)	----
Crosshead Shoe to Guide (Cold) 1 - piece 3 - piece Minimum (Hot)	0.33 to 0.46 0.43 to 0.56 -----	0.30 to 0.43 0.41 to 0.53 0.18
Main Bearing Tie Rod Spacer to Frame (Interference) [Spacer Length Less Opening Stamped on Frame]	(0.08 to 0.13)	----

### 5-3. TIGHTENING REQUIREMENTS

#### WARNING

The fasteners used in compressors must be correctly tightened to the design pre-stress to ensure safe operation of the equipment. Prior to the initial start-up of the equipment, or before starting an overhauled machine, fasteners must be checked for proper tightness to ensure the full mechanical integrity of the unit. After start-up, fasteners that were properly tightened can loosen due to operating temperatures and pressures, gasket crush, fastener and joint relaxation, and other factors. THEREFORE, IT IS IMPORTANT THAT ALL FASTENERS SUBJECTED TO THE ABOVE CONDITIONS BE PERIODICALLY RECHECKED FOR TIGHTNESS. (Particular attention should be given to all bolts and nuts on the compressor cylinders and distance pieces and to the cylinder-to-frame bolting.)

Fasteners should be checked for proper tightness during the break-in period and again after the first week of operation. Check them monthly thereafter for a period of three months and then once every three months until a full year of operation has been completed. Beyond this point, experience will dictate how often these tightness checks should be made. In any event, a check should be made at least once a year.

To check the tightness of a fastener, first mark the position of the bolt head or nut and then loosen it; clean and re-lubricate; the fastener should then be re-tightened to the required value. Observe to see whether the bolt head or nut has advanced past its reference position. If it has, this indicates that the fastener was loose and that it should be replaced and closely observed during all future tightness checks.

Fastener pre-stress (initial tightening) is calculated to prevent separation of the connected members when they are subjected to operating forces and, in cases of cyclic loading, to protect the fastener from the fatigue effects of the alternating tensile and compressive stresses.

Measuring bolt stretch or using wrench torque are the two most widely used methods of applying fastener pre-stress. When using a torque wrench, a *properly calibrated* wrench is essential in obtaining correct fastener pre-stress. An accurate torque cannot be applied to a nut or bolt using a commercial air impact wrench or "air hammer". ***Under no circumstances is an air impact wrench to be used for FINAL tightening of any fastener.***

Preparation of thread and seating faces is important. In most torque applications, more than 80 percent of the applied torque is used to overcome friction and the balance to actually stress the fastener.

It is therefore imperative that threads be clean and free of nicks and burrs; that seating faces on the nut or bolt head and mating surface be smooth, flat and parallel; and that the threads and contact faces be well lubricated with oil only.

All fasteners used on multi-fastener joints require a tightening procedure that will allow the fasteners to be evenly and sequentially tightened, in gradual increments, to the specified torque. This prevents distortion of mating surfaces and "cocking" of flanged connections.

Closely observe the following tightening requirements and recheck fastener tightness periodically as dictated by the local operating conditions.

1. All torque values are for clean, well-lubricated threads free of nicks and burrs. For stud (or bolt) and nut combinations, the nut should turn freely on the stud threads. Capscrews should run in freely at least up to the final assembled depth. (Some thread interference is normal on certain self-locking fasteners.) Lubricant should be applied to both internal and external threads and evenly distributed. A uniform coating of lubricant should be applied to the fastener and seating surfaces.
2. Wrench torques can produce fastener pre-stress variations of plus or minus 35 percent, depending on the degree of lubrication or non-lubrication and also on the condition of seating surfaces.
3. Unless otherwise specified, the tightening torques given are applicable to fasteners lubricated with common petroleum lubricating oils. Using molybdenum disulfide lubricants and similar products having extremely high anti-friction properties can result in increased fastener pre-stress when these torques are applied.
4. Geared head wrenches (torque multipliers) will not produce the full mechanical advantage from the reduction gears. There are mechanical and friction losses of about 10 percent in the tool head. The tool manufacturer's instructions should be observed to determine the exact reduction percentage for a particular torque multiplier. The required input torque must then be increased by that percentage.

### WARNING

**The wrench torques listed in the standard table should be used only on those fasteners for which a specific torque is not given.**

The torque values listed in the Standard Torque Table 5-3 for Engine Process Compressor Division products should be used for all fasteners for which a specific torque value is not given. Pay particular attention to the following note when selecting torque values from the standard table.

### IMPORTANT NOTE

**Unless otherwise stated, the tightening stress levels for a particular bolting application can be determined as follows:**

- **For connections with metal-to-metal contact, use 30 000 PSI (207 MPa) stress level.**
- **For connections with non-metallic gaskets, use 20 000 PSI (138 MPa) stress level.**
- **For foundation bolts, use 25 000 PSI (172 MPa) stress level.**

## General Data & Specifications

Table 5-3. Standard Torque Table

NOMINAL BOLT SIZE (inches)	20,000 PSI (138 MPa) Bolt Stress		25,000 PSI (172 MPa) Bolt Stress		30,000 PSI (207 MPa) Bolt Stress		40,000 PSI (276 MPa) Bolt Stress	
	Torque		Torque		Torque		Torque	
	ft-lbs	N•m	ft-lbs	N•m	ft-lbs	N•m	ft-lbs	N•m
1/4	3	4	3	4	4	6	5	74
5/16	5	7	7	10	8	11	11	15
3/8	9	12	12	16	14	19	19	26
7/16	15	20	18	24	22	30	29	39
1/2	22	30	28	30	33	45	44	60
9/16	31	42	39	53	47	64	63	85
5/8	44	60	55	75	66	90	88	119
3/4	76	103	95	129	114	155	152	206
7/8	120	163	150	203	180	244	240	325
1	175	237	220	300	265	360	350	475
1-1/8	260	355	330	450	390	530	520	705
1-1/4	360	490	450	610	530	720	710	965
1-3/8	480	650	600	815	710	965	950	1290
1-1/2	620	840	770	1045	920	1250	1230	1670
1-3/4	950	1290	1190	1615	1420	1925	1890	2565
2	1470	1990	1830	2480	2200	2980	2930	3970
2-1/4	2130	2890	2670	3620	3200	4340	4270	5970
2-1/2	2950	4000	3650	4950	4400	5970	5850	7930
2-3/4	3950	5360	4900	6640	5900	8000	7850	10640
3	5150	6980	6400	8680	7700	10440	10250	13900

*Observe the following when using this torque table:*

- All information and instructions given under TIGHTENING REQUIREMENTS must be thoroughly reviewed before applying the specified wrench torques.
- The wrench torques are applicable to both National Fine and National coarse thread series. Any difference in the torque values because of thread series is within the normal variation of torque wrench accuracy.
- When tightening fasteners incorporating a self-locking feature, a certain amount of the applied torque is lost because of the additional friction of the locking feature. To properly tighten these fasteners, use a torque wrench to measure the "run-down" torque and then add it to the listed value.

Table 5-4. Compressor Cylinder Bolting

For compressor cylinder bolting, use the torque values from Table 5-3 to obtain the bolt pre-stress levels indicated below:

APPLICATION	BOLT PRE-STRESS
Valve Cover and Unloader Setscrews <sup>1,2</sup> < 2000 PSI MAWP RATING 2000 PSI MAWP AND UP RATING	25 000 PSI (172 MPa) 30 000 PSI (207 MPa)
Valve Cover Studs and Capscrews <sup>2</sup> < 2000 PSI MAWP RATING 2000 PSI MAWP AND UP RATING	25 000 PSI (172 MPa) 30 000 PSI (207 MPa)
Outer Head & Clearance Bottle Studs (With Standard Gaskets)	25 000 PSI (172 MPa)
Outer Head & Clearance Bottle Studs (With Flexitallic Gaskets)	30 000 PSI (207 MPa)
All Other Cylinder Bolting	20 000 PSI (138 MPa)

<sup>1</sup> Inlet valve unloader setscrews may be oversize to accommodate a through-hole for the unloader actuating rod. This can be determined by comparing the unloader setscrew diameter to that of a discharge valve setscrew on the same cylinder. IF THE SETSCREW IS OVERSIZE, APPLYING THE TORQUE VALUE FROM THE TABLE WILL OVER-TIGHTEN THE SETSCREW. Oversize unloader setscrews are properly tightened by (1) determining the correct torque from the table for the DISCHARGE valve setscrew and (2) ADDING 25 percent to that torque value. It must be noted that this only applies to OVERSIZE setscrews.

<sup>2</sup> Pressure ratings refer to the cylinder maximum allowable working pressure (MAWP) stamped on the cylinder nameplate.

**▲ CAUTION**

Special compressor cylinder fastener torque values may be supplied with your order. If so, the data above is superseded.

## General Data & Specifications

Table 5-5. Frame & Running Gear Bolting

Bolt or Stud Location	Size & Pitch (Inches)	Distance Across Flats (Inches)	Bolt Pre-Stress (PSI)	Torque (Ft-lbs)	Torque (N×m)
Main Bearing Cap Bolt	1 - 8	1-5/8	50 000 Nominal	420	569
Connecting Rod Bolt Nut	1-3/4 - 12	2-5/8	48 000 Nominal	0.018 to 0.020 in. <sup>1</sup> (0.46 to 0.51 mm)	
Frame Tie Rod Nut	1-1/2 - 8UN	2-3/8	30 000	<sup>2</sup>	<sup>2</sup>
Cylinder Tie Rod Nut	1-1/2 - 8	2-3/8	40 000	1230	1670
Crosshead Shoe Nut (3 Piece only)	¾ - 10UN	1-1/4	30 000	114	155

**NOTES:**

- <sup>1</sup> = Stretch method required for this fastener.  
<sup>2</sup> = See Paragraph 4-7.2. Number 11 for frame tie rod nut tightening procedure.



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DWG NO. R82120A-008 SH 2

CUSTOMER : SEE LEAD SHEET  
ORDER NO. : SEE LEAD SHEET  
FRAME SERIAL NO(S.) : SEE LEAD SHEET

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
FOR REV. SEE 3 OF 3				

15.00" AC / PF67

NOTE:  
1) SEE LEAD SHEET FOR  
NAMEPLATE STAMPING INFO.

ORIGINAL WITHOUT RIDER BANDS

NYO: NA

S/N: NA

DRAWINGS

CYLINDER: G12203

PISTON: F32177P4

VALVES: MLH56039AG11 INLET

CLEAR. CALC. BY:

NAME: G. LORTIE

DATE: 12/2/93

NOTE: PISTON AND ROD WEIGHT  
TO BE STAMPED ON NAMEPLATE  
AFTER ASSEMBLY HAS BEEN  
WEIGHED.

CYLINDER TYPE	HOS	SERIAL NO	STROKE
NOMINAL BORE	LINERED BORE		
15.00 IN 381.0 MM	IN MM	6.00 IN 152.4 MM	
RATED DISCHARGE PRESS.	450 PSIG	31.64	KG/CM <sup>2</sup>
MAX. ALLOW. WORKING PRESS.	495 PSIG	34.80	KG/CM <sup>2</sup>
HYDROSTATIC TEST PRESS.	745 PSIG	52.0	KG/CM <sup>2</sup>
MAX. COOLING WATER PRESS.	PSIG		KG/CM <sup>2</sup>
MAX. ALLOW. DISCH. GAS TEMP.	350 °F	177	°C
MAXIMUM SPEED	1200 RPM	OUTER END	FRAME END
BASE CYLINDER CLEARANCE		14.5 %	14.2 %
NORMAL LINEAL CLEARANCE	.09 IN 2.3 MM	.06 IN 1.5 MM	
ADDED FIXED CLEARANCE	IN <sup>3</sup> MM <sup>3</sup>	IN <sup>3</sup> MM <sup>3</sup>	

ALWAYS GIVE SERIAL NO. WHEN ORDERING SPARE PARTS  
MADE IN U.S.A

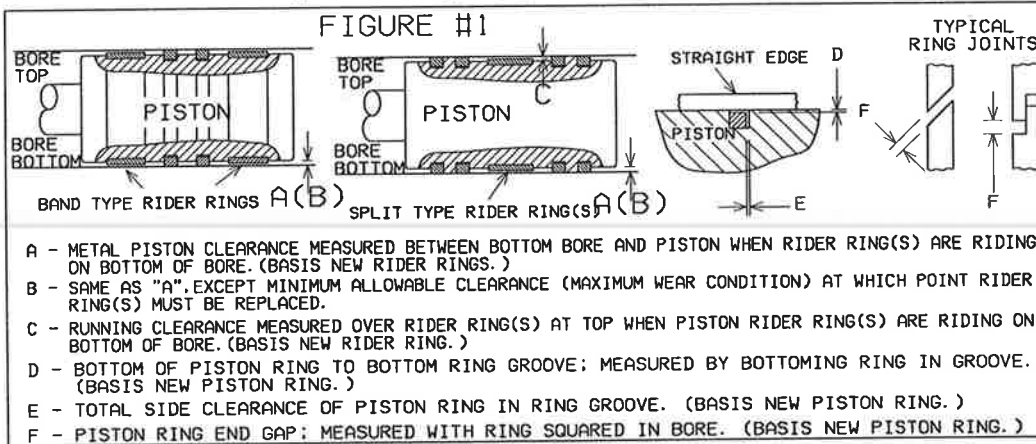
CYLINDER SIZE	FRAME END CLEARANCE	OUTER END CLEARANCE
15.00	.043 .082	.064 .123

CYLINDER SIZE	NUMBER OF LUBRICATION FEEDS			
	CYLINDER TOP	CYLINDER BOTTOM	PACKING	OTHER
15.00	1	1	1	NONE

- FULL LUBE
- MIN. LUBE
- NL

PISTON DIAMETER AND MATERIAL	REFER TO FIGURE #1 FOR CLEARANCE LOCATION AND DESCRIPTION						PISTON/RIDER RING MATERIAL AND TYPE
	A	B	C	D	E	*F	
15.00 1 PIECE CAST IRON	.034 TO .025	.010	.056 TO .041		.011 TO .007	.150 TO .105	(COMBO RING) 2-PC GR. 12 THERMOPLASTIC (ORANGE)

\*F = .255 TO .300 FOR TFE RINGS



CHG TO: 29C 109 124C 149C

THIRD ANGLE PROJECTION DRAWN D. J. CHICUORKA DATE 12/23/93 CHECKED G. R. LORTIE DATE 12/23/93 APPROVED G. R. LORTIE DATE 12/23/93	<b>DR DRESSER-RAND</b> TULSA, OKLAHOMA 74146		
	SIZE 15.00	STROKE 6.00	TYPE HOS
NAME OF PART CYLINDER INSTRUCTIONS			REV. C
SIZE B	FEDERAL SUPPLY CODE	DWG NO. R82120A-008	SCALE NTS WT.
SHEET 2 OF 3			

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# DRESSER-RAND CYLINDER INSTRUCTIONS

## SPECIAL CYLINDER BOLTING TORQUE VALUES

CUSTOMER: SEE LEAD SHEET

ORDER NO.: SEE LEAD SHEET

### CYLINDER SERIAL NUMBERS

SEE LEAD SHEET

DESCRIPTION (REFER TO FIGURE 1)	REF. NO. SEE FIGURE 1	BOLT SIZE (INCHES)	FINAL ASSY. & HELIUM TEST STRESS PSI (MPA)	FINAL ASSY. & HELIUM TEST TORQUE FT. LBS. (N-M)	HYDRO TEST STRESS PSI (MPA)	HYDRO TEST TORQUE FT. LBS. (N-M)
CYLINDER TO OUTER HEAD	1	1.000	25,000	220 (300)		
CYLINDER TO VALVE COVER	2	.750	25,000	95 (129)		
VALVE COVER SET SCREW (INLET)	3					
VALVE COVER SET SCREW (DISCH)	4					
CYLINDER TO FRAME HEAD	5					
CYLINDER TO DISTANCE PIECE	6					
FRAME HD. TO DISTANCE PIECE	7					
DISTANCE PC. TO DISTANCE PC.	8					
FRAME HD. TO PACKING	9	.750	20,000	76 (103)		
INLET & DISCHARGE FLANGE	10	.875	20,000	120 (163)		
RAM COVER	11					
CYLINDER TIE ROD	12	1.500	40,000	1230 (1670)		

THE TABLE ABOVE REFERS TO SPECIAL TORQUES FOR COMPRESSOR CYLINDER BOLTING ILLUSTRATED ON FIGURE 1.

NOT ALL LOCATIONS ARE USED ON ALL CYLINDER DESIGNS.  
"SEE TIGHTENING INSTRUCTIONS" IN CHAPTER 5 OF THE INSTRUCTION BOOK.

DWG NO.

SH

2

1

### REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	ADDED A & B ON PG 2. REVISED FIGURES ON PG 3 94B0260	5-11-94	JMV
	B	ADDED NEW CYL. INSTR. PLT. ON SHT. 2: 96B0021	02/19/96	MDK/GRL
	C	PG2-ADDED *F NOTE 99B0443	9/14/99	KWL/GWT

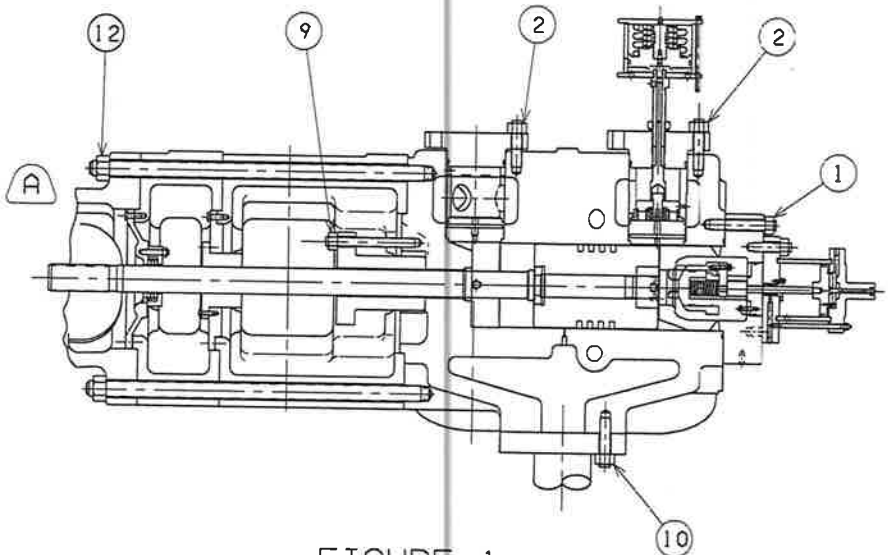


FIGURE 1

CHG TO: 29C 109 124C 149C			
		<b>DR DRESSER-RAND</b> TULSA, OKLAHOMA 74146	
THIRD ANGLE PROJECTION	SIZE	STROKE	TYPE
DRAWN D. J. CHICUORKA	15.00	6.00	HOS
DATE 12/23/93	NAME OF PART CYLINDER INSTRUCTIONS		
CHECKED G. R. LORTIE	DATE 12/23/93	SIZE	FEDERAL SUPPLY CODE
APPROVED G. R. LORTIE	DATE 12/23/93	B	R82120A-008
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES		DRAWING NO.	REV.
SCALE NTS WT.			C
SHEET 3 OF 3			

CUSTOMER : SEE LEAD SHEET  
 ORDER NO. : SEE LEAD SHEET  
 FRAME SERIAL NO(S.) : SEE LEAD SHEET

DWG NO. R82120A-004 SH 2

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
FOR REV. SEE 3 OF 3				

9.50" AC / PF48

NOTE:  
 1) SEE LEAD SHEET FOR  
 NAMEPLATE STAMPING INFO.

ORIGINAL WITHOUT RIDER BANDS

NYO: NA

S/N: NA

DRAWINGS

CYLINDER: G12199

PISTON: H49973P1

VALVES: MLH56190BG1 INLET

MLH56191BG1 DISCH

CLEAR. CALC. BY:

NAME: G. LORTIE

DATE: 12/2/93

NOTE: PISTON AND ROD WEIGHT  
 TO BE STAMPED ON NAMEPLATE  
 AFTER ASSEMBLY HAS BEEN  
 WEIGHED.

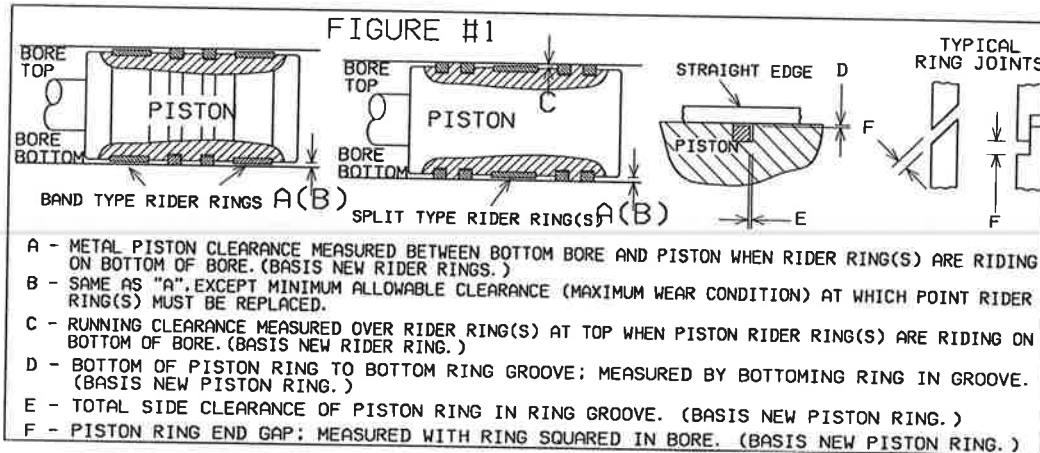
DRESSER-RAND GAS FIELD COMPRESSORS				
CYLINDER TYPE	HOS	SERIAL NO		
NOMINAL BORE	LINERED BORE	STROKE		
9.50 IN 241.3 MM	IN MM	6.00 IN 152.4 MM		
RATED DISCHARGE PRESS.	1150	PSIG	80.86	KG/CM <sup>2</sup> G
MAX. ALLOW. WORKING PRESS.	1265	PSIG	88.94	KG/CM <sup>2</sup> G
HYDROSTATIC TEST PRESS.	1900	PSIG	133.6	KG/CM <sup>2</sup> G
MAX. COOLING WATER PRESS.		PSIG		KG/CM <sup>2</sup> G
MAX. ALLOW. DISCH. GAS TEMP.	350	*F	177	*C
MAXIMUM SPEED	1200 RPM	OUTER END	FRAME END	
BASE CYLINDER CLEARANCE		17.1 X	17.8 X	
NORMAL LINEAL CLEARANCE	.09 IN 2.3 MM	.06 IN 1.5 MM		
ADDED FIXED CLEARANCE	IN <sup>3</sup> MM <sup>3</sup>	IN <sup>3</sup> MM <sup>3</sup>		
ALWAYS GIVE SERIAL NO. WHEN ORDERING SPARE PARTS				
MADE IN U.S.A. HDZP0001				

CYLINDER SIZE	FRAME END CLEARANCE	OUTER END CLEARANCE
9.50	.043 .082	.064 .123

CYLINDER SIZE	NUMBER OF LUBRICATION FEEDS			
	CYLINDER TOP	CYLINDER BOTTOM	PACKING	OTHER
9.50	1	1	1	NONE

- FULL LUBE  
 MIN. LUBE  
 NL

PISTON DIAMETER AND MATERIAL	REFER TO FIGURE #1 FOR CLEARANCE LOCATION AND DESCRIPTION						PISTON/RIDER RING MATERIAL AND TYPE
	A	B	C	D	E	F	
9.50 TO .024 CAST IRON	.033 TO .024	.010	.034 TO .020		.015 TO .011	.095 TO .067	(COMBO RING) 2-PC GR. 12 THERMOPLASTIC (ORANGE)



CHG TO: 16C 29C 124C 149C

		<b>DR DRESSER-RAND</b> TULSA, OKLAHOMA 74146	
THIRD ANGLE PROJECTION	DATE	SIZE	STROKE
DRAWN	12/23/93	9.50	6.00
D. J. CHICUORKA	DATE	TYPE	HOS
CHECKED	12/23/93	NAME OF PART	
G. R. LORTIE	DATE	CYLINDER INSTRUCTIONS	
APPROVED	12/23/93	SIZE	FEDERAL SUPPLY CODE
G. R. LORTIE	DATE	B	R82120A-004
		DWG NO.	REV.
			B
		SCALE	NTS
		WT.	
		SHEET 2 OF 3	

# DRESSER-RAND CYLINDER INSTRUCTIONS

## SPECIAL CYLINDER BOLTING TORQUE VALUES

CUSTOMER: SEE LEAD SHEET

ORDER NO.: SEE LEAD SHEET

CYLINDER SERIAL NUMBERS

SEE LEAD SHEET

DESCRIPTION (REFER TO FIGURE 1)	REF. NO. SEE FIGURE 1	BOLT SIZE (INCHES)	FINAL ASSY. & HELIUM TEST STRESS PSI (MPA)	FINAL ASSY. & HELIUM TEST TORQUE FT. LBS. (N-M)	HYDRO TEST STRESS PSI (MPA)	HYDRO TEST TORQUE FT. LBS. (N-M)
CYLINDER TO OUTER HEAD	1	1.000	25,000	220 (300)		
CYLINDER TO VALVE COVER	2	1.000	25,000	220 (300)		
VALVE COVER SET SCREW (INLET)	3					
VALVE COVER SET SCREW (DISCH)	4					
CYLINDER TO FRAME HEAD	5					
CYLINDER TO DISTANCE PIECE	6					
FRAME HD. TO DISTANCE PIECE	7					
DISTANCE PC. TO DISTANCE PC.	8					
FRAME HD. TO PACKING	9	.625	20,000	44 (60)		
INLET & DISCHARGE FLANGE	10	1.000	20,000	175 (237)		
RAM COVER	11					
CYLINDER TIE ROD	12	1.500	40,000	1230 (1670)		

THE TABLE ABOVE REFERS TO SPECIAL TORQUES FOR COMPRESSOR CYLINDER BOLTING ILLUSTRATED ON FIGURE 1.

NOT ALL LOCATIONS ARE USED ON ALL CYLINDER DESIGNS.  
"SEE TIGHTENING INSTRUCTIONS" IN CHAPTER 5 OF THE INSTRUCTION BOOK.

DWG NO.

SH

2

1

### REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	ADDED A & B ON PG 2. REVISED FIGURES ON PG 3 94B0256	5-11-94	JMV
	B	ADDED NEW CYL. INSTR. PLT. ON SH. 2: 96B0021	02/19/96	MDK/GRL

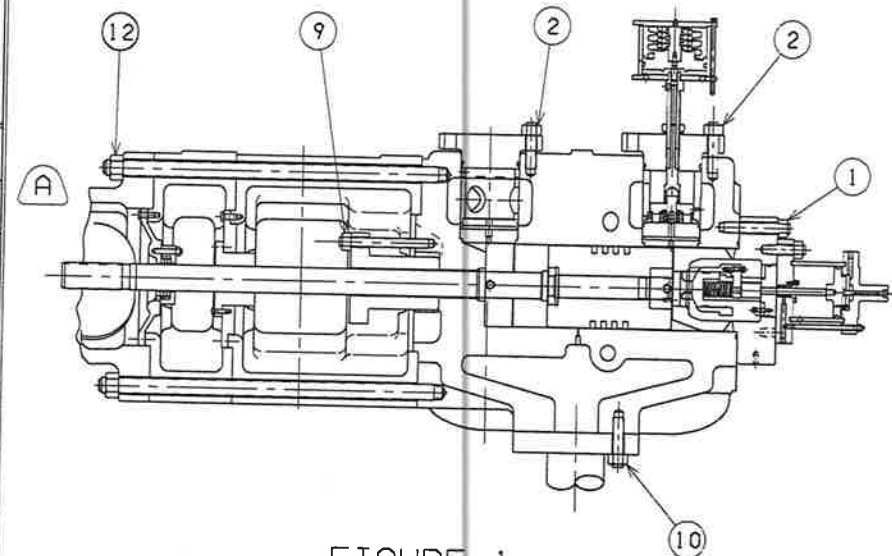


FIGURE 1

CHG TO: 16C 29C 124C 149C

		<b>DR DRESSER-RAND</b> TULSA, OKLAHOMA 74146	
THIRD ANGLE PROJECTION	DATE	SIZE	STROKE
DRAWN D. J. CHICUORKA	12/23/93	9.50	6.00
CHECKED G. R. LORTIE	DATE	NAME OF PART	
	12/23/93	CYLINDER INSTRUCTIONS	
APPROVED G. R. LORTIE	DATE	SIZE/FEDERAL	DRAWING NO.
	12/23/93	B	R82120A-004
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES		SUPPLY CODE	REV.
		B	B
SCALE	NTS	WT.	SHEET 3 OF 3

PLANBT PLAN FORMAT(ANSI 14.5Y 1982) (TULSA)  
B SIZE (FULL 11.00 X 17.00 ) FORMAT

D

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A

DWG NO. R82120A-002 SH 2

CUSTOMER : SEE LEAD SHEET  
 ORDER NO. : SEE LEAD SHEET  
 FRAME SERIAL NO(S.) : SEE LEAD SHEET

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
FOR REV. SEE 3 OF 3				

6.00" AC / PF48

NOTE:  
 1) SEE LEAD SHEET FOR  
 NAMEPLATE STAMPING INFO.

ORIGINAL WITHOUT RIDER BANDS

NYO: NA  
 S/N: NA  
 DRAWINGS  
 CYLINDER: G12196  
 PISTON: H50084P6  
 VALVES: MLH56190BG1 INLET  
 MLH56191BG1 DISCH  
 CLEAR. CALC. BY:

NAME: G. LORTIE

DATE: 12/2/93

NOTE: PISTON AND ROD WEIGHT  
 TO BE STAMPED ON NAMEPLATE  
 AFTER ASSEMBLY HAS BEEN  
 WEIGHED.

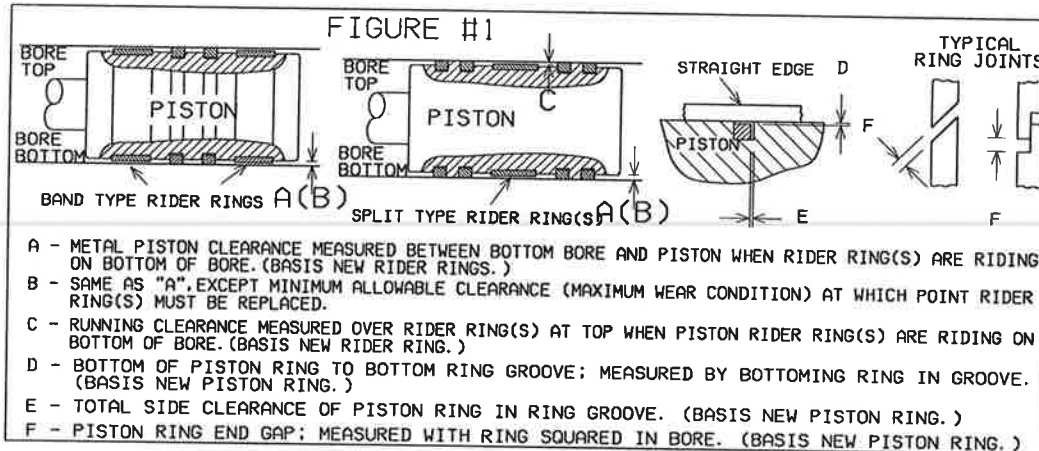
DRESSER-RAND GAS FIELD COMPRESSORS			
CYLINDER TYPE	HOS	SERIAL NO	
NOMINAL BORE	LINERED BORE	STROKE	
6.00 IN 152.4 MM	IN MM	6.00 IN 152.4 MM	
RATED DISCHARGE PRESS.	1750	PSIG	123.04 KG/CM <sup>2</sup>
MAX. ALLOW. WORKING PRESS.	1925	PSIG	135.35 KG/CM <sup>2</sup>
HYDROSTATIC TEST PRESS.	2890	PSIG	203.2 KG/CM <sup>2</sup>
MAX. COOLING WATER PRESS.		PSIG	KG/CM <sup>2</sup>
MAX. ALLOW. DISCH. GAS TEMP.	350	*F	177 *C
MAXIMUM SPEED	1200 RPM		
BASE CYLINDER CLEARANCE	OUTER END	FRAME END	
	24.8 X	29.9 X	
NORMAL LINEAL CLEARANCE	.09 IN 2.3 MM	.06 IN 1.5 MM	
ADDED FIXED CLEARANCE	IN <sup>3</sup> MM <sup>3</sup>	IN <sup>3</sup> MM <sup>3</sup>	
ALWAYS GIVE SERIAL NO. WHEN ORDERING SPARE PARTS			
MADE IN U.S.A. H02P001			

CYLINDER SIZE	FRAME END CLEARANCE	OUTER END CLEARANCE
6.00	.043 .082	.064 .123

CYLINDER SIZE	NUMBER OF LUBRICATION FEEDS			
	CYLINDER TOP	CYLINDER BOTTOM	PACKING	OTHER
6.00	1	1	1	NONE

FULL LUBE  
 MIN. LUBE  
 NL

PISTON DIAMETER AND MATERIAL	REFER TO FIGURE #1 FOR CLEARANCE LOCATION AND DESCRIPTION						PISTON/RIDER RING MATERIAL AND TYPE
	A	B	C	D	E	F	
6.00 1 PIECE CAST IRON	.034 TO .025	.010	.026 TO .012		.013 TO .009	.062 TO .042	(COMBO RING) 2-PC. GR. 12 THERMOPLASTIC (ORANGE)



CHG TO: 16C 29C 124C 149C			
		<b>DR DRESSER-RAND</b> TULSA, OKLAHOMA 74146	
THIRD ANGLE PROJECTION DRAWN D. J. GRANNIS	DATE 1/13/94	SIZE 6.00	STROKE 6.00
CHECKED G. R. LORTIE		DATE 1/13/94	
APPROVED G. R. LORTIE		DATE 1/13/94	
NAME OF PART CYLINDER INSTRUCTIONS		SIZE B	FEDERAL SUPPLY CODE
DWG NO. R82120A-002		REV. B	
SCALE NTS	WT.	SHEET 2 OF 3	

D

C

B

A

# DRESSER-RAND CYLINDER INSTRUCTIONS

## SPECIAL CYLINDER BOLTING TORQUE VALUES

CUSTOMER: SEE LEAD SHEET ORDER NO.: SEE LEAD SHEET

CYLINDER SERIAL NUMBERS

SEE LEAD SHEET

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	ADDED A & B ON PG 2. REVISED FIGURES ON PG 3 94B0245	5-11-94	JMV
	B	ADDED NEW CYL. INSTR. PLT. ON SH. 2: 96B0021	02/19/96	MDK/GRL

DESCRIPTION (REFER TO FIGURE 1)	REF. NO. SEE FIGURE 1	BOLT SIZE (INCHES)	FINAL ASSY. & HELIUM TEST STRESS PSI (MPA)	FINAL ASSY. & HELIUM TEST TORQUE FT. LBS. (N-M)	HYDRO TEST STRESS PSI (MPA)	HYDRO TEST TORQUE FT. LBS. (N-M)
CYLINDER TO OUTER HEAD	1	1.125	25,000	330 (450)		
CYLINDER TO VALVE COVER	2	1.000	25,000	220 (300)		
VALVE COVER SET SCREW (INLET)	3					
VALVE COVER SET SCREW (DISCH)	4					
CYLINDER TO FRAME HEAD	5					
CYLINDER TO DISTANCE PIECE	6					
FRAME HD. TO DISTANCE PIECE	7					
DISTANCE PC. TO DISTANCE PC.	8					
FRAME HD. TO PACKING	9	.750	20,000	76 (103)		
INLET & DISCHARGE FLANGE	10	1.125	20,000	260 (355)		
RAM COVER	11					
CYLINDER TIE ROD	12	1.500	40,000	1230 (1670)		

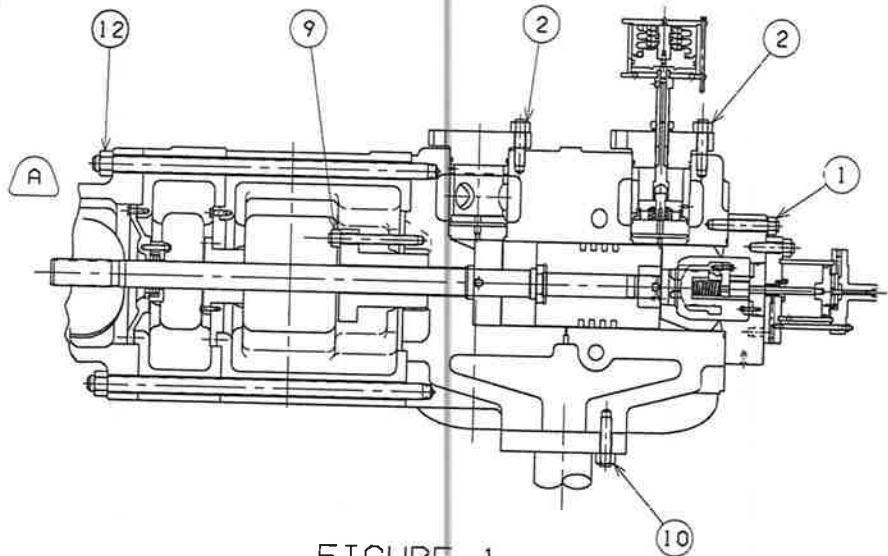


FIGURE 1

THE TABLE ABOVE REFERS TO SPECIAL TORQUES FOR COMPRESSOR CYLINDER BOLTING ILLUSTRATED ON FIGURE 1.  
 NOT ALL LOCATIONS ARE USED ON ALL CYLINDER DESIGNS.  
 "SEE TIGHTENING INSTRUCTIONS" IN CHAPTER 5 OF THE INSTRUCTION BOOK.

CHG TO: 16C 29C 124C 149C			
		<b>DR DRESSER-RAND</b> TULSA, OKLAHOMA 74146	
THIRD ANGLE PROJECTION	SIZE	STROKE	TYPE
DRAWN D. J. GRANNIS	6.00	6.00	HOS
CHECKED G. R. LORTIE	NAME OF PART CYLINDER INSTRUCTIONS		
APPROVED G. R. LORTIE	SIZE/FEDERAL B	SUPPLY CODE	DRAWING NO. R82120A-002
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES		SCALE	REV. B
		NTS	WT.
		SHEET 3 OF 3	



**6HOS4 FRAME**

**6HF853 / 6HF854**



2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

6HF853/6HF854		FRAME 6HOS4			OI	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
	.MLAAHK0401G2	F & G 6HOS4 STD.	1.00	EA		
	.ML11373230G1	COVER FR PUMP END	1.00	EA		
	.MLWAZA2402G1	OIL FILTER ASSY 2/4 HOS/DVIP (CAST HEAD	1.00	EA		
	.W106865	COOLER,FR RDS 4-6TH	1.00	EA	M	
	.MLH50032CG1	CYLINDER BALANCE 6HOS 160.6 LBS	1.00	EA		
	.MLW140338G6	WEIGHT XHD BAL 23.8#	1.00	EA		

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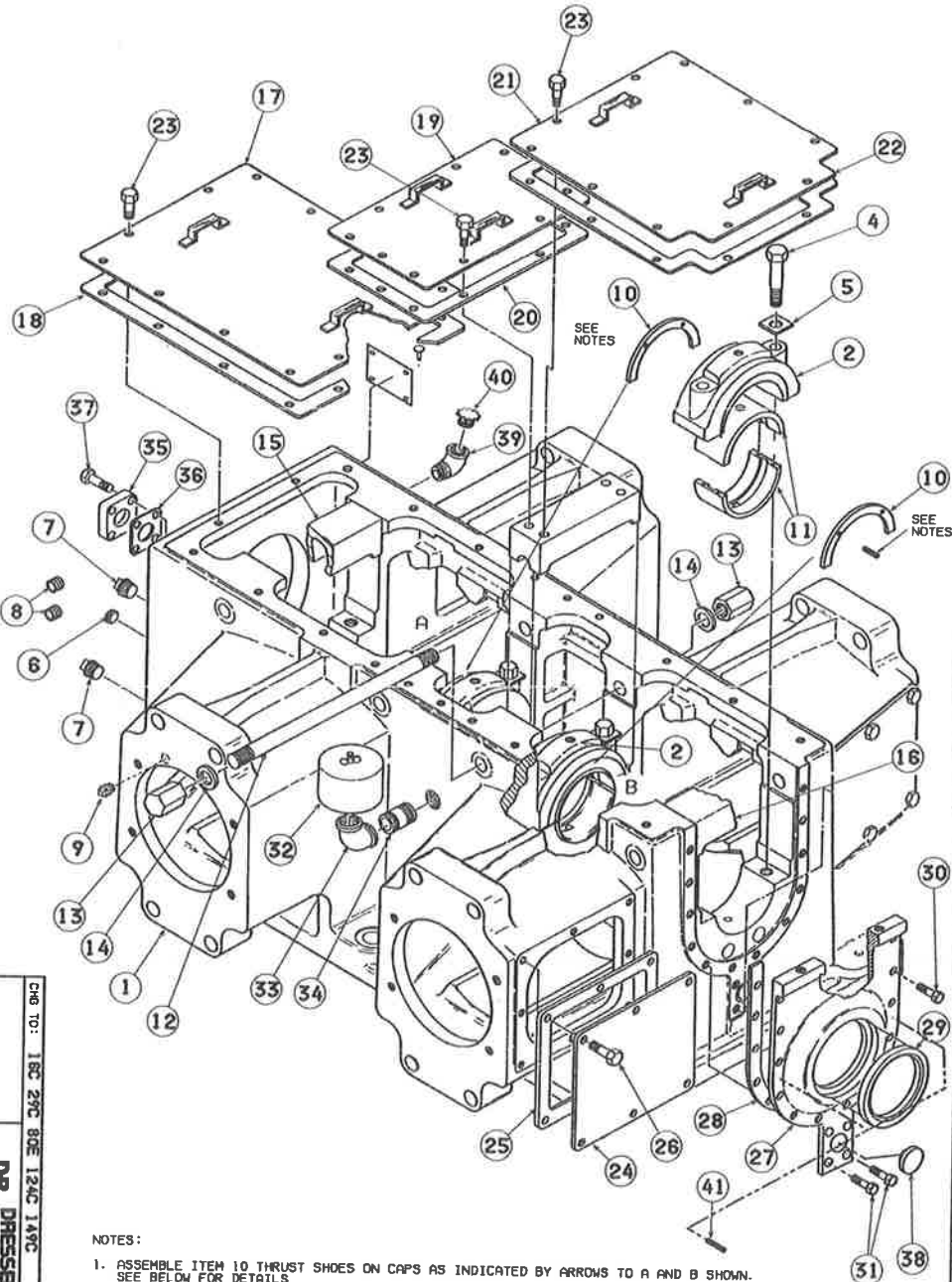
DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

2000/09/21

MLAAHK0401G2		F & G 6HOS4 STD.			1999B0175	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
	.MLAAHA4001G1	FRAME ASSEMBLY 6HOS4/D-VIP4 (STD)	1.00	EA		
	.MLBAHA4001G1	CRANKSHAFT 6HOS4	1.00	EA		
	.MLH52699G6	CONNECTING ROD 6HOS (STD)	4.00	EA		
	.MLH54288G12	CROSSHEAD HOS, STANDARD	4.00	EA		
	.MLFAZA4001G1	PUMP, OIL ASSY COMPLETE 4TH HOS/D-VIP	1.00	EA		
	.MLH50006G1	PUMP, PRIMING	1.00	EA		
	.MLW129085AG1	CONNECTION FR OIL	1.00	EA		
	.ZBHM0001	ADAPTER, PISTON NUT HOS	1.00	EA		
	.ADHP0001	NAMEPLATE, HOS	1.00	EA		
	.122A2S78	DRIVESCREW	4.00	EA		

# FOUR THROW FRAME ASSEMBLY

(B)



**NOTES:**

- ASSEMBLE ITEM 10 THRUST SHOES ON CAPS AS INDICATED BY ARROWS TO A AND B SHOWN. SEE BELOW FOR DETAILS.
  - LOCATE THE PRE-DRILLED THRUST SHOES ON THE MAIN BEARING CAPS USING THE SHOE AS A TEMPLATE. DRILL .250 DIA. HOLES / .65 DEEP IN THE CAP.
  - INSTALL THE ROLLPIN IN THE CAP AND INSURE THE PROJECTION OF THE PIN IS AT LEAST .380(IN.) OUT OF THE CAP (INTO THE SHOE).
  - LOCATE THE THRUST SHOE ON THE PROJECTING ROLLPINS. FOR ASSEMBLY.

AAHA4001

REVISIONS		DATE	APPROVED
A	ADDED ITEM #1 ROLLPIN	2/18/79	K.M.L./T.B.
B	REPLACED THRUST SHOES TO BEAD ROLL PIN	5/27/79	K.M.L./D.F.

CHG TO: 1BC 2YC 80E 124C 1A9C <b>DR DRESSER-RAND</b>		DATE 11/10/78
DESIGNED BY K.M. LOONEY	CHECKED BY T. GRESHAM	DATE 11/10/78
DRAWING NO. AAHA4001	SIZE 4 1/4" x 5 7/8"	TYPE HCS/VPD
SHEET 1 OF 1	SCALE 1:1	TITLE FOUR THROW FRAME ASSEMBLY

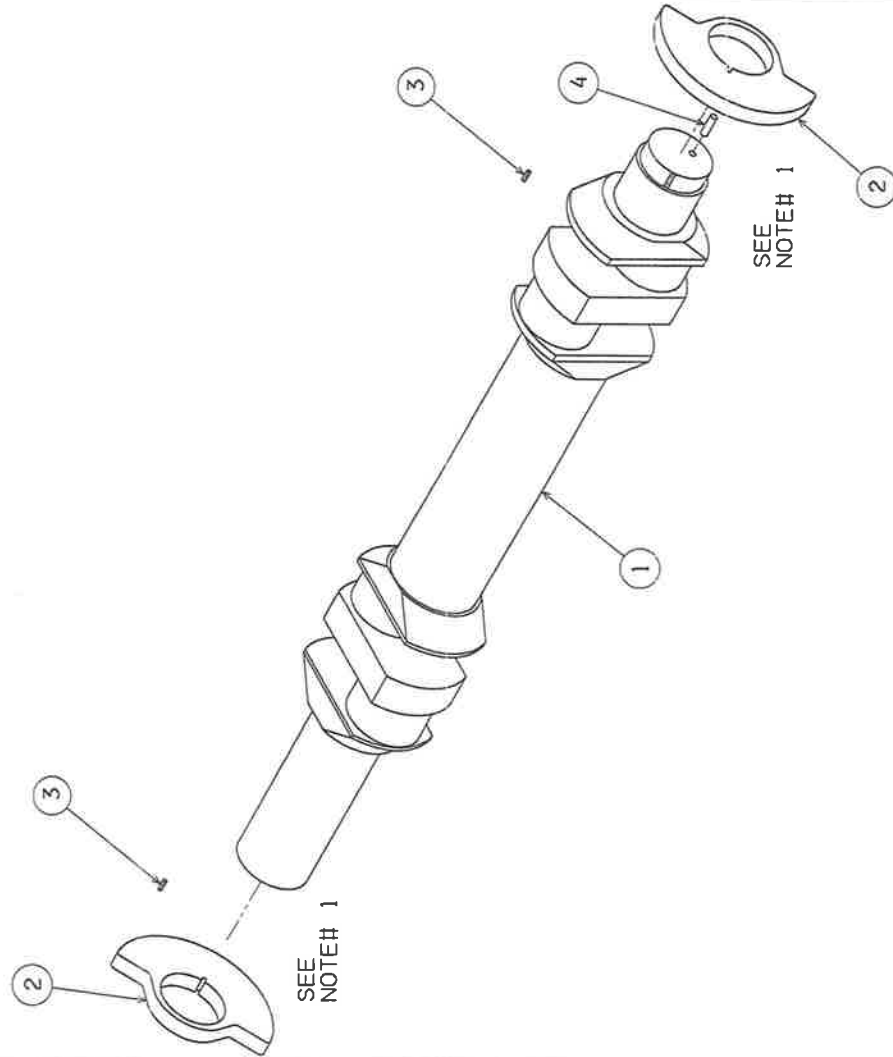
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLAAHA4001G1		FRAME ASSEMBLY 6HOS4/D-VIP4 (STD)	1999B0450		
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE
	.AAHK4101	FRAME HOS4/D-VIP4	1.00	EA	
	.MLAAHK4201G1	FRAME HOS4/D-VIP4	1.00	EA	
001	..AAHM4001	FRAME HOS/VPD4	1.00	EA	
002	..ABHM2401	CAP, MN BRG THRUST HOS/VPD	4.00	EA	
002	..ABHM2402	CAP, MN BRG THRUST HOS/VPD SRVC	4.00	EA	
004	.W36756	BOLT, MAIN BEARING CAP	8.00	EA	
005	.W29804	BOLT, LOCK HOS MAIN BRG	8.00	EA	
006	.W82537	GAUGE, OIL LEVEL RDS/HOS	1.00	EA	M
007	.30A7S10	PIPE PLUG 2.00 NPT	2.00	EA	
008	.11021946	PIPE PLUG .50 NPT	2.00	EA	
009	.11021953	PIPE PLUG .75 NPT	6.00	EA	
010	.1EFZP2001	THRUST SHOE (KIT WITH ROLLPINS)	2.00	EA	
011	.EAZP2001	SHELL, MAIN BEARING HALF, HOS/VPD	8.00	EA	
012	.1W139460	TIEROD MAIN BRG	4.00	EA	
013	.46A4K14	NUT 1.50X8UNC HEAVY HEX	2.00	EA	
014	.X1016T6	WASHER	2.00	EA	
015	.R16912AP2	SPACER	2.00	EA	
016	.R16912AP2	SPACER	2.00	EA	
017	.MLRAZM4001G1	COVER FRAME TOP		EA	
018	.VAZM4001	GASKET FRAME TOP ### SEE NOTE ###	1.00	EA	OC
019	.MLRAZM4002G1	COVER FRAME TOP	1.00	EA	
020	.VAZM4002	GASKET FRAME TOP	1.00	EA	OC
021	.MLRAZM4003G1	COVER FRAME TOP	1.00	EA	
022	.VAZM4003	GASKET FRAME TOP	1.00	EA	OC
023	.35A2C217	CAPSCREW	32.00	EA	
024	.W102367A	COVER FR CROSSHEAD, HOS	4.00	EA	
025	.W30768B	GASKET X-HEAD DOOR	4.00	EA	ROCEM
026	.35A2C217	CAPSCREW	32.00	EA	
	.RCZK0004	COVER OIL RING VPD4	1.00	EA	
027	.RCZM0002	COVER DRIVE END (6HOS2/4)	1.00	EA	
041	.25A13C289	ROLLPIN	2.00	EA	
028	.VAZM0002	GASKET, END COVER, HOS/VPD	1.00	EA	
029	.W76556C	SEAL, CRANKSHAFT WAS 1W76556	1.00	EA	ROCEM
030	.35A2C232	CAPSCREW	14.00	EA	
031	.35A2C219	CAPSCREW	2.00	EA	
032	.W82559	BREATHING, FRAME	1.00	EA	O EM
033	.65A7M9	ELBOW	1.00	EA	
034	.2SCH40S4.0C	NIPPLE	1.00	EA	
035	.1UBHM0001	FLANGE FRAME OIL INLET	1.00	EA	
	.11021920	PLUG PIPE .25 NPT	2.00	EA	
036	.W129064	GASKET OIL HEADER	1.00	EA	ROCEM
037	.35A2C224	CAPSCREW	4.00	EA	
038	.9211WA	SWITCHGAUGE, OIL PRESSURE	1.00	EA	
039	.68A7M8	ELBOW 45 DEG ST	1.00	EA	

# CRANKSHAFT

BAHA4001



NOTE:  
1. ITEM 2 (COUNTERWEIGHTS) ARE INTERFERENCE FIT ON THE CRANKSHAFT

CHG TO: 16C, 29C, 80, 124C, 149C

ML ISSUED

**DR DRESSER-RAND**  
TULSA, OKLAHOMA 79146

DRAWN K. W. LOCEY	DATE 7/06/98
CHECKED T. GRESHAM	DATE 7/06/98
APPROVED K. W. LOCEY	DATE 7/06/98

SIZE 4 THROW	STROKE 6.00	TYPE HOS
-----------------	----------------	-------------

NAME OF PART  
CRANKSHAFT

SIZE C	FEDERAL SUPPLY CODE	DRAWING NO. BAHA4001	ML -	REV. -
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LTR	DESCRIPTION	DATE	APPROVED
REVISIONS			

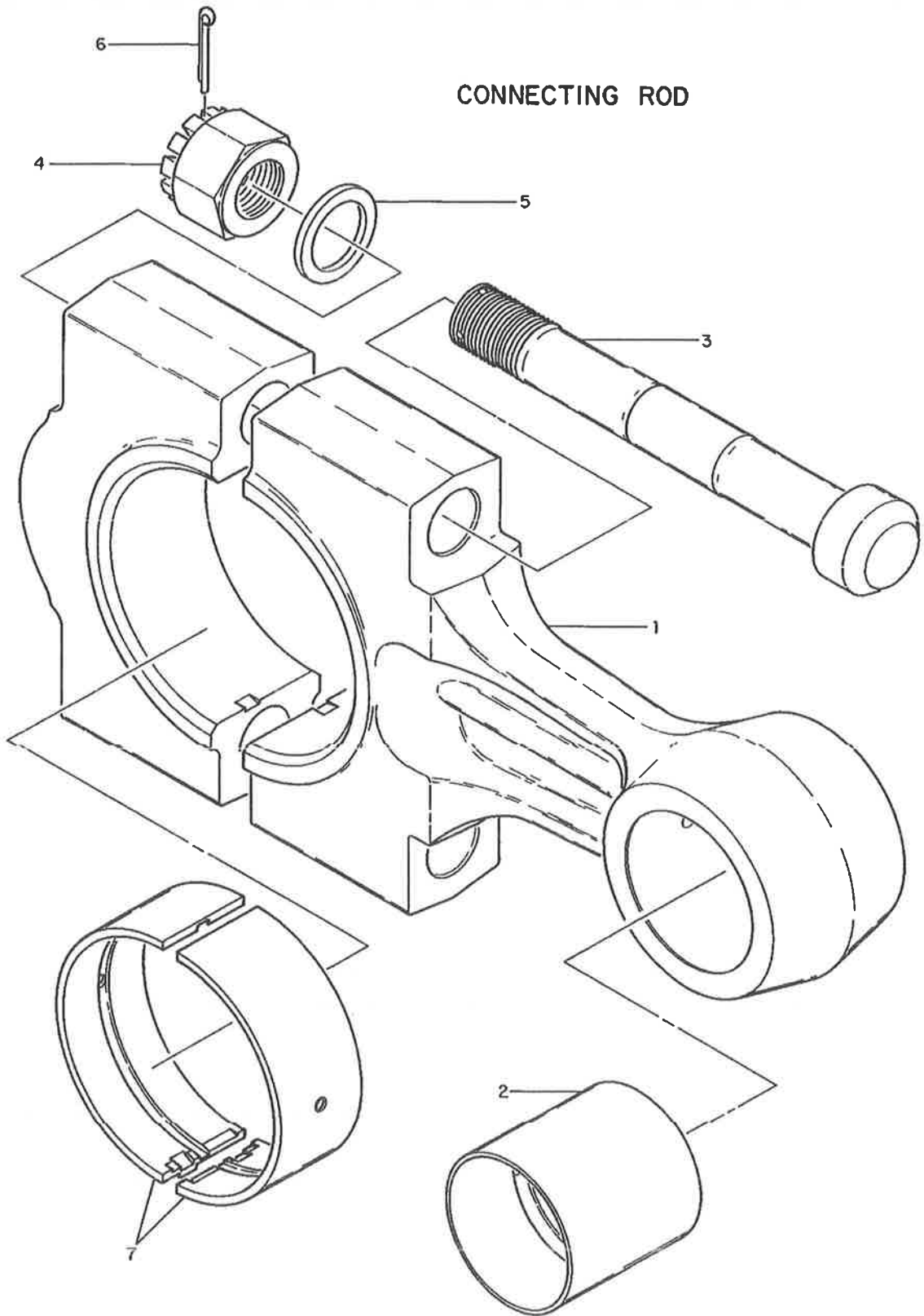
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES  
SCALE NTS WT. SHEET 1 OF 1

2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLBAHA4001G1		CRANKSHAFT 6HOS4			1999B0076	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.BAHK4001	CRANKSHAFT 6HOS4	1.00	EA	M	
002	.XBHM4401	COUNTERWEIGHT HOS4	2.00	EA		
003	.VKZM0001	KEY .375X1.25	2.00	EA		
004	.17A13A416	PIN, PUMP OIL HUB	1.00	EA	O EM	

# D-R PARTS LIST



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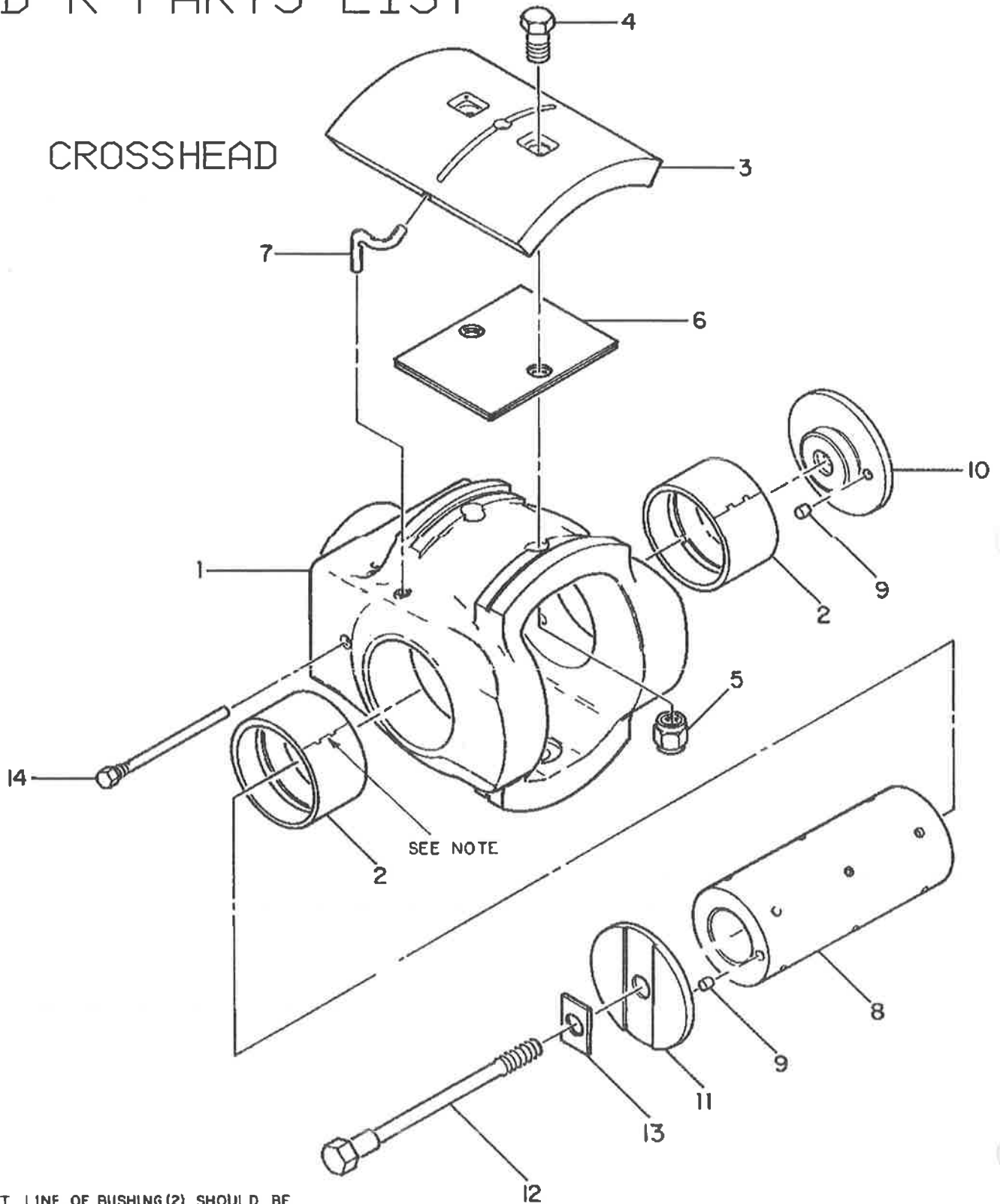
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH52699G6		CONNECTING ROD 6HOS (STD)		OI	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE
001	.1F32150A	CONNECTING ROD HOS (STD) USE MLH52699G6	1.00	EA	M
002	.EBHP0001	BUSHING CONN ROD	1.00	EA	O EM
003	.1R74322	BOLT, CONNROD	2.00	EA	EM
004	..R74323	NUT CONNROD BOLT, VPD / HOS / HHE-VB	1.00	EA	
005	..W86526	WASHER BOLT NUT	1.00	EA	EM
006	..11A13C88E	PIN, COTTER CONNROD NUT	1.00	EA	
007	.12531562	BEARING CONNROD	1.00	EA	O EM

# D-R PARTS LIST

## CROSSHEAD



SEE NOTE

NOTE  
SPLIT LINE OF BUSHING (2) SHOULD BE  
90° FROM NOSE OF CROSSHEAD WHILE  
MAINTAINING ALIGNMENT OF OIL HOLES

H54288

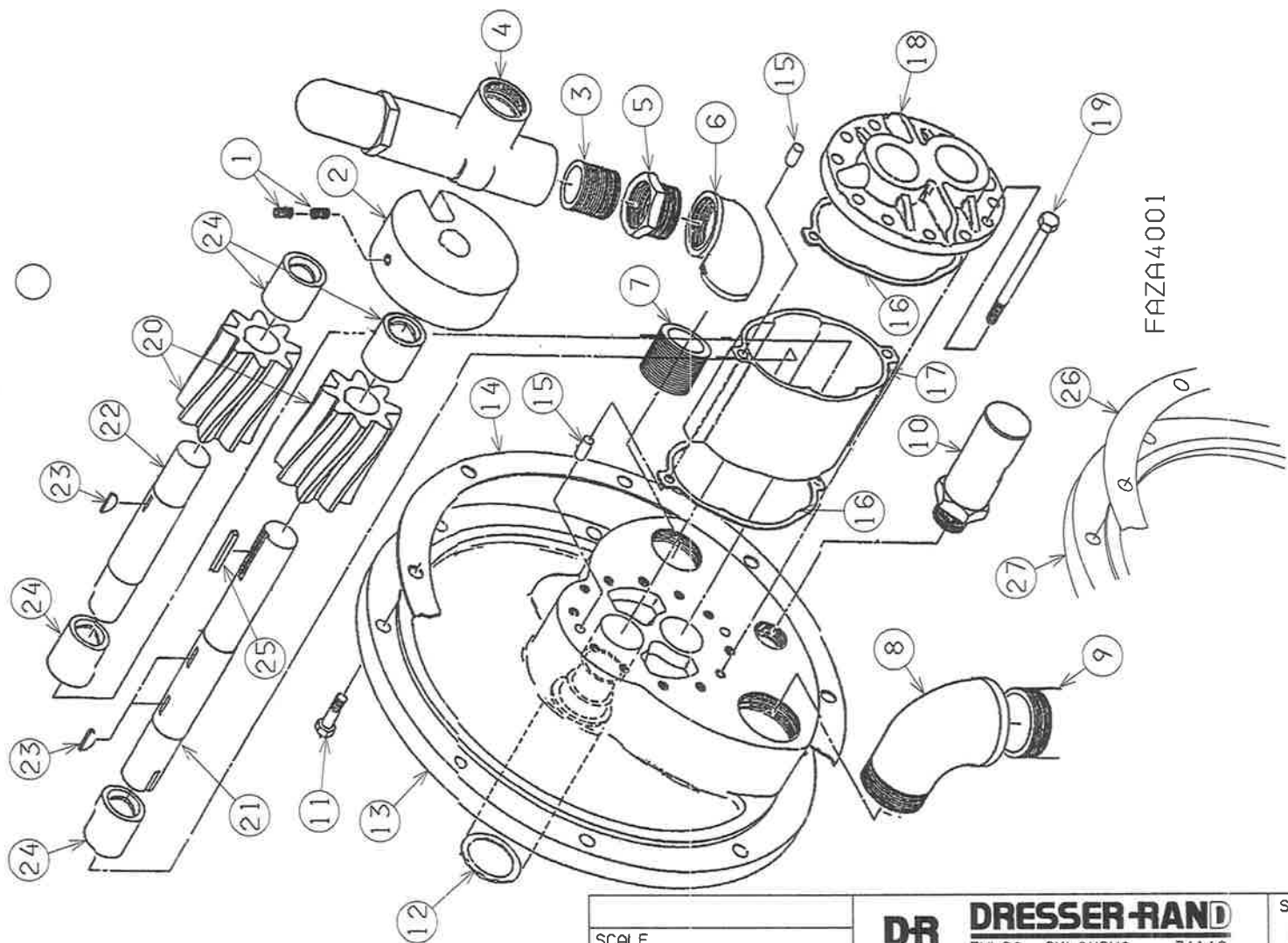
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH54288G12		CROSSHEAD HOS, STANDARD			1997B0639	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.1H49923C	CROSSHEAD HOS STD (NI)	1.00	EA	M	
002	.R71921A	BUSHING, CROSSHEAD HOS	2.00	EA	O EM	
003	.1H27213B	SHOE, CROSSHEAD HOS	2.00	EA	O EM	
004	.W98039	BOLT, CROSSHEAD SHOE HOS	2.00	EA		
005	.W122156	NUT,	2.00	EA		
006	.2VG493	SHIM SET X-HEAD	1.00	EA	ROCEM	
007	.W145445	PIPE, CROSSHEAD OIL HOS	2.00	EA		
008	.R71923	PIN, CROSSHEAD HOS	1.00	EA	O EM	
009	.29A13F106	GROOVE PIN	2.00	EA		
010	.W28027	CAP, CROSSHEAD	1.00	EA		
011	.W25452	CAP, DRILLED PIN CROSSHEAD PIN COVER	1.00	EA		
012	.W25453	BOLT, CROSSHEAD	1.00	EA		
013	.W28028	BOLT, LOCK RDS CROSSHEAD PIN	1.00	EA	EM	

CHG TO: 16C 29C 80E 109C 149C  
 UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES

OIL PUMP ASSEMBLY



FAZA4001

LTR	DESCRIPTION	DATE	APPROVED
A	REMOVED 2 SETSCREWS AT ITEM 1 99B0478	10/25/99	KWL/GWT
REVISIONS			

SCALE NTS		<b>DR DRESSER-RAND</b> TULSA, OKLAHOMA 74146		SIZE A
DRAWN K. W. LOCEY	DATE 4/12/99	SIZE	STROKE	TYPE HOS/VPD
CHECKED J. D. CARR	DATE 4/12/99	NAME OF PART OIL PUMP ASSEMBLY		
APPROVED K. W. LOCEY	DATE 4/12/99	FED. SUPPLY CODE	DRAWING NO. FAZA4001	REV. A

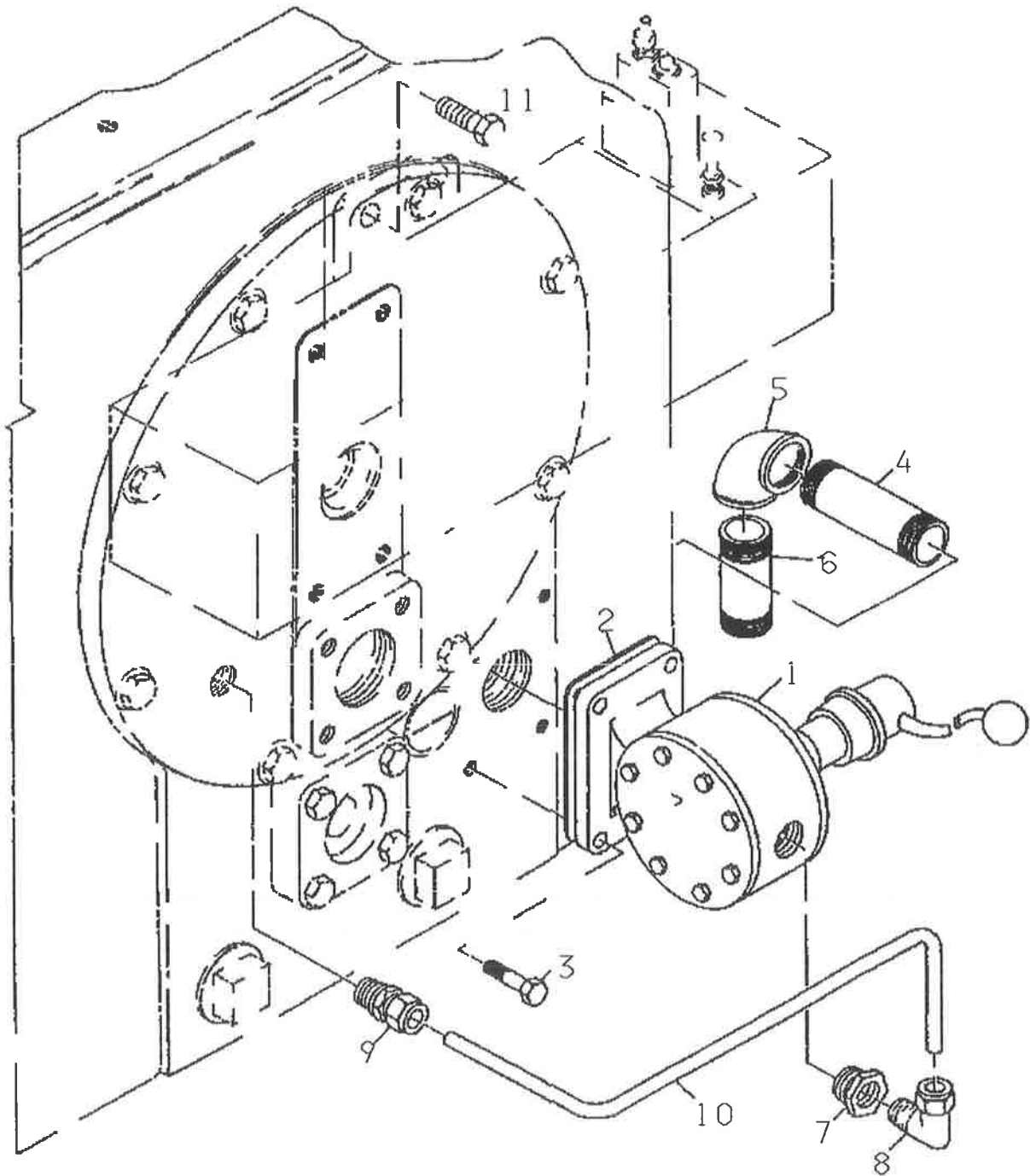
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLFAZA4001G1		PUMP, OIL ASSY COMPLETE 4TH HOS/D-			1999B0478	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
	.MLFAZA4002G1	PUMP, OIL SUB-ASSY 4TH HOS/D-VIP	1.00	EA		
001	.109A2A47	SETSCREW HEX SKT	2.00	EA	EM	
002	.W86236P1	HUB, HOS	1.00	EA		
003	.1.25SCH80J2.0C	NIPPLE	1.00	EA		
004	.W82718	VALVE,RELIEF PUMP OIL RDH/VIP	1.00	EA	M	
005	.23A7M21	BUSHING REDUCING	1.00	EA		
006	.65A7M8	ELBOW 90 DEGREE	1.00	EA		
007	.1.5SCH80J2.2C	NIPPLE	1.00	EA		
008	.67A7M9	ELBOW 90 DEG ST	1.00	EA		
009	.1UEHW0002	PIPE SUCTION WITH SCREEN 6HOS2/4	1.00	EA		
010	.W63792	VALVE,RELIEF PUMP OIL	1.00	EA	M	

# D-R PARTS LIST

## PRIMING PUMP ASSEMBLY



H50006

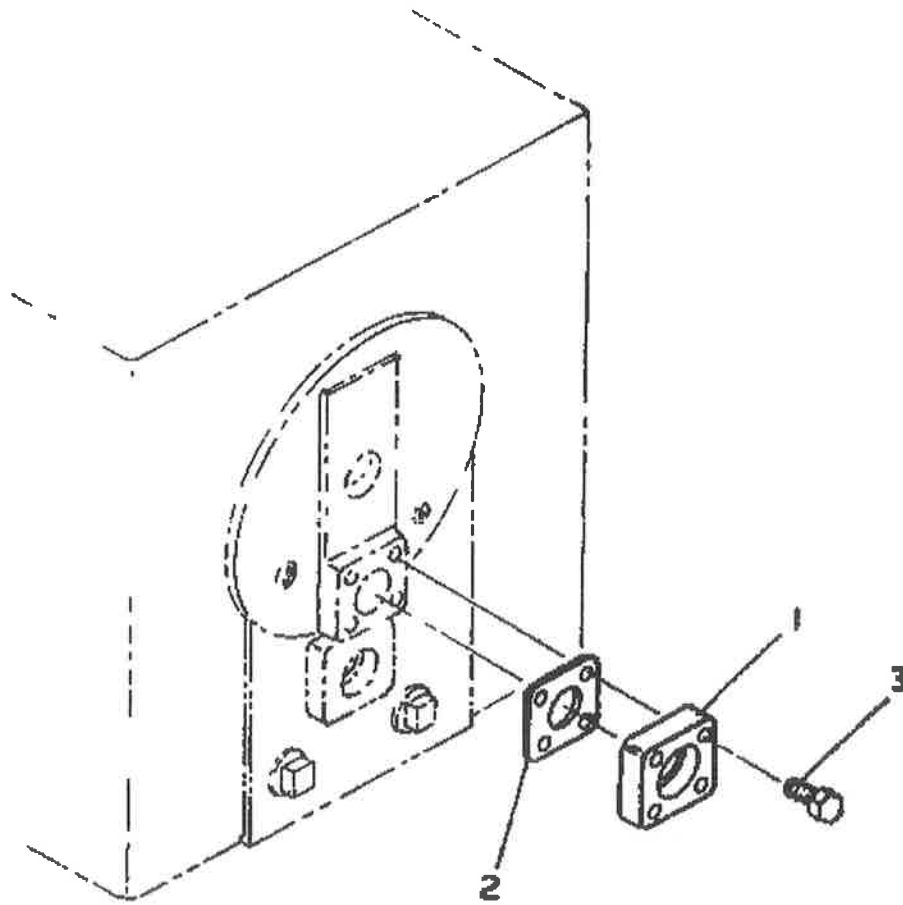
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH50006G1		PUMP, PRIMING			1996B0737	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.W92433	PUMP, PRIMING H03/4A4A-H/S1	1.00	EA	O EM	
002	.W93326	GASKET PRIM'G PUMP	1.00	EA	ROCEM	
003	.35A2C111	CAPSCREW	4.00	EA		
004	.1SCH80J4.0C	NIPPLE	1.00	EA		
005	.65A7M6	ELBOW 90 DEGREE	1.00	EA		
006	.1SCH80J3.0C	NIPPLE	1.00	EA		
007	.23A7M7	BUSHING REDUCING	1.00	EA		
008	.428A10S15	ELBOW MALE	1.00	EA		
009	.426A10S17	CONNECTOR MALE	1.00	EA		
010	.33942186	TUBING 0.50X035W	24.00	IN		
011	.35A2C221	CAPSCREW	4.00	EA		

# D-R PARTS LIST

## FRAME OIL DISCHARGE CONNECTION



W129085A



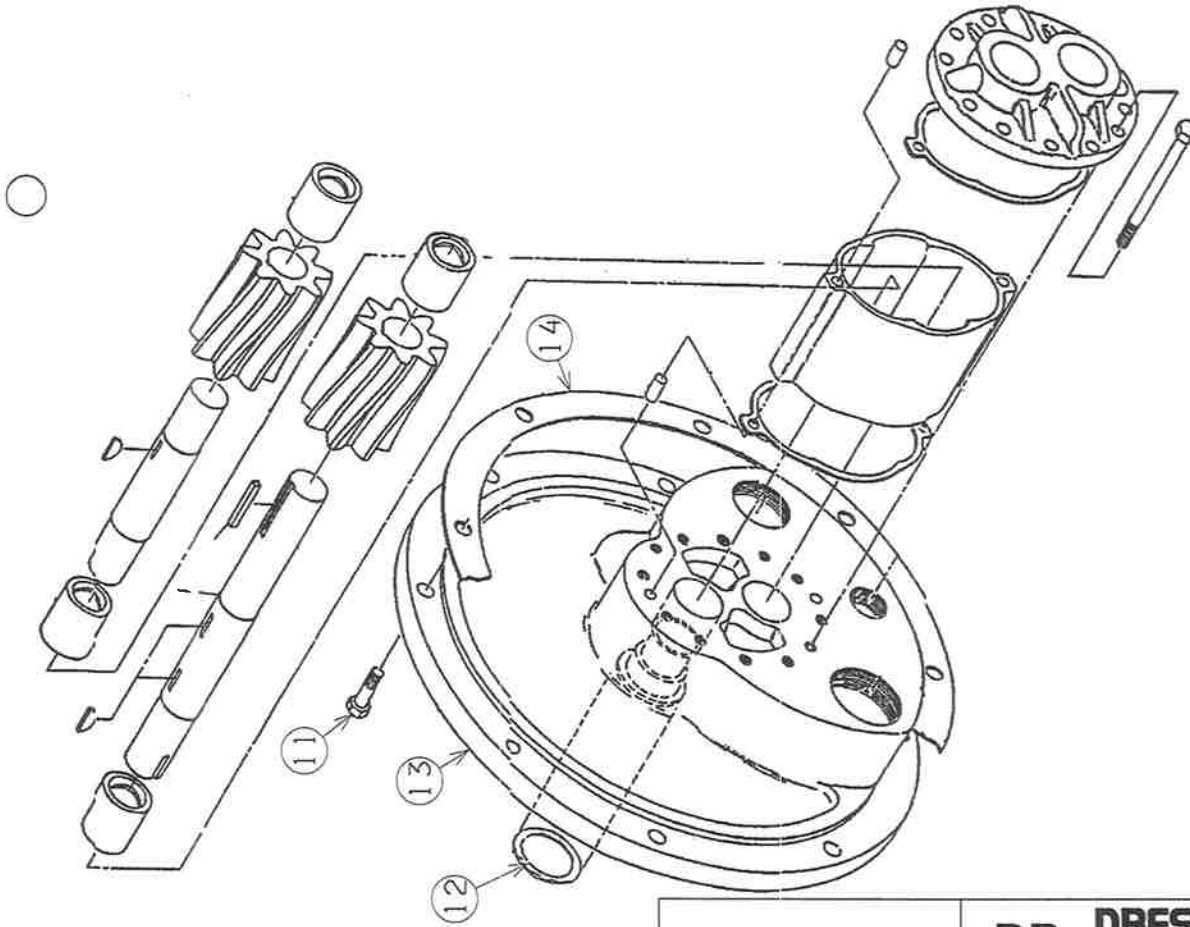
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLW129085AG1		CONNECTION FR OIL			1986B0318	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.R64772	FLANGE, HOS/RDS	1.00	EA		
002	.W129064	GASKET OIL HEADER	1.00	EA	ROCEM	
003	.119A2A254	CAPSCREW	4.00	EA		

CHG TO: 16C 29C 80E 109C 149C  
 UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES

OIL PUMP SUB ASSEMBLY



FAZA4002

LTR	DESCRIPTION	DATE	APPROVED
	REVISIONS		

SCALE		NTS	
DRAWN	DATE		
K. W. LOCEY	4/12/99		
CHECKED	DATE		
J. D. CARR	4/12/99		
APPROVED	DATE		
K. W. LOCEY	4/12/99		

<b>DR DRESSER-RAND</b>			SIZE
TULSA, OKLAHOMA 74146			A
SIZE	STROKE	TYPE	
		HOS/VPD	
NAME OF PART			
OIL PUMP SUB ASSEMBLY			
FED. SUPPLY CODE	DRAWING NO.	REV.	
	FAZA4002		

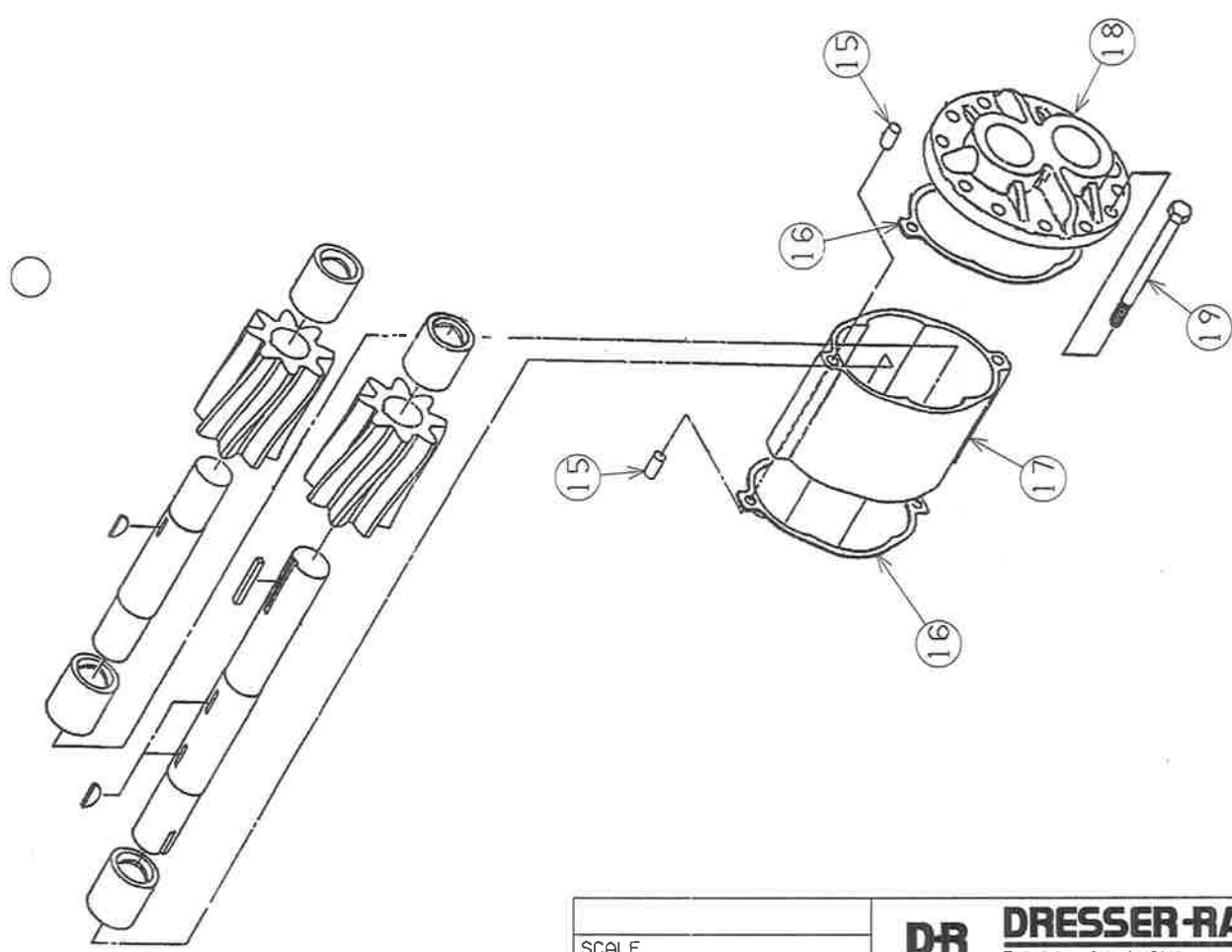
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLFAZA4002G1		PUMP, OIL SUB-ASSY 4TH HOS/D-VIP			OI
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE
	.MLFAZA4003G1	PUMP, OIL SUB-ASSY 4TH HOS/D-VIP	1.00	EA	
011	.35A2C219	CAPSCREW	8.00	EA	
012	.20A11CM328	ORING	1.00	EA	ROCEM
013	.1F17271B	COVER FRAME END	1.00	EA	
002	.W31371P1	BUSHING, OIL PUMP	2.00	EA	O EM
014	.W76487	GASKET FRAME COVER	1.00	EA	ROCEM

CHG TO: 16C 29C 80E 109C 149C  
 UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES

OIL PUMP SUB ASSEMBLY



FAZA4003

LTR	DESCRIPTION	DATE	APPROVED
	REVISIONS		

SCALE NTS		<b>DR DRESSER-RAND</b> TULSA, OKLAHOMA 74146		SIZE A
DRAWN K. W. LOCEY	DATE 4/12/99	SIZE	STROKE	TYPE HOS/VPD
CHECKED J. D. CARR	DATE 4/12/99	NAME OF PART OIL PUMP SUB ASSEMBLY		
APPROVED K. W. LOCEY	DATE 4/12/99	FED. SUPPLY CODE	DRAWING NO. FAZA4003	REV.

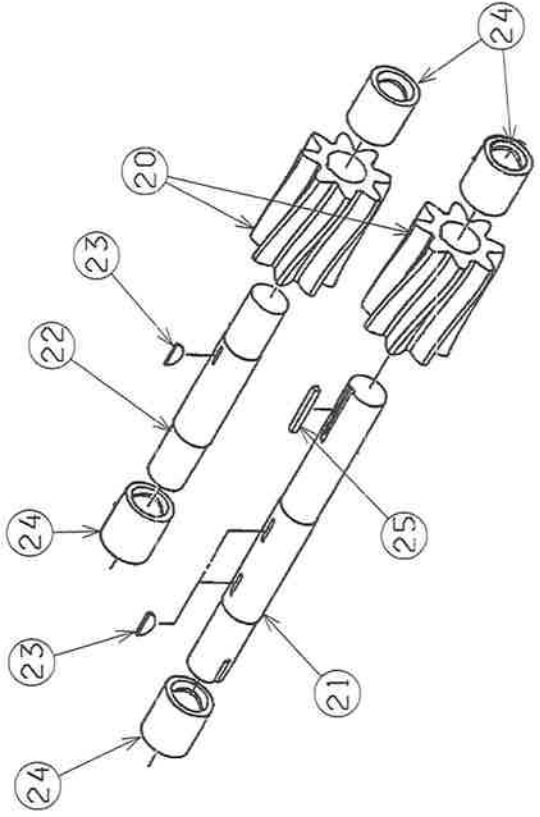
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLFAZA4003G1		PUMP, OIL SUB-ASSY 4TH HOS/D-VIP			OI
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE
	.MLFAZA4004G1	PUMP, OIL SUB-ASSY (SHAFT/GEARS)	1.00	EA	
015	.17A13A208	DOWEL PIN	4.00	EA	
016	.R74379A	GASKET, PUMP OIL 2 /4 THROW NEW STYLE	2.00	EA	ROCEM
017	.1H52753A	BODY OIL PUMP	1.00	EA	
004	.17A13A208	DOWEL PIN	4.00	EA	
018	.1H26851B	HEAD, OIL PUMP HOS/RDS/HHE	1.00	EA	
002	.W31371P1	BUSHING, OIL PUMP	2.00	EA	O EM
019	.35A2C129	CAPSCREW	12.00	EA	

CHG TO: 16C 29C 80E 109C 149C  
 UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES

OIL PUMP SUB ASSEMBLY  
 (SHAFT AND GEARS) ○



FAZA4004

LTR	DESCRIPTION	DATE	APPROVED
	REVISIONS		

SCALE NTS		<b>DR DRESSER-RAND</b> TULSA, OKLAHOMA 74146		SIZE A
DRAWN K. W. LOCEY	DATE 4/12/99	SIZE	STROKE	TYPE HOS/VPD
CHECKED J. D. CARR	DATE 4/12/99	NAME OF PART OIL PUMP SUB ASSEMBLY		
APPROVED K. W. LOCEY	DATE 4/12/99	FED. SUPPLY CODE	DRAWING NO. FAZA4004	REV.

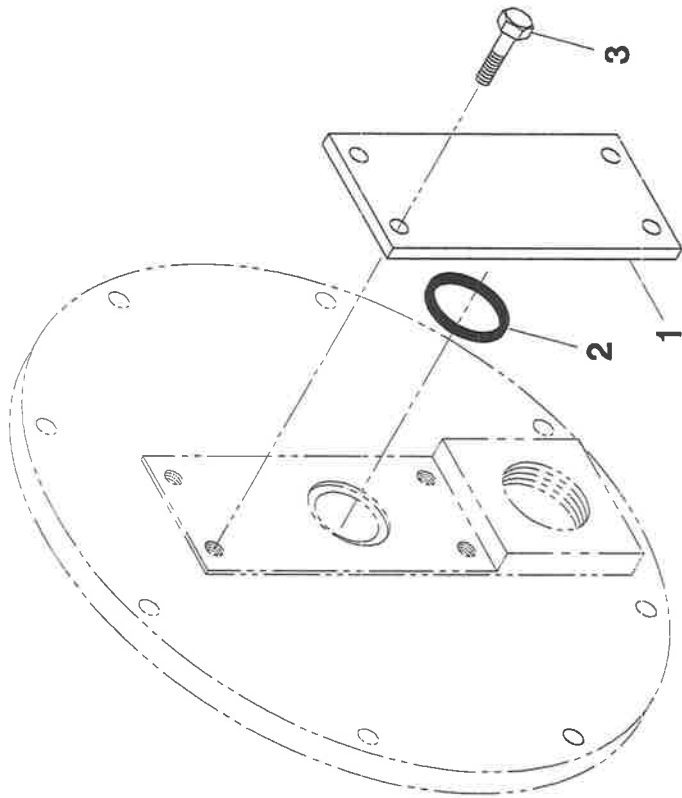
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLFAZA4004G1		PUMP, OIL SUB-ASSY (SHAFT/GEARS)			1999B0206	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
023	.23A9C807	KEY, WOODRUFF OIL PUMP	3.00	EA	M	
024	.W31371P1	BUSHING, OIL PUMP	4.00	EA	O EM	
025	.11A9C83	KEY	1.00	EA		

# FRAME PUMP END COVER

11373230



19871 (SHEET) COMPANY (1989) (TULSA) (DRESSER)  
 C-SIZE (FULL 11.00 X 22.00) FORM

CHG TO: 29c 109 124c 149c

ML ISSUED

**DR DRESSER-RAND**  
TULSA, OKLAHOMA 79146

DRAWN  
J. CRISS

DATE  
1/5/89

SIZE STROKE TYPE  
RDS

CHECKED  
H. NUSOM

DATE  
1/5/89

NAME OF PART  
FRAME PUMP END COVER

APPROVED  
H. NUSOM

DATE  
1/5/89

SIZE FEDERAL DRAWING NO. ML REV.  
SUPPLY CODE 11373230 -

LTR	DESCRIPTION	DATE	APPROVED
REVISIONS			

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES

SCALE NTS WT. SHEET 1 OF 1

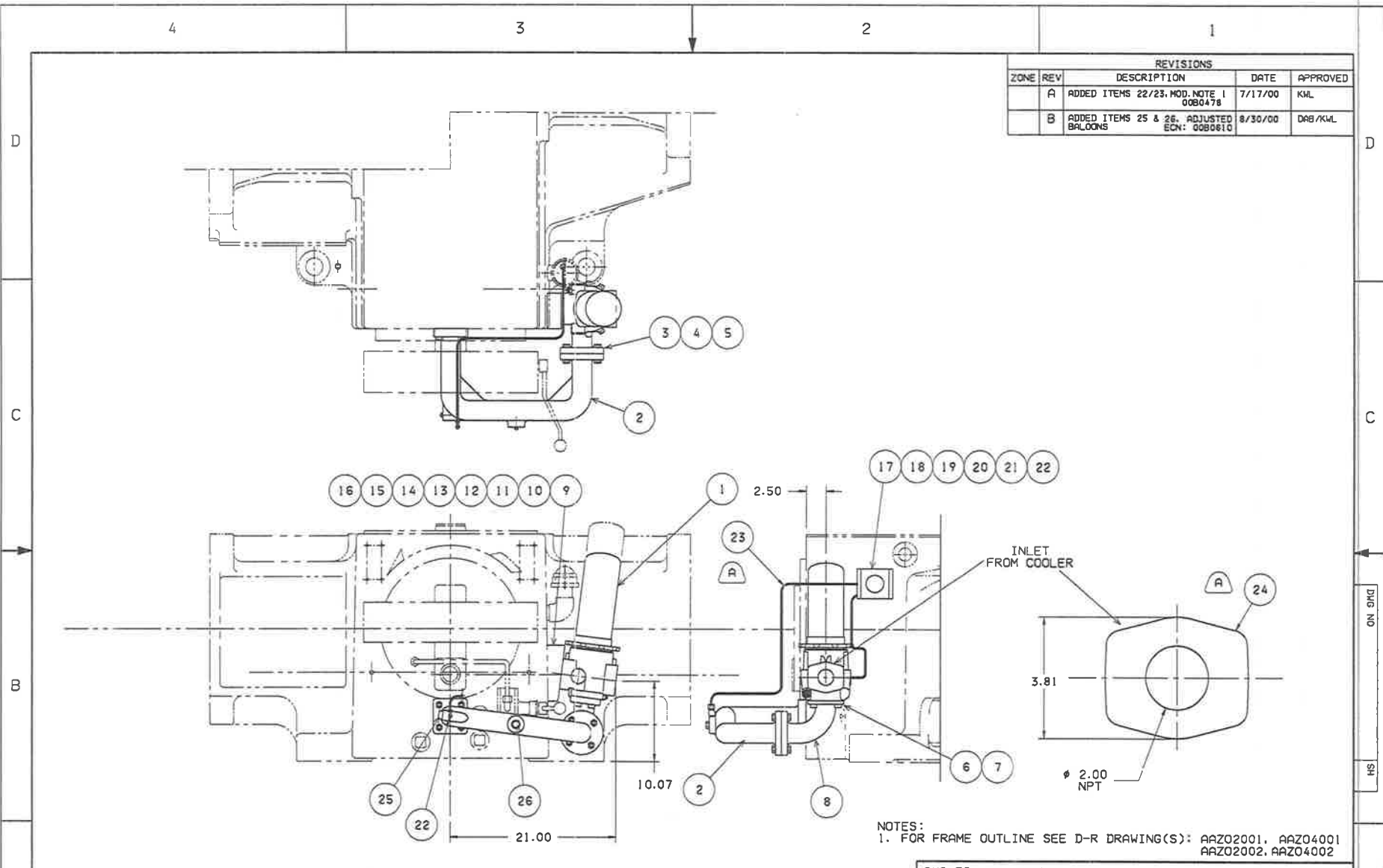


2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

ML11373230G1		COVER FR PUMP END			OI	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.W129061	COVER LUBR DR	1.00	EA		
002	.20A11CM328	ORING	1.00	EA	ROCEM	
003	.35A2C217	CAPSCREW	4.00	EA		

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	ADDED ITEMS 22/23. MOD. NOTE 1 0080478	7/17/00	KWL
	B	ADDED ITEMS 25 & 26. ADJUSTED ECL: 0080610	8/30/00	DAB/KWL



THIS DRAWING CONTAINS CONFIDENTIAL AND TRADE SECRET INFORMATION, IS THE PROPERTY OF DRESSER-RAND COMPANY, AND IS PROVIDED TO THE RECEIVER IN CONFIDENCE. THE RECEIVER BY RECEPTION AND RETENTION OF THE DRAWING ACCEPTS THE DRAWING IN CONFIDENCE AND AGREES THAT, EXCEPT AS AUTHORIZED IN WRITING BY DRESSER-RAND COMPANY, IT WILL (1) NOT USE THE DRAWING OR ANY COPY THEREOF OR THE CONFIDENTIAL OR TRADE SECRET INFORMATION THEREIN; (2) NOT COPY THE DRAWING; (3) NOT DISCLOSE TO OTHERS EITHER THE DRAWING OR THE CONFIDENTIAL OR TRADE SECRET INFORMATION THEREIN; AND (4) UPON COMPLETION OF THE NEED TO RETAIN THE DRAWING, OR UPON DEMAND, RETURN THE DRAWING AND ALL COPIES THEREOF IN ANY FORM.

NOTE: THIS DRAWING CONFORMS TO ANSI STD Y14.5M-1982  
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES

CASTING		MACHINING		GEOMETRIC SYMBOLS		MATERIAL	
DIMENSION	TOLERANCE	DIMENSION	TOLERANCE	SYMBOL	GEOMETRY	HEAT TREAT	HARDNESS
UNDER 2"	+ .002" - .002"			2 PL	CYLINDRICITY		
2" TO 5"	+ .003" - .003"	UNDER 24"	± .010" ± .010"	3 PL	FLATNESS		
5" TO 8"	+ .005" - .005"	24" AND UP	± .010" ± .010"		PERPENDICULARITY		
8" TO 12"	+ .007" - .007"	ANGLES	± .010"		PARALLELISM		
12" TO 18"	+ .010" - .010"	UNSPECIFIED FILLETS	20 30"		CONCENTRICITY		
18" AND UP	+ .015" - .015"	AND RADII TO BE .125			POSITION		

UNLESS OTHERWISE SPECIFIED REMOVE ALL BURRS AND SHARP CORNERS AND COUNTER SINK TAPPED HOLES TO BODY SIZE

PATTERN NO.	
THIRD ANGLE PROJECTION	
DRAWN	K. W. LOCEY
CHECKED	J. SLOAN
APPROVED	K. W. LOCEY

CHG TO: 29C 109 124C 149C

<b>DR DRESSER-RAND</b> TULSA, OKLAHOMA 74146			
SIZE	STROKE	TYPE	
2/4TH	5/6	HOS/DVIP	
NAME OF PART FILTER ASSEMBLY W/ CAST HEADER			
SIZE	FEDERAL SUPPLY CODE	DWG NO.	REV.
C		WAZA2402	B
SCALE	NTS	WT.	SHEET 1 OF 1

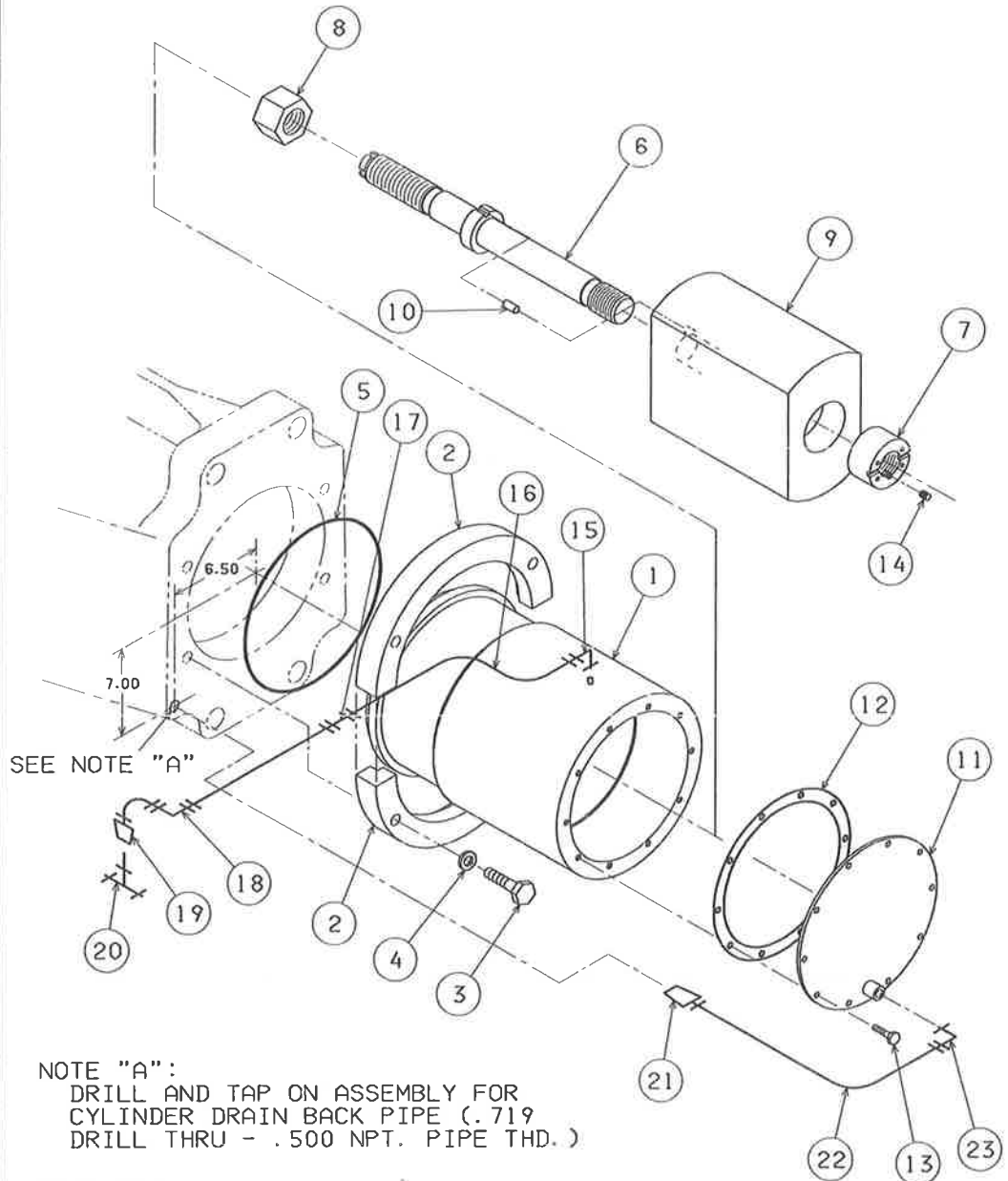
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLWAZA2402G1		OIL FILTER ASSY 2/4 HOS/DVIP (CAST)			2000B0610	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
000	.WAZK0002	OIL FILTER KIT HOS&D-VIP 2/4THROW	1.00	EA		
001	.WAZP0002T1	OIL FILTER ASSY (FLANGED)	1.00	EA		
000	.WAZP0001T2	ELEMENT, OIL FILTER (13")USED ON 2/4 TH	1.00	EA		
000	.1300852	SEAL KIT, FILTER (HOS/D-VIP)	1.00	EA		
002	.UHHM0001	HEADER, FRAME OIL (CAST)	1.00	EA		
003	.VAZM0004	GASKET, FILTER ADAPTER (HDR TO ADAPTER)	1.00	EA		
004	.35A2C224	CAPSCREW	4.00	EA		
005	.38A4C5	NUT, .500-13	4.00	EA		
006	.VAZM0003	GASKET, FILTER ADAPTER (FILTER SIDE)	1.00	EA		
007	.143A2A83	CAPSCREW, FERRY HEAD 12PT .500-13-2.25	4.00	EA		
008	.UCHM0002	ELBOW, FLGD - FILTER ADAPTER (CI)	1.00	EA		
009	.35A2C229	CAPSCREW	4.00	EA		
010	.W129064	GASKET OIL HEADER	1.00	EA	ROCEM	
011	.SDHM0001	FILTER SUPPORT BRACKET	1.00	EA		
012	.35A2C219	CAPSCREW	4.00	EA		
013	.11A5C6	WASHER	4.00	EA		
014	.35A2C223	CAPSCREW	2.00	EA		
015	.35A2C219	CAPSCREW	2.00	EA		
016	.11A5C6	WASHER	4.00	EA		
017	.20DPG-OS-30	GAUGE, DIFF PRESSURE (MURPHY)	1.00	EA		
018	.50220708	BRACKET, DIFF.PRESS.	1.00	EA		
019	.35A2C1	CAPSCREW	4.00	EA		
020	.11A5C2	WASHER	4.00	EA		
021	.428A10S06	ELBOW MALE	1.00	EA		
022	.426A10S04	CONNECTOR FEMALE	2.00	EA		
023	.33942152	TUBING 0.38X035W	60.00	IN		
024	.SP43-32-32	FILTER FLG CONN 2"NPT W/SEAL & BOLTS	1.00	EA		
025	.11021920	PLUG PIPE .25 NPT	2.00	EA		
026	.11021953	PIPE PLUG .75 NPT	1.00	EA		

# CYLINDER-BALANCE

(B)



NOTE "A":  
 DRILL AND TAP ON ASSEMBLY FOR  
 CYLINDER DRAIN BACK PIPE (.719  
 DRILL THRU - .500 NPT. PIPE THD.)

NOTE "B":  
 CONSULT FRAME LEAD SHEET FOR LOCATION ON FRAME.  
 IF LOCATION IS NOT LISTED THEN  
 CONTACT ENGINEERING.

H50032C

REV.	DESCRIPTION	DATE	APPROVED
A	ADDED NOTE "B"	9980104	2/26/99
LTR			KAL. DGP

CHG TO: 16C, 29C, 80, 124C		ML ISSUED	
DESIGN	D. GRANNITS	DATE	10/31/93
CHECKED	G. F. BISEL	DATE	11/01/93
APPROVED	M. A. ERDE	DATE	11/01/93
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES			
SIZE	8.00/5.50	TYPE	HOS/RDS
NAME OF PART	CYLINDER-BALANCE		
GENERAL DRAWING NO.	H50032C		
SCALE	NTS	MT.	SHEET 1 OF 1

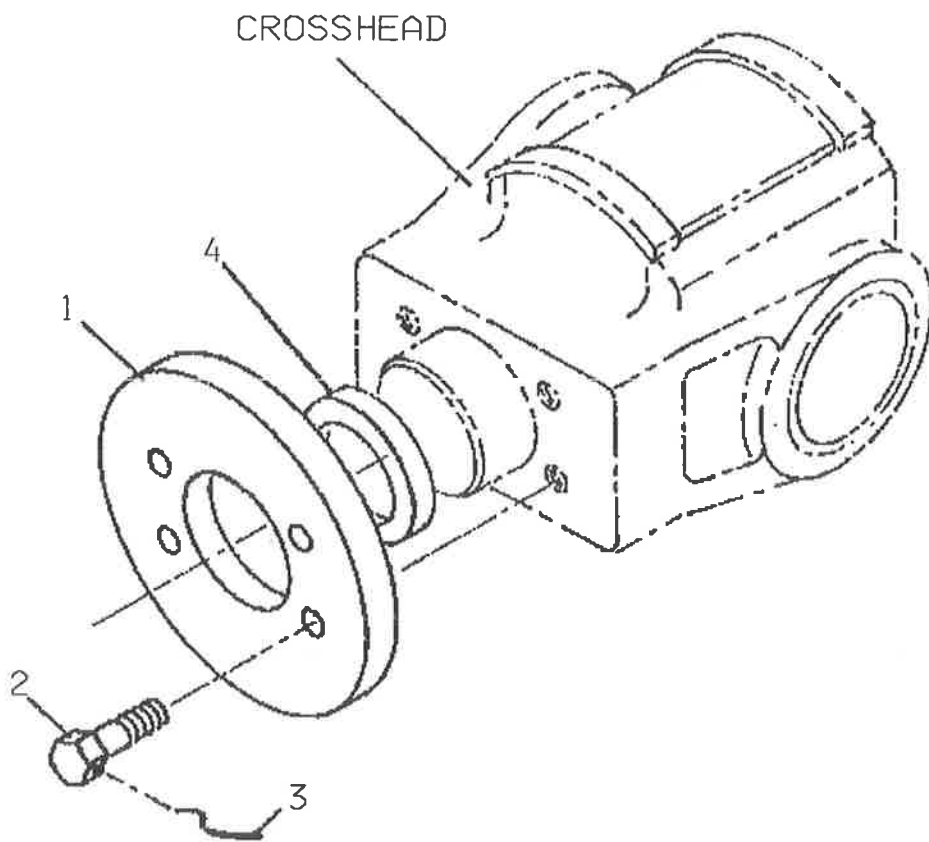
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH50032CG1		CYLINDER BALANCE 6HOS 160.6 LBS			1999B0247	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.H59608P1	CYLINDER, BALANCE HOS/D-VIP	1.00	EA		
002	.1H59609	RING LOCKING	1.00	EA		
003	.35A2J382	CAPSCREW	4.00	EA		
004	.12A5C9	WASHER,	4.00	EA		
005	.20A11EM279	ORING	1.00	EA	ROCEM	
	.12459228	PISTON 11.50 BALANCE	1.00	EA		
006	.R72014	ROD BAL PISTON, HOS	1.00	EA	M	
007	.W98966	NUT, PISTON	1.00	EA	M	
008	.X1010T12	NUT, ROD LOCKING (JAM NUT)	1.00	EA	M	
009	.1H50029AP1	PISTON 11.50 BAL	1.00	EA		
010	..25A13C329	ROLLPIN	1.00	EA		
	.109A2A44	SET SCREW	1.00	EA	M	
011	.W139561P2	COVER BALANCE CYLINDER END	1.00	EA		
012	.W139562P1	GASKET BALANCE CYLINDER END COVER	1.00	EA	ROCEM	
013	.35A2C219	CAPSCREW	20.00	EA		
014	.109A2A44	SET SCREW	1.00	EA	M	
015	.428A10C05E062	ELBOW MALE	1.00	EA		
016	.11113412	TUBING 0.25X035W	96.00	IN		
017	.437A10C04	UNION TUBE	2.00	EA		
018	.430A10C04	ELBOW UNION	1.00	EA		
019	.426A10C06	CONNECTOR 1/4 X 1/4	1.00	EA		
020	.72A7M2	TEE STREET	1.00	EA		
021	.426A10C20	CONNECTOR MALE	1.00	EA		
023	.428A10C16	ELBOW MALE	1.00	EA		

D-R PARTS LIST

CROSSHEAD BALANCE WEIGHT



W140338

2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLW140338G6		WEIGHT XHD BAL 23.8#			1991B0492	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.H49944T6	WEIGHT BALANCE XHD HOS 22.4LBS	1.00	EA		
002	.35A2J377E	CAPSCREW	4.00	EA		
003	.X1636T062	LOCKWIRE, STEEL .062" DIA.	24.00	IN		

**15.00" X 6HOS CYLINDERS**

**6HC2654 / 6HC2657**

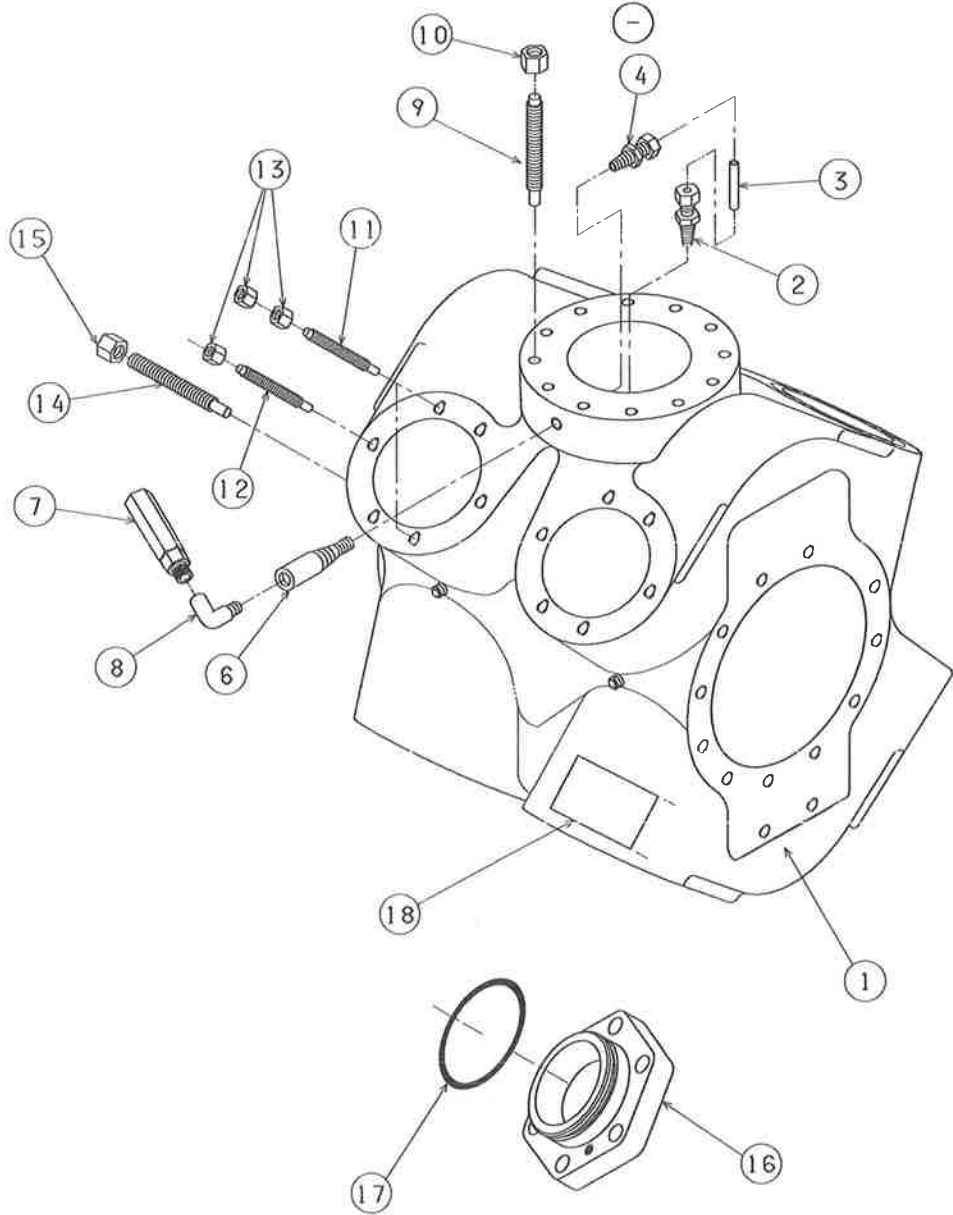


2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

6HC2654/6HC2657		CYL 15.00 X 6HOS (#67) NIGC		OI	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE
	.MLHJHA1501G2	CYLINDER 15.00 ( 495#/PF67) NI GC PRGD	1.00	EA	
	.MLH52503DG1	HEAD 15.00 VVC PKT OUTER	1.00	EA	
	.MLH56039LG1	VALVE PF67 INLET	4.00	EA	
	.MLH56040JG1	VALVE PF67 DISCHARGE	4.00	EA	
	.MLH50037G6	ACCESS VALVE	8.00	EA	
	.MLH59960BG1	PACKING ROD COMPL PURGED	1.00	EA	
	.MLH50042DG19	PISTON 15.00 & ROD 4140/TC3/1	1.00	EA	
	.MLGAHA0001G4	YOKE 13.00 HOS SOUR GAS (W/SLINGER)	1.00	EA	

# CYLINDER ASSEMBLY



HJHA1501

REV. NO.	DESCRIPTION	DATE	APPROVED

CHG TO: 16C 29C 80E 109C 149C		ML ISSUED	
DESIGN	K. M. LOCEY	DATE	10/23/79
CHECKED	G. M. TBS	DATE	10/23/79
APPROVED	G. M. TBS	DATE	10/23/79
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES.			
DR	DRESSER-RAND	TULSA, OKLAHOMA	79148
SIZE	15.00	STROKE	6.00
NAME OF PART	CYLINDER ASSEMBLY		
SIZE FEDERAL	DRAWING NO.		
SYMBOL CODE	HJHA1501		
SCALE	NTS	WT.	SHEET 1 OF 1

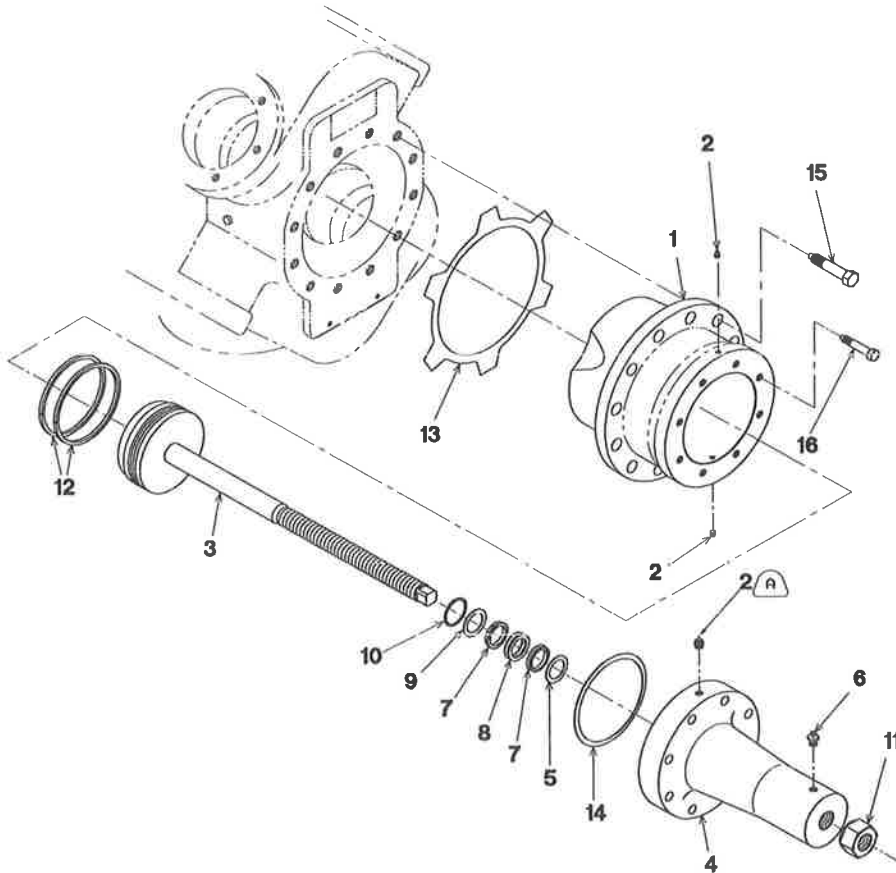
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLHJHA1501G2		CYLINDER 15.00 ( 495#/PF67) NI GC			2000B0220	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.1HJHM1501	CYLINDER 15.00 ( 495#/PF67) NI GC	1.00	EA		
	.HJHM1501	CYLINDER 15.00 ( 495#/PF67) GC	1.00	EA		
	.11021946	PIPE PLUG .50 NPT	4.00	EA		
002	.426A10S06	CONNECTOR MALE	2.00	EA		
003	.34624742	STLG.25X065W	36.00	FT		
004	.426A10S06	CONNECTOR MALE	2.00	EA		
006	.UAZM0003T2	ADAPTER QUILL	2.00	EA		
007	.33037417	VALVE, CHECK LUBR	2.00	EA	ROCEM	
008	.143A7TT2	ELBOW 90 DEG SS	2.00	EA		
009	.R78164X07042R	STUD	24.00	EA		
010	.38A4K9	NUT 7/8-9 HEAVY	24.00	EA		
011	.R78164X06042R	STUD	16.00	EA		
012	.R78164X06035R	STUD	32.00	EA		
013	.38A4K8	NUT 3/4-10 HEAVY	64.00	EA		
014	.R78164X06061R	STUD	4.00	EA		
015	.38A4K8	NUT 3/4-10 HEAVY	4.00	EA		
016	.R70784	COVER, VALVE	8.00	EA	M	
017	.20A11EM445	ORING, VALVE COVER	8.00	EA	ROCEM	
018	.11117074	KIT NAMEPLATE	1.00	EA		
	.12217261	NAMEPLATE CYLINDER	1.00	EA		
	.11065554	NAMEPLATE WARNING	1.00	EA		
000	.VAHK1501	GASKET KIT 15.00 HOS GC CYL	1.00	EA	ROCEM	
	.20A11EM445	ORING, VALVE COVER	8.00	EA	ROCEM	
	.X1498T29F	GASKET, PKG CASE	1.00	EA	ROCEM	
	.33A11C13	GASKET	2.00	EA	ROCEM	

# VARIABLE VOLUME CLEARANCE POCKET OUTER HEAD

(A)



H52503D

LTR	ITEM #	CHANGED TO OR ITEM #	DESCRIPTION	DATE	APPROVED
A	6	2	CHANGED TO OR ITEM #	7/26/00	KAL
			DESCRIPTION		

REVISIONS	DATE	APPROVED
1	08/28/93	G. LOKTIE
2	08/28/93	G. TYLER
3	08/28/93	G. LOKTIE

CHG TO: 29c 109 124c 149c	ML ISSUED	DR DRESSER-RAND	PRINTED POST. N.Y. 14870
DR	SIZE	STROKE	TYPE
6.00	6.00		HOS-AC
VAR. VOL. CLEAR. PKT. O.H.	NAME OF PART	DATE	DATE
H52503D	VAR. VOL. CLEAR. PKT. O.H.	08/28/93	08/28/93
A	SIZE	FEDERAL	DISPATCHING NO.
A	C	SCALE	H52503D
A	NTS	MT.	SHEET 1 OF 1

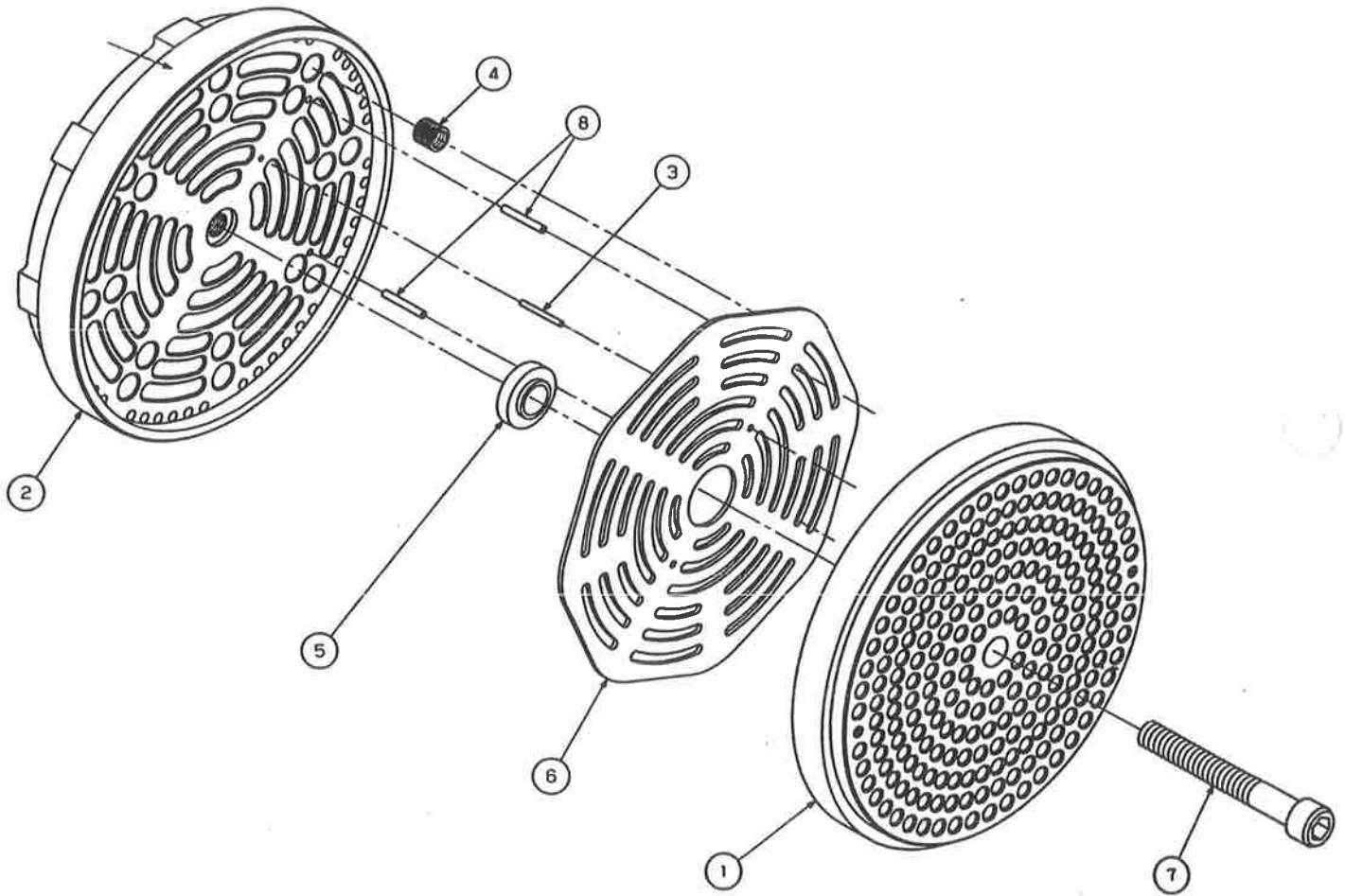
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH52503DG1		HEAD 15.00 VVC PKT OUTER			1996B0846	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.1H52353AP1	HEAD VVC PKT OUTER	1.00	EA		
002	.11021920	PLUG PIPE .25 NPT	3.00	EA		
	.11275260	VALVE VVC PKT YOKE	1.00	EA		
003	.12435483	PISTON 10.00 & ROD	1.00	EA		
004	.1H49883P2	YOKE CL PKT	1.00	EA		
	.11111853	KIT 2.125 SEAL	1.00	EA	ROCEM	
005	..W127907A	WASHER	1.00	EA	O EM	
006	..258A10X1650	FITTING GREASE	1.00	EA		
007	..11318623	SEAL, RDS/HOS	2.00	EA	ROCEM	
008	..W127841P1	LANTERN, RDS/HOS	1.00	EA	O EM	
009	..W127907	WASHER	1.00	EA	O EM	
010	..183A13SXRRT287	RETAINER RING	1.00	EA	O EM	
011	.46A4K18	NUT HVY HEX	1.00	EA		
012	.11143708	RING, PISTON 10.00 RDS/HOS	2.00	EA	ROCEM	
013	.W139566	GASKET, OUTERHEAD	1.00	EA	ROCEM	
014	.G711121038G	GASKET	1.00	EA	ROCEM	
015	.44A2J480	CAPSCREW	12.00	EA		
016	.44A2J436	BOLT	8.00	EA		

# PARTS LIST

## 67PF INLET VALVE ASSEMBLY



H56039L

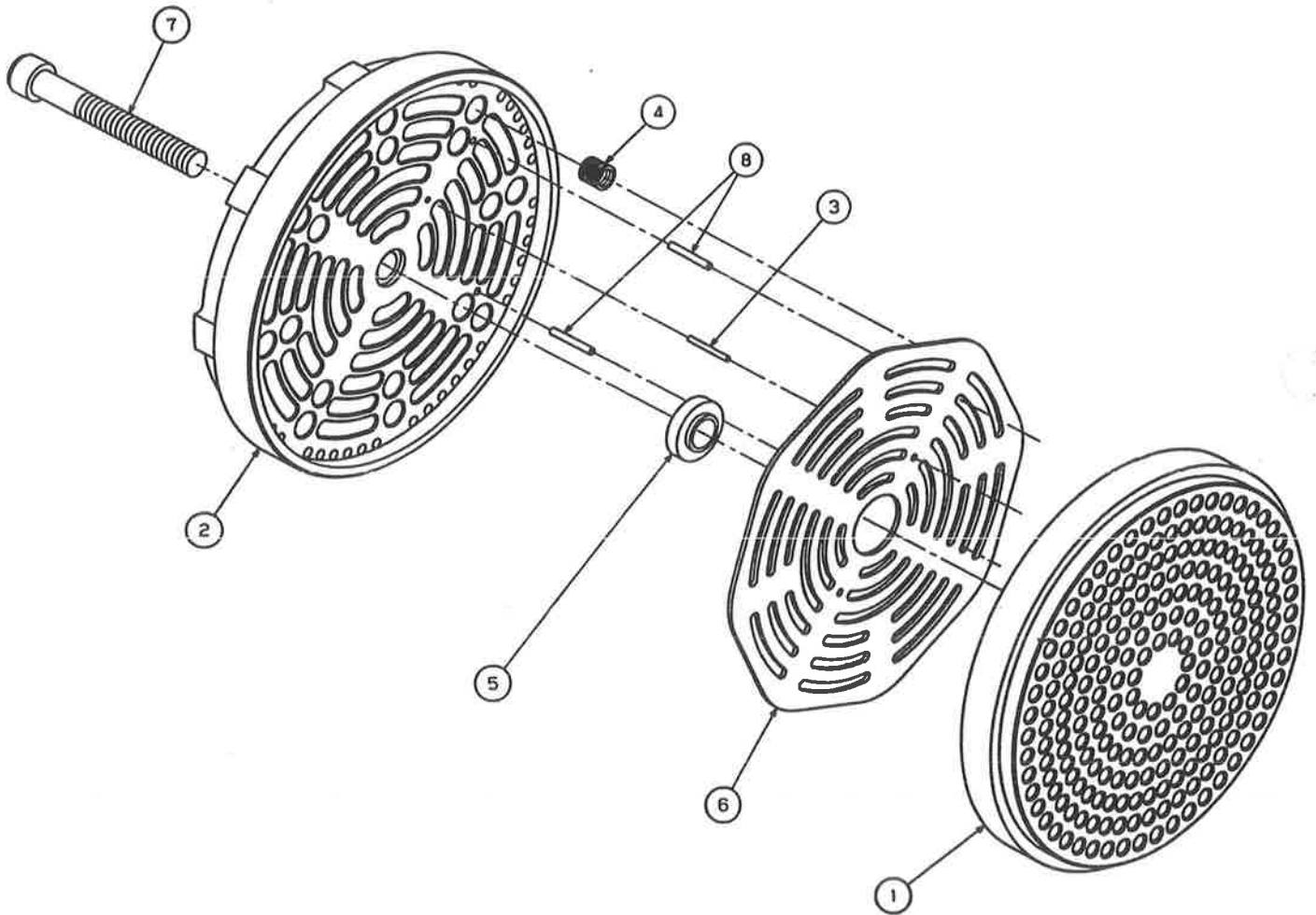
# PARTS LIST

VALVE 67PF INLET		MLH56039LG1	REV. 01
ILLUS. NO.	PART NUMBER	PART NAME	UNITS PER ASSEMBLY
1	.F36497J	SEAT VALVE INLET	1.00PC
2	.F36498LT3	STOPPLATE INLET	1.00PC
3	.25A13C69	ROLLPIN	1.00PCROCEM
4	.PP1344	SPRING	16.00PCROCEM
5	.H60519KT3	GUIDE RING	1.00PCDEM
6	.H56068D	PLATE VALVE	1.00PCROCEM
7	.119A2R254	CAPSCREW	1.00PCROCEM
8	.25A13C98	ROLLPIN	2.00PCROCEM
		/USE LOCTITE #242	
		/TO ASSEMBLE ITEMS	
		/2 & 7.	

+SEE ACCESSORY LITERATURE SECTION

# PARTS LIST

## 67PF DISCHARGE VALVE ASSEMBLY



H56040J



# PARTS LIST

VALVE 67PF DISCH

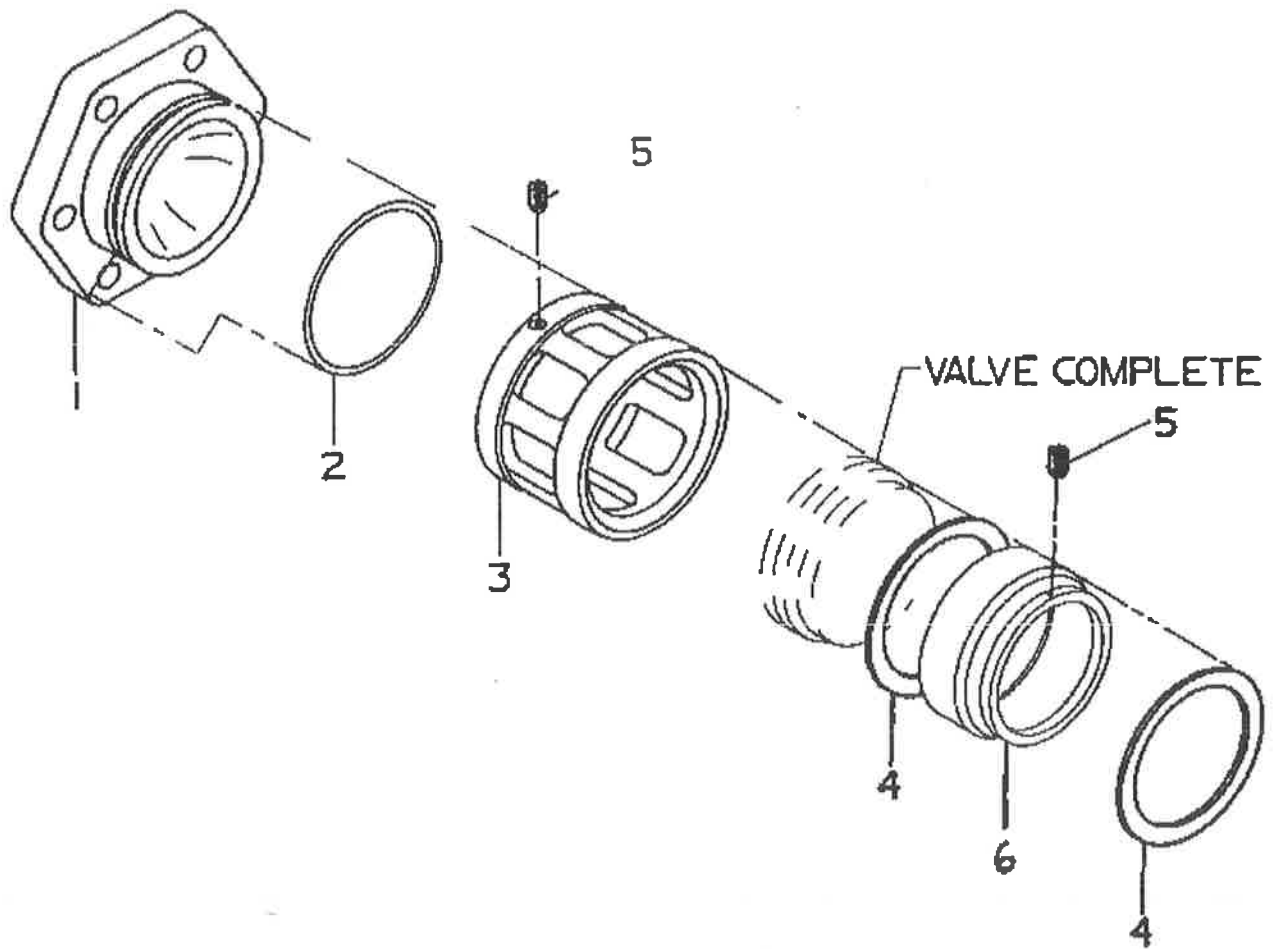
MLH56040JG1

REV. 01

ILLUS. NO.	PART NUMBER	PART NAME	K I T	UNITS PER ASSEMBLY	U N I T S	SPARES USAGE CODE
1	.F36499H	SEAT VALVE DISCH		1.00		PC
2	.F36500JT3	STOPPLATE DISCH		1.00		PC
3	.25A13C69	ROLLPIN		1.00		PCROCEM
4	.PP1344	SPRING		16.00		PCROCEM
5	.H60519KT3	GUIDE RING		1.00		PCOEM
6	.H56068D	PLATE VALVE		1.00		PCROCEM
7	.119A2R253	CAPSCREW		1.00		PCROCEM
8	.25A13C98	ROLLPIN		2.00		PCROCEM
		/USE LOCTITE #242 /TO ASSEMBLE ITEMS /1 & 7.				

+SEE ACCESSORY LITERATURE SECTION

# VALVE ASSEMBLY



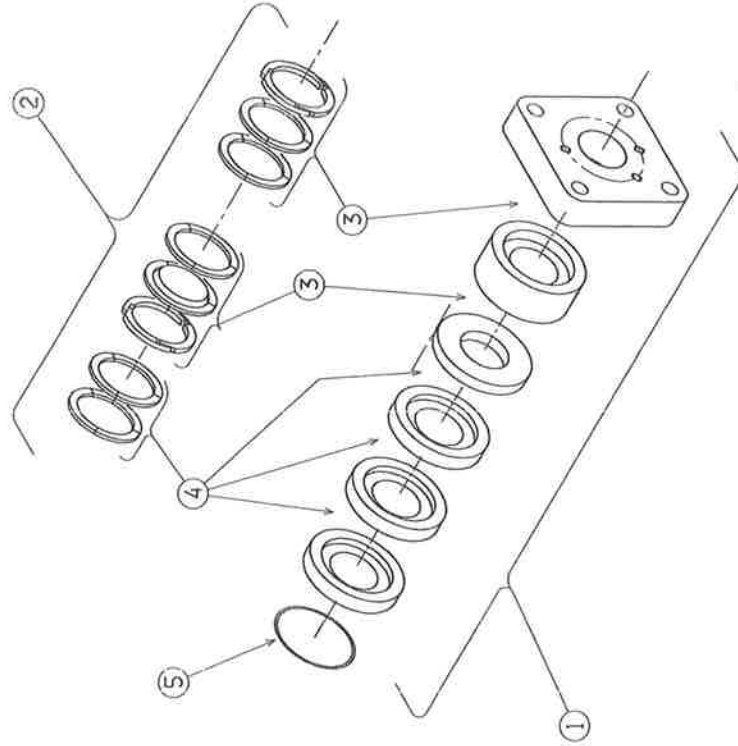
H50037

2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH50037G6		ACCESS VALVE			1995B0484	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
003	.R70778P7	CRAB, VALVE	1.00	EA	EM	
004	.30A11F0740X13	GASKET	1.00	EA	ROCEM	
005	.112A2S23	SET SCREW	1.00	EA		

PACKING ROD PURGED



H59960B

CHG TO: 16C, 29C, 80, 124C, 149C		ML ISSUED		DR DRESSER-RAND		TULSA, OKLAHOMA 77148	
DRG. BY	R. SEYMOUR	DATE	07/28/74	SIZE	STROKE	TYPE	HOS
CHECKED	G. R. LORTIE	DATE	07/28/74	PACKING ROD PURGED			
APPROVED	G. R. LORTIE	DATE	07/28/74	SIZE	FEDERAL	DESIGNING NO.	ML REV.
ALL DIMENSIONS ARE IN INCHES			C	SUPPLY CODE	H59960B	ML	-
REVISIONS			DATE	APPROVED	SCALE: NTS		
LTR	DESCRIPTION	DATE	APPROVED	WT.			
SHEET 1 OF 1				SHEET 1 OF 1			

2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH59960BG1		PACKING ROD COMPL PURGED			OI
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE
001	.H59951B	CASE PKG PURGED	1.00	EA	
002	.12475919	RING SET RENEWAL	1.00	EA	
003	.5A11J40	RING PACKING	2.00	EA	
004	.16A11JG40	RING PACKING	3.00	EA	ROCEM
005	.X1498T29F	GASKET, PKG CASE	1.00	EA	ROCEM

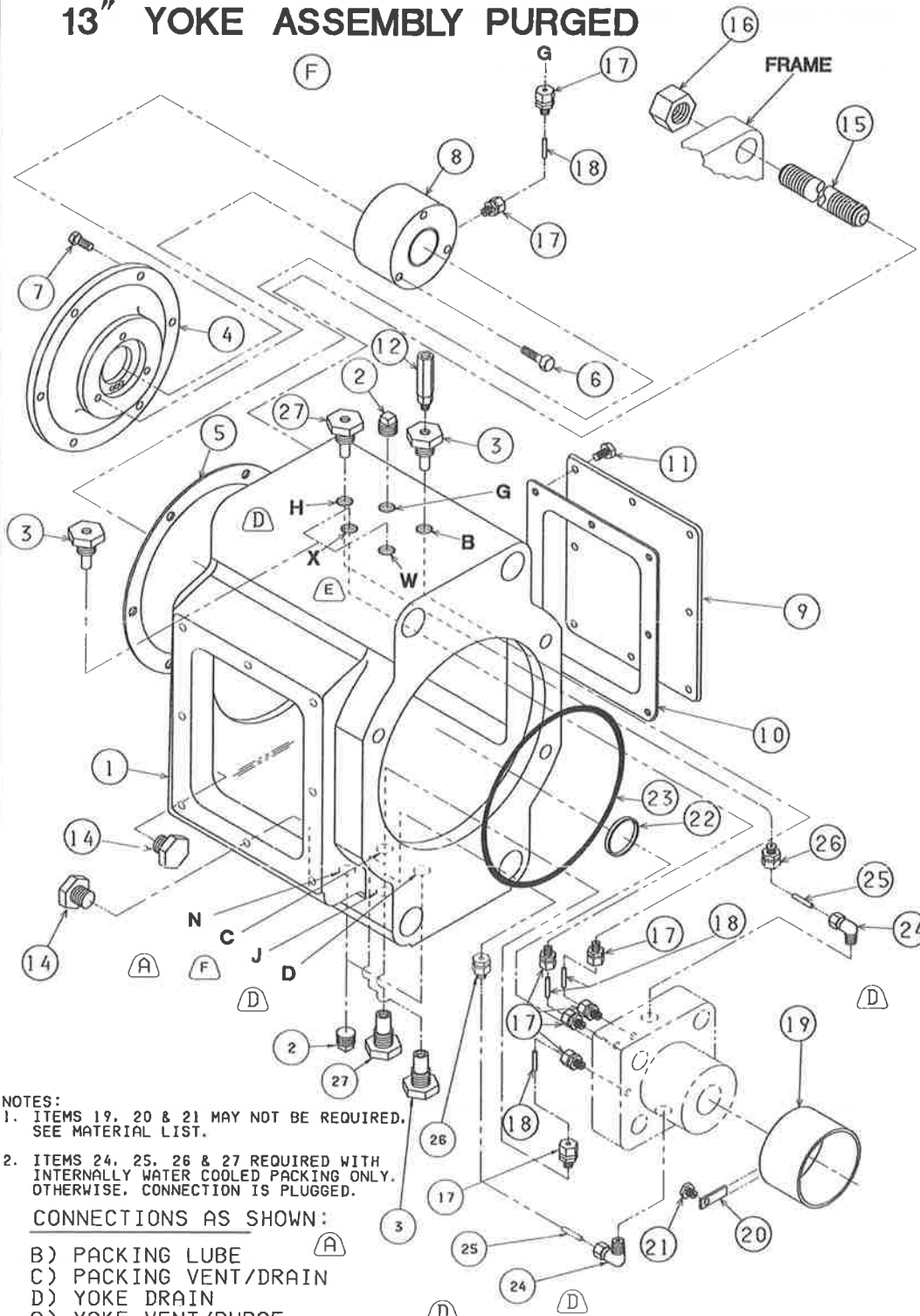


2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH50042DG19		PISTON 15.00 & ROD		4140/		OI	
ILLUS NO.	PART NUMBER	PART NAME		QTY.	UM	SPARES USAGE CODE	
001	.IEHM1508T1	ROD PISTON 15.00 NIGC	(4140/TC3	1.00	EA		
002	.W84456B	NUT, PISTON		1.00	EA		M
003	.109A2A44	SET SCREW		1.00	EA		M
004	.X1010T12	NUT, ROD LOCKING (JAM NUT)		1.00	EA		M
005	.1F32177P4	PISTON 15.00		1.00	EA		M
006	.KCHP1402	RING 15.00 COMBO (P-I TFE)		2.00	EA	ROCEM	
007	.R72004CP1	COLLAR FRAME END, HOS		1.00	EA		M
008	.R72005P4	COLLAR OUTER END, HOS		1.00	EA		M
	.ZBHM0001	ADAPTER, PISTON NUT HOS		1.00	EA		

# 13" YOKE ASSEMBLY PURGED



- NOTES:
- ITEMS 19, 20 & 21 MAY NOT BE REQUIRED. SEE MATERIAL LIST.
  - ITEMS 24, 25, 26 & 27 REQUIRED WITH INTERNALLY WATER COOLED PACKING ONLY. OTHERWISE, CONNECTION IS PLUGGED.

### CONNECTIONS AS SHOWN:

- B) PACKING LUBE
- C) PACKING VENT/DRAIN
- D) YOKE DRAIN
- G) YOKE VENT/PURGE
- H) PACKING COOLANT DISCHARGE (IF REQUIRED)
- J) PACKING COOLANT INLET (IF REQUIRED)
- N) SPARE CONNECTION
- X) PACKING PURGE

## GAHA0001

F	MODIFIED NOTES: HMODIFIED LETTERING TO HOLES ECN 0080204	3/15/00	DDC/KWL
E	RELETTERED ALL CONNS. 9780536	7/31/97	KWL

REV	DESCRIPTION	DATE	APPROVED
D	ADDED H AND ITEMS 24, 25, 26, 27. ECN 9780184	3/11/97	BRENNITT
C	REMOVED STREET ELL 90° ILLUS. 13 ECN 9780184	01/10/97	HDR/GWT
B	ADDED O-RING ITEM 23 ECN 9580490	9/28/95	KWL/GRL
A	PLUGGED B, C, D: MODIFIED TO FOUR HOLES ON BOTTOM ECN 9580461	9/13/95	KWL/DGP

CHG TO: 18C 29C 72C 124C 149C		ML ISSUED	
DESIGN	K.H. LOEY	DATE	13.00
CHECKED	G.R. LORTIE	DATE	6.00
APPROVED	G.R. LORTIE	DATE	
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES		DR DRESSER-RAND	
TULSA, OKLAHOMA 74145		YOKE ASSEMBLY	
SIZE	13.00	STROKE	6.00
TYPE	HOS		
FEDERAL SUPPLY CODE	GAHA0001		
SCALE	NTS		
WT.			
SHEET 1 OF 1			

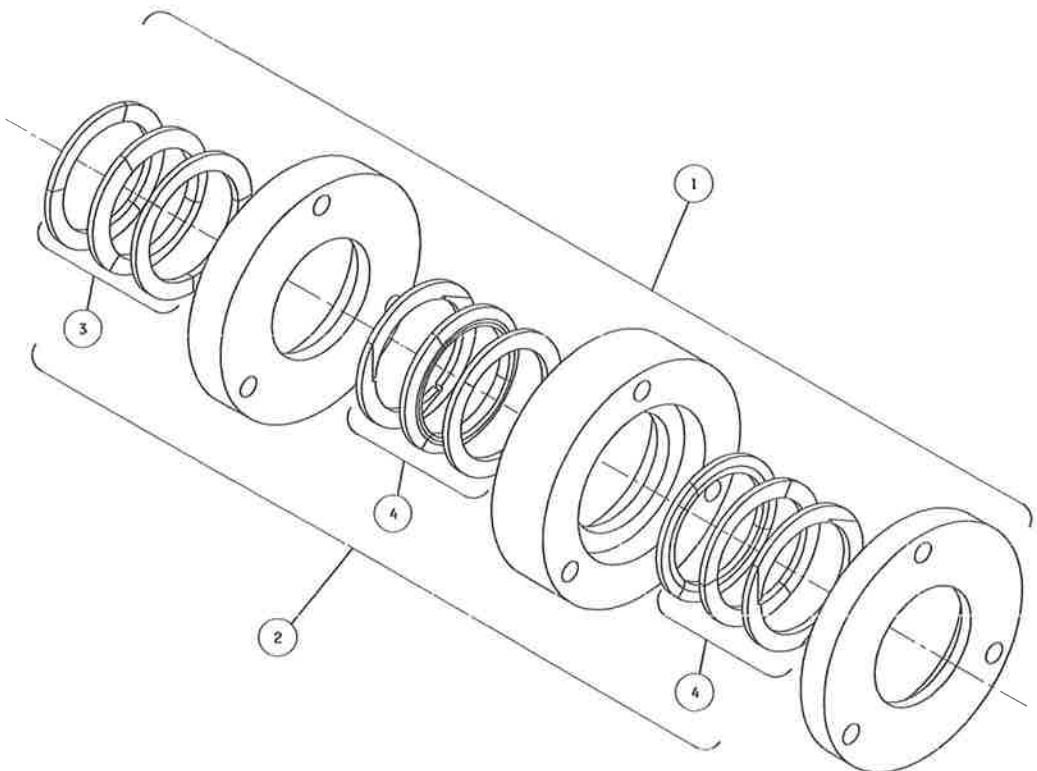


2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLGAHA0001G4		YOKE 13.00 HOS SOUR GAS (W/SLINGER)			1997B0011	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.F32134AP2	YOKE 13.00, HOS	1.00	EA		
002	.30A7C6	PLUG PIPE	4.00	EA		
003	.W47886	ADAPTER, PIPE	4.00	EA		
004	.R70691P1	OIL STUFFER HOS	1.00	EA		
005	.W139350	GASKET,OIL STUFFER HOS	1.00	EA	ROCEM	
006	.35A2C231	CAPSCREW	3.00	EA		
007	.35A2C219	CAPSCREW	6.00	EA		
008	.MLH57758CG4	SCRAPER PURGE OIL	1.00	EA		
009	.W78603	COVER, YOKE RDS/HOS	2.00	EA		
010	.W78604	GASKET, YOKE COVER	2.00	EA	ROCEM	
011	.35A2C217	CAPSCREW	16.00	EA		
012	.33037417	VALVE, CHECK LUBR	1.00	EA	ROCEM	
014	.35A2C382	CAPSCREW	8.00	EA		
015	.R70754	TIEROD (13"YOKE)	4.00	EA		
016	.46A4K14	NUT 1.50X8UNC HEAVY HEX	4.00	EA		
017	.426A10C06	CONNECTOR 1/4 X 1/4	7.00	EA		
018	.33942129	TUBING 0.25X035W	48.00	IN		
	.NOTE	INFORMATION	1.00	EA		
022	.300018AK9	SEAL OIL DEFLECTOR (2.50" ROD)	1.00	EA	M	
023	.20A11CM279	ORING	1.00	EA	ROCEM	

# PURGED OIL SCRAPER



ILLUS. NO. 2  
INCLUDES NO. 3 & NO. 4

**H57758C**

CHG TO: 16C 29C 124C 149C		ML ISSUED	
DRGSMN	DATE	DRGSMN	DATE
STUN	12/90	STUN	12/90
CHECKED	DATE	CHECKED	DATE
F KEMP	12/90	F KEMP	12/90
APPROVED	DATE	APPROVED	DATE
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES		UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES	
SCALE	NTS	WT.	1
12307781			
NAME OF PART		SIZE	
SCRAPER PURGED OIL		SIZE	
DR DRESSER-RAND		STROKE	
TULSA, OKLAHOMA 74114S		TYPE	
FEDERAL SUPPLY CODE		DRAWING NO.	
H57758C		H57758C	
M.L. REV.		M.L. REV.	
-		-	
SHEET		OF	
1		1	

2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH57758CG4		SCRAPER PURGE OIL			OI	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.LEZP0001T3	CASE OIL SCRAPER	1.00	EA		
002	.12475091	RING SET RENEWAL	1.00	EA		
003	.R79480T4G	RING OIL SCRAPER	1.00	EA		
004	.5A11J40	RING PACKING	2.00	EA		

**9.50" X 6HOS CYLINDERS**

**6HC2655 / 6HC2658**

2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

6HC2655/6HC2658		CYL 9.50" X 6HOS (#48) NIGC			OI
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE
	.MLHJHA0901G3	CYLINDER 9.50 (1265#/PF48) NI GC PRGD	1.00	EA	
	.MLH49997AG1	HEAD OUTER	1.00	EA	
	.MLH56190YG6	VALVE PF48 INLET	4.00	EA	
	.MLH56191YG6	VALVE PF48 DISCHARGE	4.00	EA	
	.MLH49937G4	ACCESS VALVE	8.00	EA	
	.MLH49998G18	PISTON 9.50 & ROD 4140/TC3/18DP	1.00	EA	
	.MLH59960AG1	PACKING ROD COMPL PURGED	1.00	EA	
	.MLH51913BFG8	YOKE 18.00 PURGED WIPER	1.00	EA	

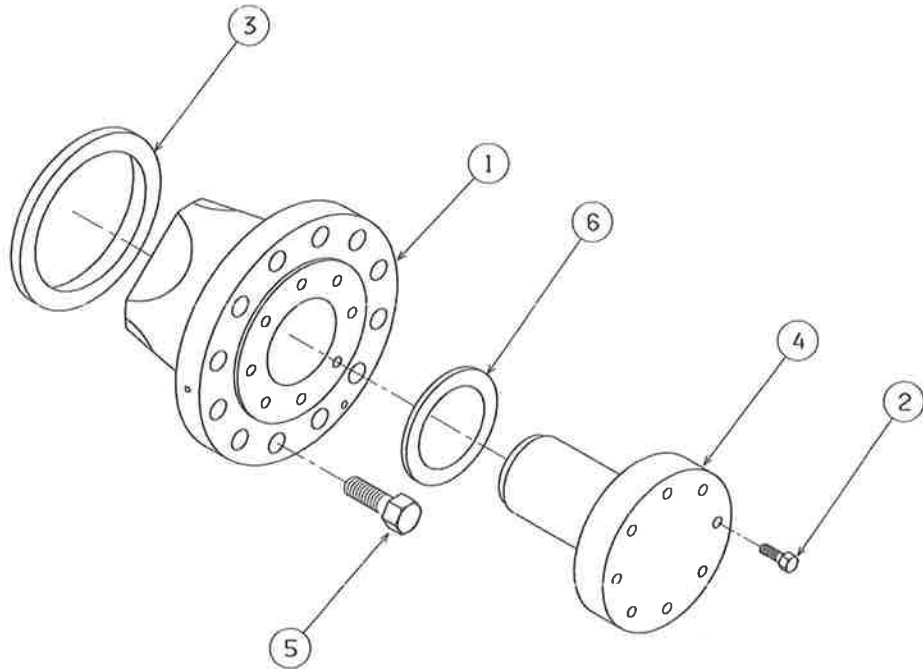


2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLHJHA0901G3		CYLINDER 9.50 (1265#/PF48) NI GC			OI
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE
001	.HJHM0901	CYLINDER 9.50 (1265#/PF48) GC	1.00	EA	
002	.426A10S06	CONNECTOR MALE	2.00	EA	
003	.34624742	STLG.25X065W	36.00	FT	
004	.426A10S07	CONNECTOR MALE	2.00	EA	
005	.UAZM0003T2	ADAPTER QUILL	2.00	EA	
006	.143A7F2	ELBOW	2.00	EA	
007	.R78164X08047R	STUD	24.00	EA	
008	.38A4K10	NUT 1.00-8UNC	24.00	EA	
009	.R78164X08052R	STUD	16.00	EA	
010	.R78164X08044R	STUD	32.00	EA	
011	.38A4K10	NUT 1.00-8UNC	64.00	EA	
012	.R78164X05059R	STUD	4.00	EA	
013	.38A4K7	NUT .625-11	4.00	EA	
014	.R70704	COVER, VALVE	8.00	EA	EM
015	.20A11KM434	ORING	8.00	EA	ROCEM
016	.33037417	VALVE, CHECK LUBR	2.00	EA	ROCEM
017	.11117074	KIT NAMEPLATE	1.00	EA	
	.12217261	NAMEPLATE CYLINDER	1.00	EA	
	.11065554	NAMEPLATE WARNING	1.00	EA	
000	.VAHK0903	GASKET KIT 9.50 HOS GC CYL	1.00	EA	ROCEM
	.20A11KM434	ORING	8.00	EA	ROCEM
	.X1498T29F	GASKET, PKG CASE	1.00	EA	ROCEM
	.37A11C12	GASKET	2.00	EA	ROCEM

# OUTER HEAD ASSEMBLY



H49997A

CHG TO: 16C 29C 124C 149C		ML ISSUED		DR DRESSER-RAND		TULSA, OKLAHOMA 74145	
DESIGN	DATE	NAME OF PART	SIZE	STROKE	TYPE	HOS-AC	
M. FANNELL	11/17/73	OUTER HEAD ASS'Y	9.50	6			
CHECKED	DATE	SIZE (GENERAL)					
G. BISEL	11/18/73	SUPPL. CODE					
APPROVED	DATE	DRAWING NO.					
G. TAS	11/18/73	H49997A					
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES				SCALE	NTS	WT.	SHEET 1 OF 1
				C			

LT#	DESCRIPTION	DATE	APPROVED



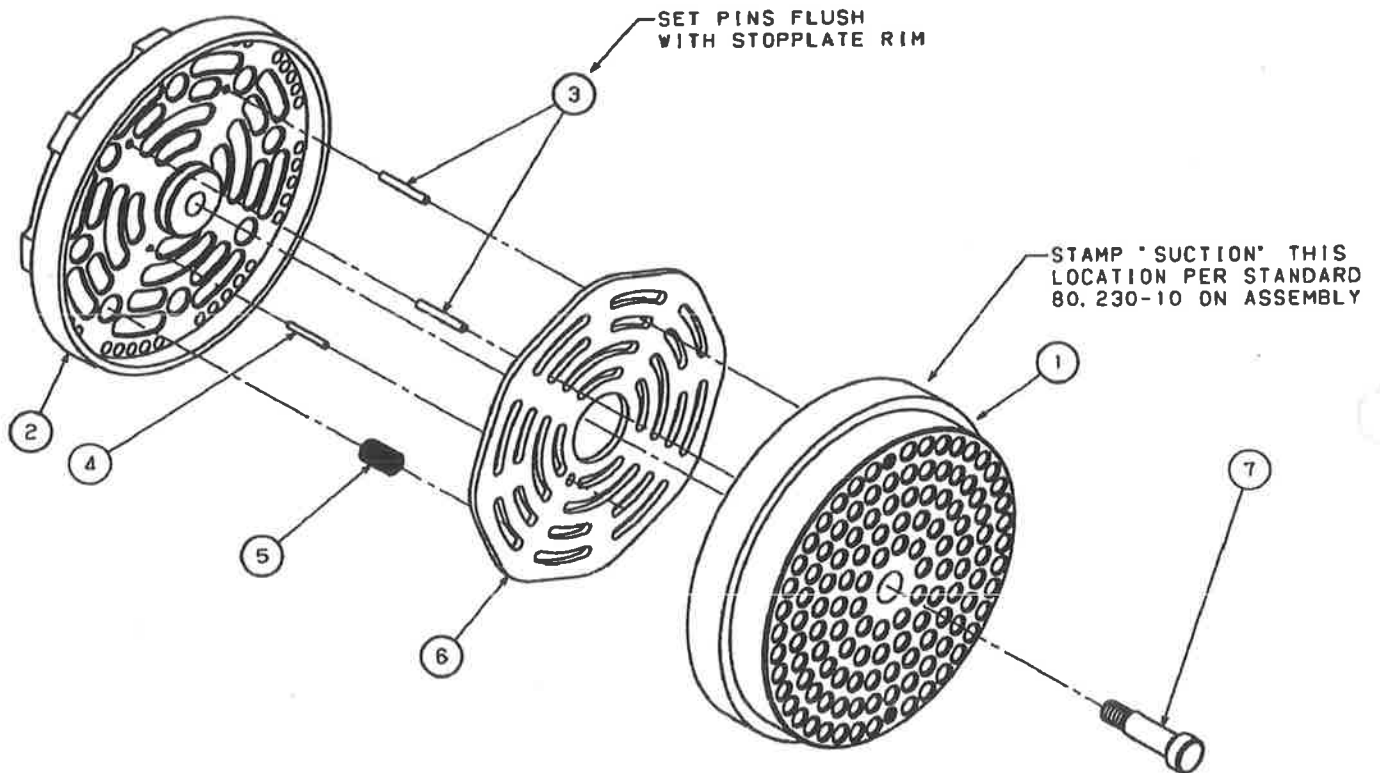
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH49997AG1		HEAD OUTER			1994B0307	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.H49972A	HEAD OUTER, HOS 9.50	1.00	EA		
002	.44A2J483	BOLT	12.00	EA		
003	.H32894T3	GASKET, OUTER HEAD	1.00	EA	ROCEM	
004	.R72046	PLUG BOTTLE, HOS 9.5,10.5 (FULL LENGTH	1.00	EA		
005	.44A2J434	BOLT	8.00	EA		
006	.X1297T61	GASKET, PLUG	1.00	EA	ROCEM	

# PARTS LIST

## 48 PF INLET VALVE



H56190Y

# PARTS LIST

VALVE 48PF INLET

MLH56190YG6

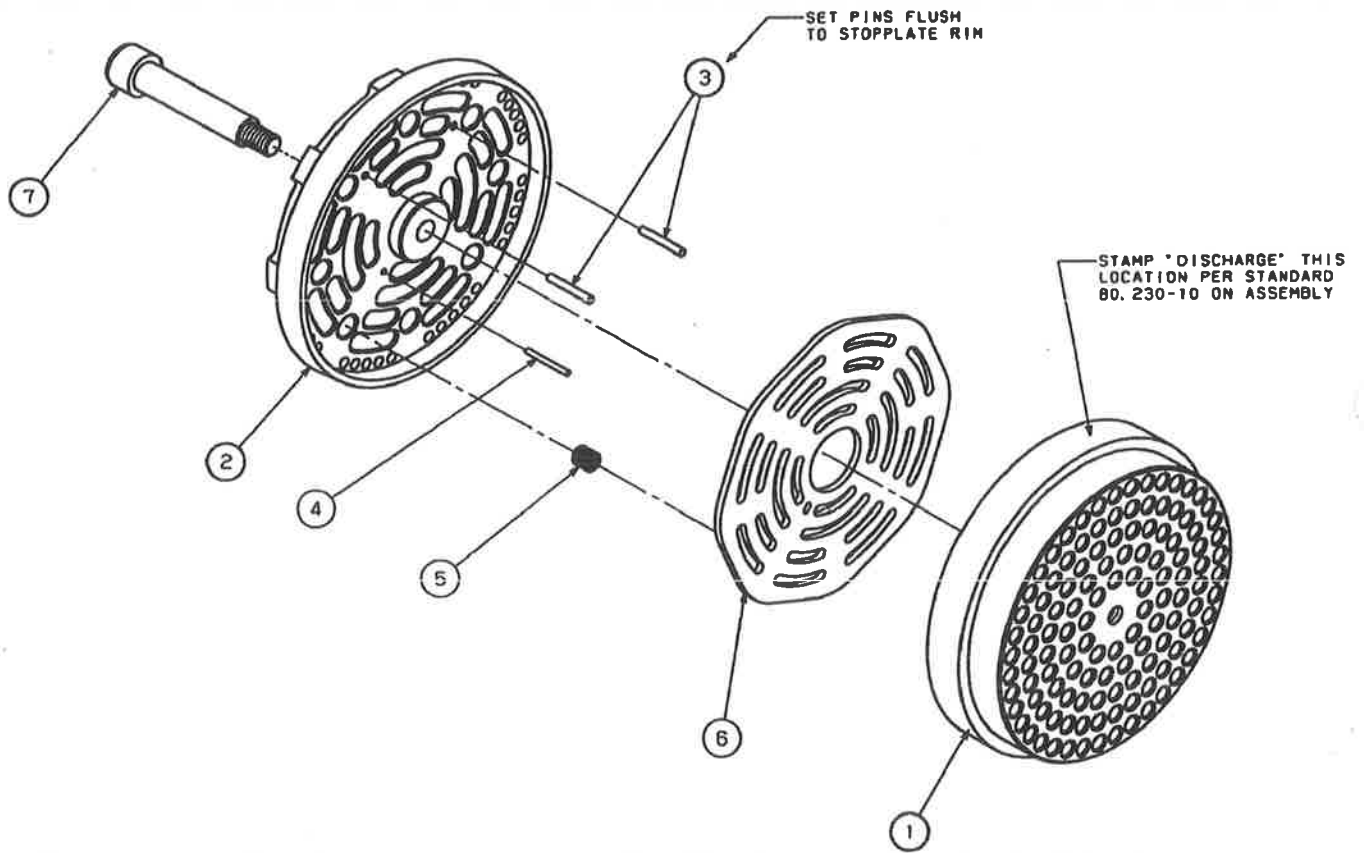
REV. 01

ILLUS. NO.	PART NUMBER	PART NAME	K I T	UNITS PER ASSEMBLY	U N I T S	SPARES USAGE CODE
		/.080 LIFT				
1	.F36931M	SEAT INLET		1.00		PCEM
2	.F36932VT3	STOPPLATE INLET		1.00		PC
3	.25A13C96	ROLLPIN		2.00		PCOEM
4	.25A13C67	ROLLPIN		1.00		PCOEM
5	.PP1344	SPRING		8.00		PCROCEM
6	.H56183AP1	PLATE VALVE		1.00		PCROCEM
7	.121A2A204	SCREW SKT SHLDR		1.00		PCOEM
		/USE LOCTITE #242				
		/TO ASSEMBLE ITEMS				
		/2 & 7				

+SEE ACCESSORY LITERATURE SECTION

# PARTS LIST

## 48 PF DISCHARGE VALVE



# PARTS LIST

VALVE 48 PF DISCH

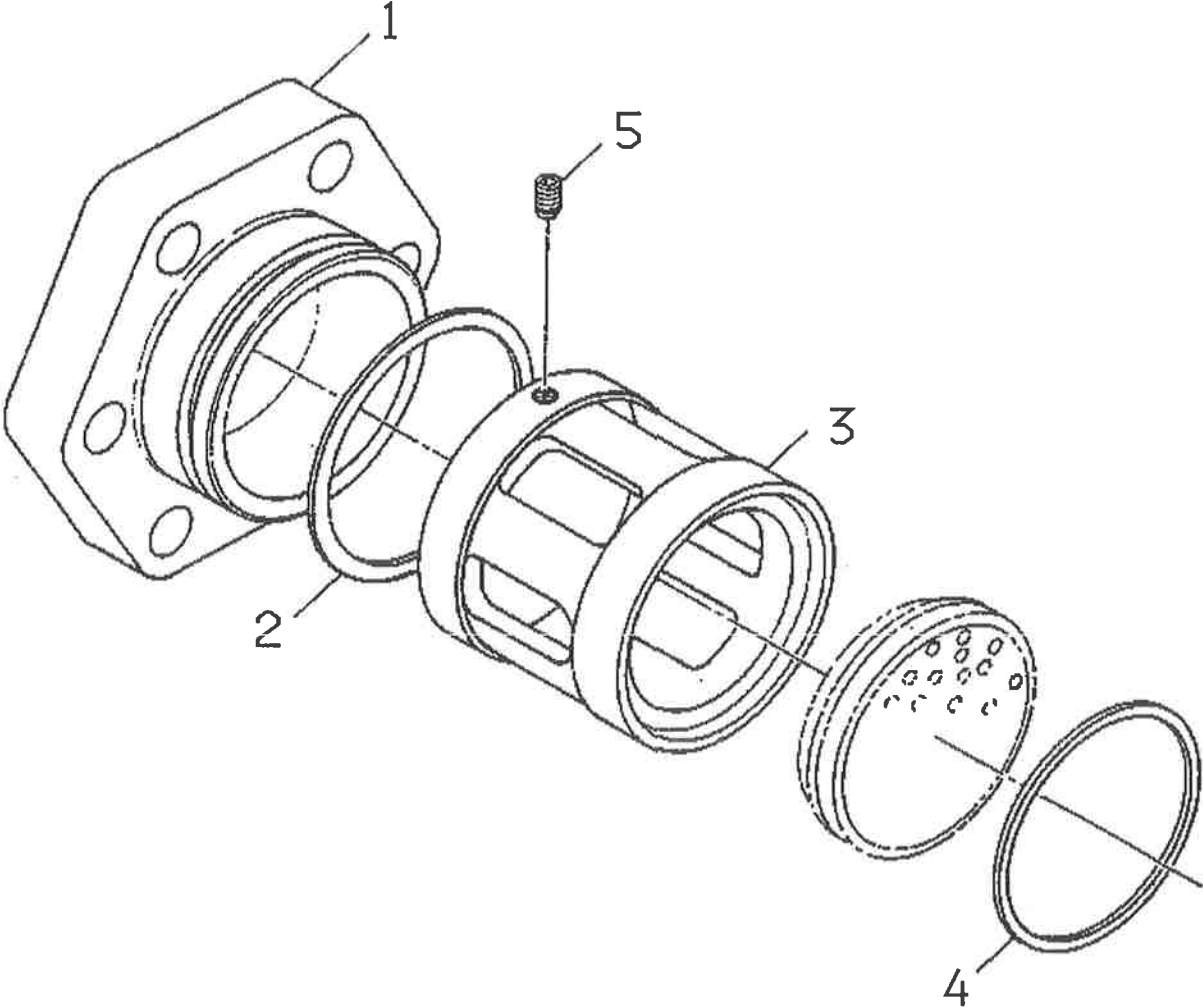
MLH56191YG6

REV. 01

ILLUS. NO.	PART NUMBER	PART NAME	K I T	UNITS PER ASSEMBLY	UNITS	SPARES USAGE CODE
		/ .080 LIFT				
1	.F36933M	SEAT DISCHARGE		1.00		PCEM
2	.F36934WT3	STOPPLATE DISCHARGE		1.00		PC
3	.25A13C96	ROLLPIN		2.00		PCOEM
4	.25A13C67	ROLLPIN		1.00		PCOEM
5	.PP1344	SPRING		8.00		PCROCEM
6	.H56183AP1	PLATE VALVE		1.00		PCROCEM
7	.121A2A204	SCREW SKT SHLDR		1.00		PCOEM
		/USE LOCTITE #242				
		/TO ASSEMBLE ITEMS				
		/1 & 7				

+SEE ACCESSORY LITERATURE SECTION

# VALVE ACCESSORIES



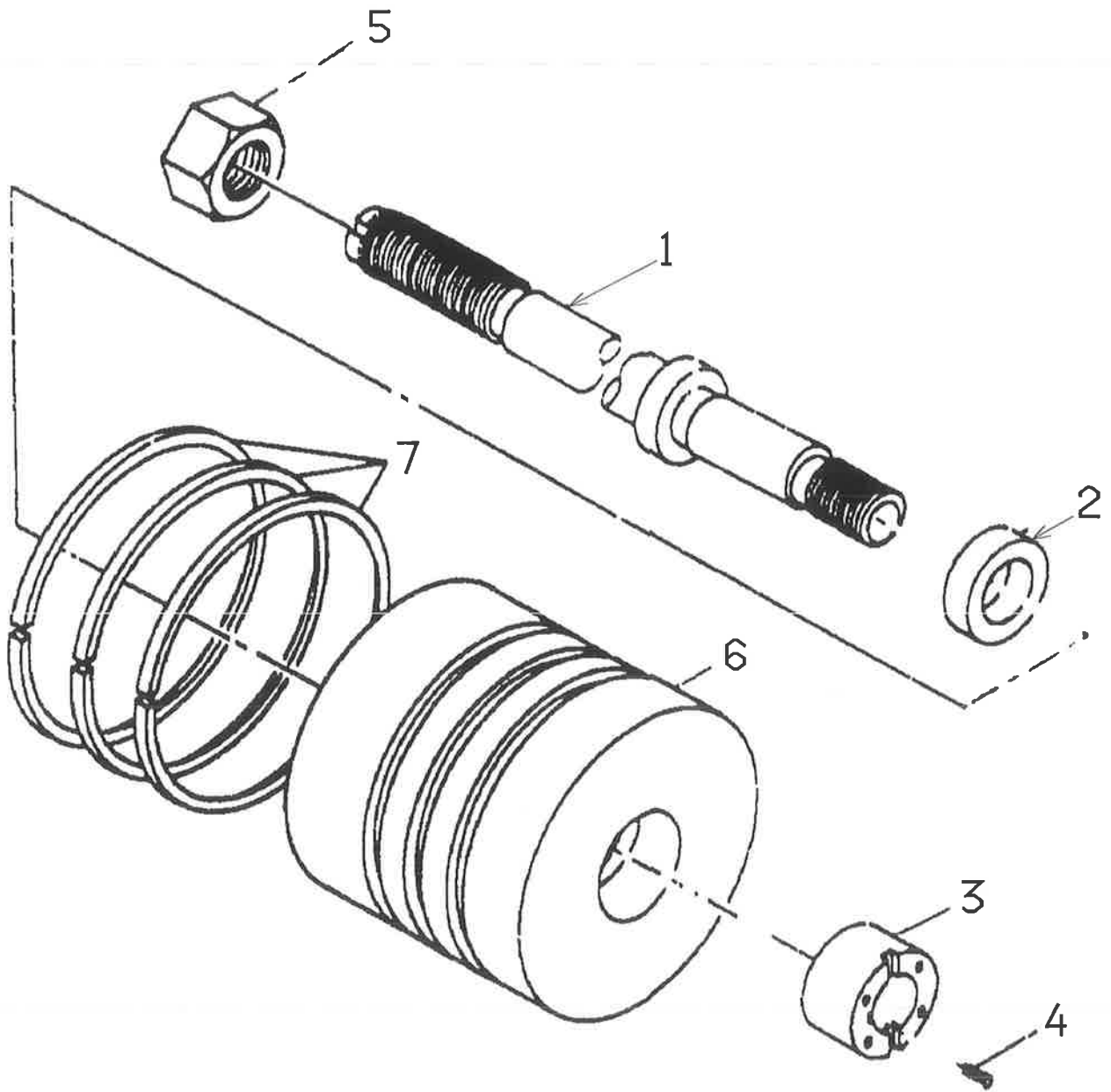
H49937

2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH49937G4		ACCESS VALVE			1994G0774	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
003	.R70705P2	CRAB, VALVE	1.00	EA	EM	
004	.30A11F0540X12	GASKET, VALVE SEAT	1.00	EA	ROCEM	
005	.112A2A23	SETSCREW	1.00	EA	EM	
006	.119A2R152	CAPSCREW	2.00	EA	O EM	

# PISTON AND ROD ASSEMBLY



H49998



2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH49998G18		PISTON 9.50 & ROD 4140/TC3/18DP			OI	
ILLUS NO.	PART NUMBER	PART NAME		QTY.	UM	SPARES USAGE CODE
001	.IEHM0407T1	ROD PISTON 9.50 HOS	4140/TC3/18D	1.00	EA	
002	.W139438	COLLAR, PISTON		1.00	EA	M
003	.W98966	NUT, PISTON		1.00	EA	M
004	.109A2A44	SET SCREW		1.00	EA	M
005	.X1010T12	NUT, ROD LOCKING (JAM NUT)		1.00	EA	M
006	.H49973P1	PISTON 9.50		1.00	EA	M
007	.11066545	RING 9.50 PISTON COMBO		3.00	EA	ROCEM

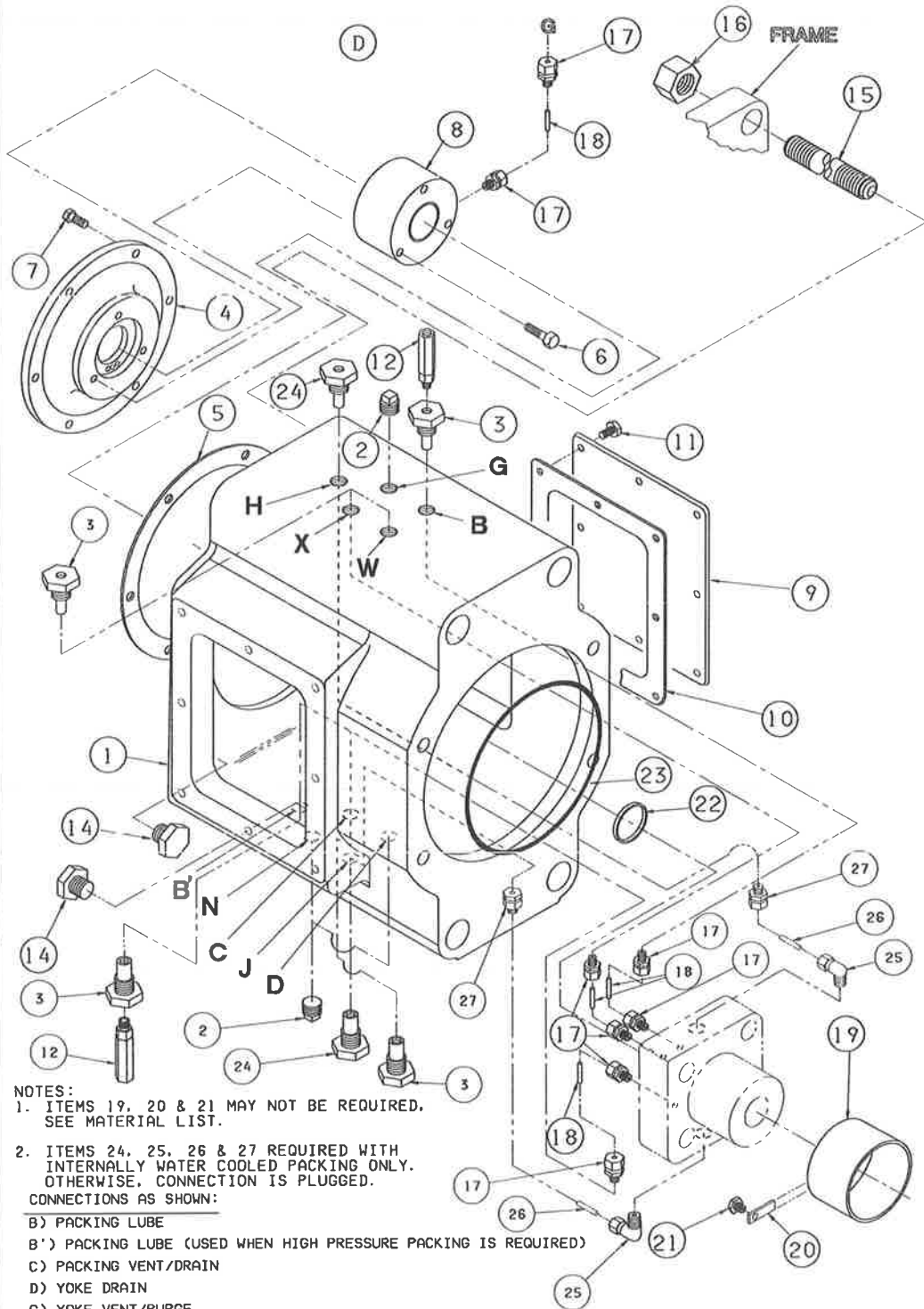


2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH59960AG1		PACKING ROD COMPL PURGED			OI
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE
001	.H59951A	CASE PKG PURGED	1.00	EA	
002	.12475901	RING SET RENEWAL	1.00	EA	
003	.5A11J40	RING PACKING	2.00	EA	
004	.16A11JG40	RING PACKING	4.00	EA	ROCEM
005	.X1498T29F	GASKET, PKG CASE	1.00	EA	ROCEM

# 18" YOKE ASSEMBLY PURGED



NOTES:  
 1. ITEMS 19, 20 & 21 MAY NOT BE REQUIRED. SEE MATERIAL LIST.

2. ITEMS 24, 25, 26 & 27 REQUIRED WITH INTERNALLY WATER COOLED PACKING ONLY. OTHERWISE, CONNECTION IS PLUGGED.

CONNECTIONS AS SHOWN:

- B) PACKING LUBE
- B') PACKING LUBE (USED WHEN HIGH PRESSURE PACKING IS REQUIRED)
- C) PACKING VENT/DRAIN
- D) YOKE DRAIN
- G) YOKE VENT/PURGE
- H) PACKING COOLANT DISCHARGE (IF REQUIRED)
- J) PACKING COOLANT INLET (IF REQUIRED)
- N) SPARE CONNECTION(S)
- W) WIPER PURGE
- X) PACKING PURGE

**H51913BF**

MODIFIED NOTES AND LETTERING	
D	ECN 0080204
A	WAS C/C WAS E/I WAS G/G WAS B:
B	WAS R; X WAS F ECN 0080204
C	REMOVED STREET ELL 90° ILLUS. 13
A	ADDED ILLUSTR. 23 ITEM 9580302

REVISIONS	DATE	APPROVED	DESCRIPTION
7/17/95	KAL/SRL	APPROVED	

ML ISSUED	
03/15/00	DOC/KAL
1/12/01	MEC/ALI
01/13/97	MOK/DNT
7/17/95	KAL/SRL

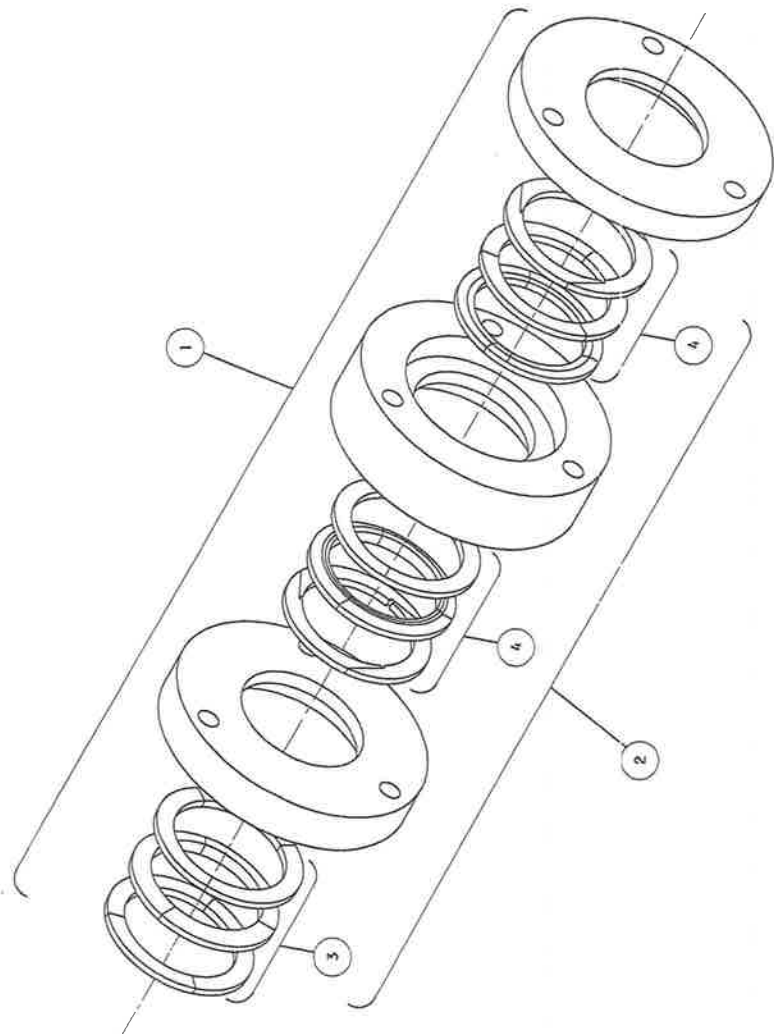
DR DRESSER-RAND	
18.00	SIZE
6.00	STROKE
HOS	TYPE
H51913BF	YOKE ASSEMBLY
D	ML REV.
1	SHEET 1 OF 1

2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH51913BFG8		YOKE 18.00 PURGED WIPER			OI
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE
001	.F32243	YOKE 18.00, HOS	1.00	EA	
002	.30A7C6	PLUG PIPE	4.00	EA	
003	.W47886	ADAPTER, PIPE	4.00	EA	
004	.R70691P1	OIL STUFFER HOS	1.00	EA	
005	.W139350	GASKET,OIL STUFFER HOS	1.00	EA	ROCEM
006	.35A2C230	CAPSCREW .500 X 3.75	3.00	EA	
007	.35A2C219	CAPSCREW	6.00	EA	
008	.MLH57758CG4	SCRAPER PURGE OIL	1.00	EA	
009	.W78603	COVER, YOKE RDS/HOS	2.00	EA	
010	.W78604	GASKET, YOKE COVER	2.00	EA	ROCEM
011	.35A2C217	CAPSCREW	16.00	EA	
012	.33037417	VALVE, CHECK LUBR	1.00	EA	ROCEM
014	.35A2C382	CAPSCREW	8.00	EA	
015	.R70754P1	TIEROD (18"YOKE)	4.00	EA	
016	.46A4K14	NUT 1.50X8UNC HEAVY HEX	4.00	EA	
017	.426A10C06	CONNECTOR 1/4 X 1/4	7.00	EA	
022	.300018AK9	SEAL OIL DEFLECTOR (2.50" ROD)	1.00	EA	M
023	.20A11CM279	ORING	1.00	EA	ROCEM

# PURGED OIL SCRAPER



ILLUS. NO. 2  
INCLUDES NO. 3 & NO. 4

**H57758C**

CHG TO: 16C 29C 124C 149C

ML ISSUED

**DR DRESSER-RAND**  
TULSA, OKLAHOMA 79145

DRAWN STUN DATE 12/90

CHECKED F KEMP DATE 12/90

APPROVED DATE

SIZE STROKE TYPE

NAME OF PART  
SCRAPER PURGED OIL

SIZE FEDERAL SUPPLY CODE DRAWING NO. ML REV.

C H57758C 1 -

SCALE NTS WT. SHEET OF

LTR	DESCRIPTION	DATE	APPROVED
REVISIONS			

UNLESS OTHERWISE SPECIFIED,  
ALL DIMENSIONS ARE IN INCHES

12307781 1

2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH57758CG4		SCRAPER PURGE OIL			OI	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.LEZP0001T3	CASE OIL SCRAPER	1.00	EA		
002	.12475091	RING SET RENEWAL	1.00	EA		
003	.R79480T4G	RING OIL SCRAPER	1.00	EA		
004	.5A11J40	RING PACKING	2.00	EA		

**6HC2656 / 6HC2659**

**6.00" X 6HOS CYLINDERS**

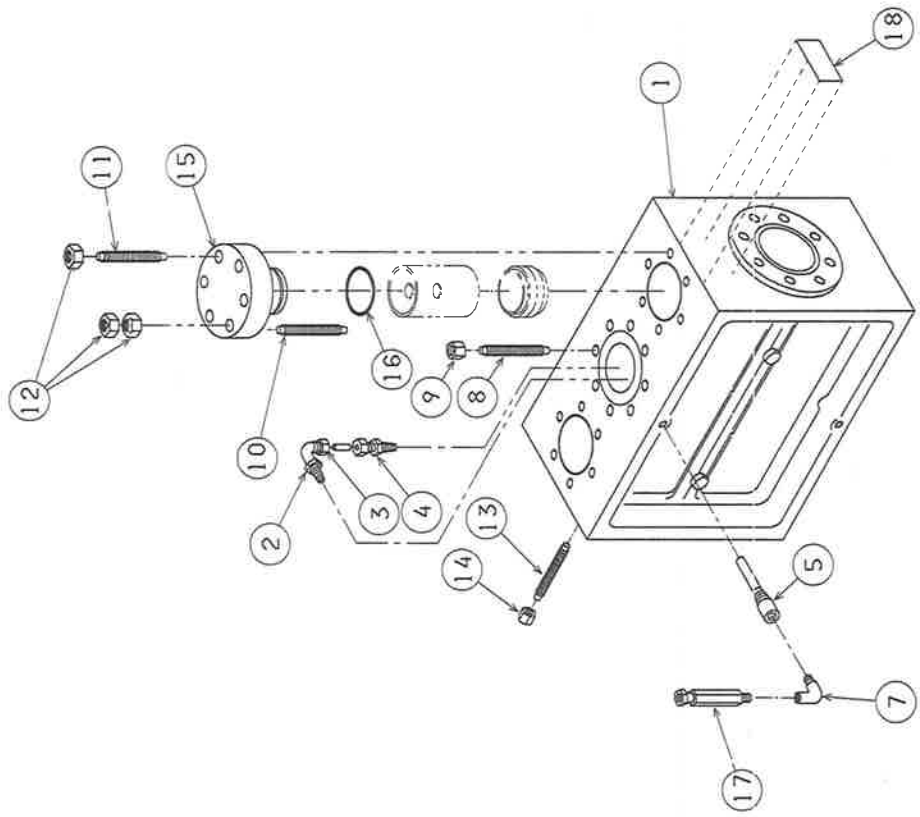


2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

6HC2656/6HC2659		CYL 6.00" X 6HOS (#48) NIGC			2000B0110	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
	.MLHJHA0601G4	CYLINDER 6.00 (1925#/PF48) NI GC PRGD	1.00	EA		
	.MLH50111G2	HEAD OUTER	1.00	EA		
	.MLH56190YG6	VALVE PF48 INLET	2.00	EA		
	.MLH56191YG6	VALVE PF48 DISCHARGE	2.00	EA		
	.MLH50115G2	ACCESS VALVE	4.00	EA		
	.MLH50113G15	PISTON 6.00 & ROD 4142/TC3/18DP	1.00	EA		
	.MLH59960G1	PACKING ROD COMPL PURGED	1.00	EA		
	.MLH51913BFG8	YOKE 18.00 PURGED WIPER	1.00	EA		

# CYLINDER ASSEMBLY ☺



HJHA0601

ISOMETRIC FORMAT (1:1) (TULSA)  
 C-SIZE (FULL 17.00 X 22.00) (FORM)

CHG TO: 29C 109 124C 149C

ML ISSUED

**DR DRESSER-RAND**  
 TULSA, OKLAHOMA 79146

SIZE	STROKE	TYPE
6.00	6.00	HOS-AC

DRAWN  
K LOCEY

DATE  
7/01/99

CHECKED  
G. W. TAS

DATE  
7/01/99

APPROVED  
G. W. TAS

DATE  
7/01/99

NAME OF PART  
CYLINDER ASSY.

SIZE	FEDERAL SUPPLY CODE	DRAWING NO.	ML	REV.
C		HJHA0601		-

LTR	DESCRIPTION	DATE	APPROVED
REVISIONS			

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES

SCALE NTS WT. SHEET 1 OF 1

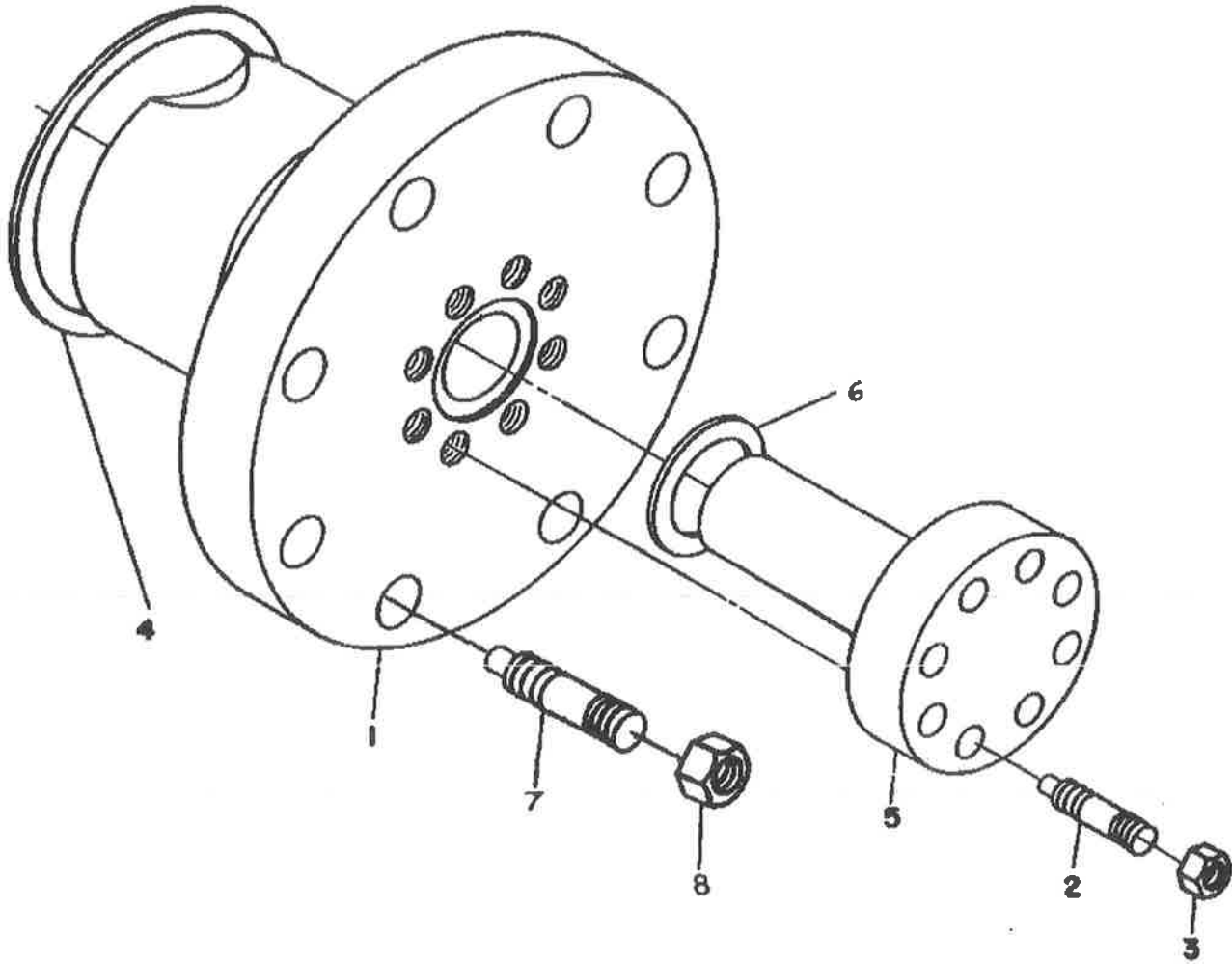
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLHJHA0601G4		CYLINDER 6.00 (1925#/PF48) NI GC		OI	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE
001	.1HJHM0601	CYLINDER 6.00 (1925#/PF48) NI GC	1.00	EA	
	.HJHM0601	CYLINDER 6.00 (1925#/PF48) GC	1.00	EA	
	.R72049T8	DOWEL PIPE PLUG	4.00	EA	
002	.428A10S11	ELBOW MALE	2.00	EA	
003	.33941881	TUBING 0.38X065W	36.00	IN	
004	.426A10S12	CONNECTOR MALE	2.00	EA	
005	.UAZM0003T1	ADAPTER QUILL	2.00	EA	
007	.143A7TT2	ELBOW 90 DEG SS	2.00	EA	
008	.R78164CX09050R	STUD	16.00	EA	
009	.46A4K11	NUT 1.125X8UNC HEAVY HEX	16.00	EA	
010	.R78164X08049R	STUD 1.00-8 X 6.125	8.00	EA	
011	.R78164X08042R	STUD	16.00	EA	
012	.38A4K10	NUT 1.00-8UNC	32.00	EA	
013	.R78164X06072R	STUD, PURGED PKG.	4.00	EA	
014	.38A4K8	NUT 3/4-10 HEAVY	4.00	EA	
015	.R72100B	COVER VALVE	4.00	EA	M
016	.VBZP0001T430	ORING (RESISTS EXPLOSIVE DECOMPRESSION)	4.00	EA	ROCEM
017	.33037417	VALVE, CHECK LUBR	2.00	EA	ROCEM
018	.11117074	KIT NAMEPLATE	1.00	EA	
	.12217261	NAMEPLATE CYLINDER	1.00	EA	
	.11065554	NAMEPLATE WARNING	1.00	EA	
000	.VAHK0603	GASKET KIT 6.00 HOS GC CYL	1.00	EA	ROCEM
	.VBZP0001T430	ORING (RESISTS EXPLOSIVE DECOMPRESSION)	4.00	EA	ROCEM
	.X1498T29F	GASKET, PKG CASE	1.00	EA	ROCEM
	.41A11C9	GASKET RING FACE	2.00	EA	

# PARTS LIST

## OUTER HEAD ASSEMBLY



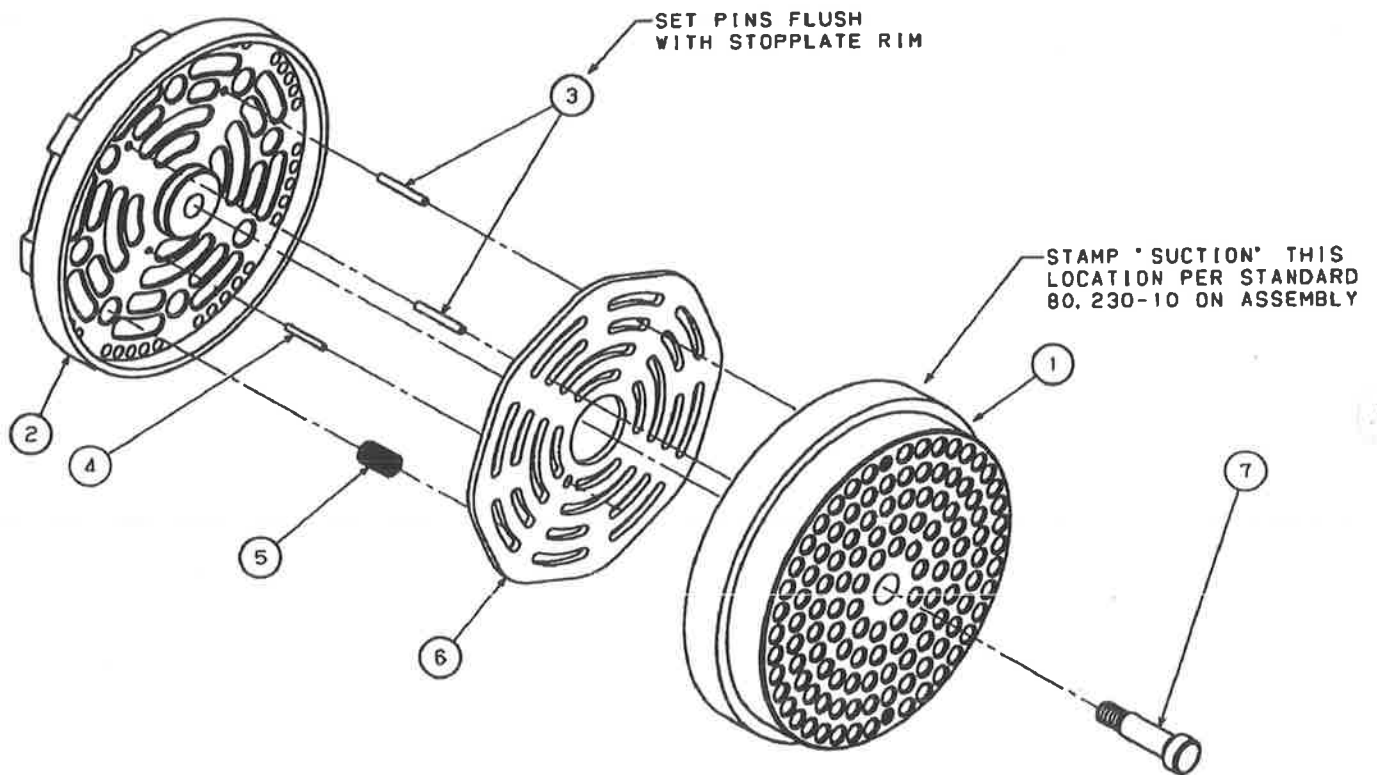
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH50111G2		HEAD OUTER			1995B0188	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.H50079	HEAD OUTER, HOS 6.00	1.00	EA		
002	.R78164X05032R	STUD	8.00	EA		
003	.38A4K7	NUT .625-11	8.00	EA		
004	.H32894T24	GASKET, OUTER HEAD	1.00	EA	ROCEM	
005	.R72083	PLUG, HOS 6.00 (CONT. CAST STOCK)	1.00	EA		
006	.30A11F0300X24	GASKET, PLUG	1.00	EA	ROCEM	
007	.R78164CX09048R	STUD	8.00	EA		
008	.46A4K11	NUT 1.125X8UNC HEAVY HEX	8.00	EA		
	.30A11F0300X24	GASKET, PLUG	1.00	EA	ROCEM	

# PARTS LIST

## 48 PF INLET VALVE



H56190Y

# PARTS LIST

VALVE 48PF INLET

MLH56190YG6

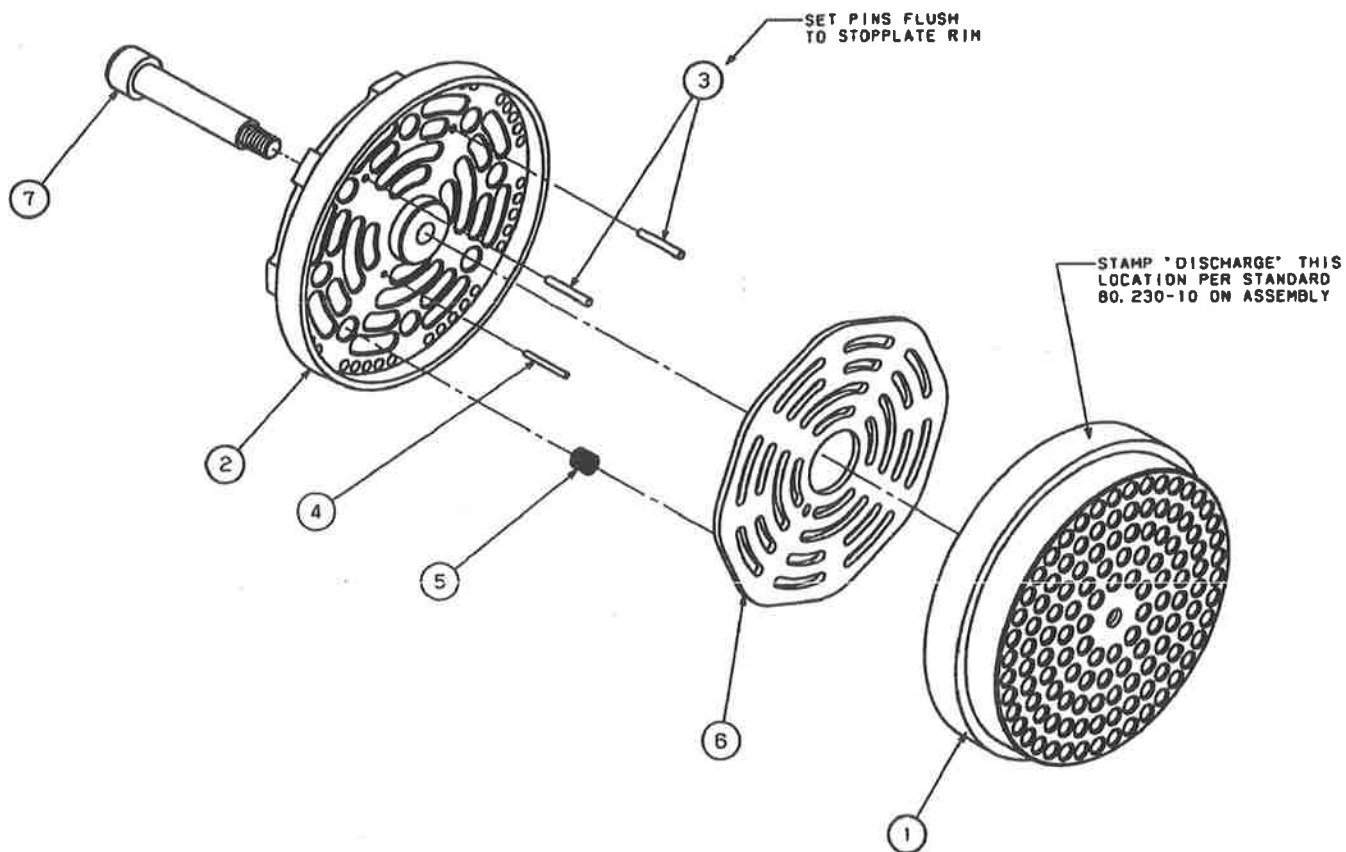
REV. 01

ILLUS. NO.	PART NUMBER	PART NAME	K I T	UNITS PER ASSEMBLY	J E T S	SPARES USAGE CODE
		/.080 LIFT				
1	.F36931M	SEAT INLET		1.00		PCEM
2	.F36932VT3	STOPPLATE INLET		1.00		PC
3	.25A13C96	ROLLPIN		2.00		PCOEM
4	.25A13C67	ROLLPIN		1.00		PCOEM
5	.PP1344	SPRING		8.00		PCROCEM
6	.H56183AP1	PLATE VALVE		1.00		PCROCEM
7	.121A2A204	SCREW SKT SHLDR		1.00		PCOEM
		/USE LOCTITE #242				
		/TO ASSEMBLE ITEMS				
		/2 & 7				

+SEE ACCESSORY LITERATURE SECTION

# PARTS LIST

## 48 PF DISCHARGE VALVE





# PARTS LIST

VALVE 48 PF DISCH

MLH56191YG6

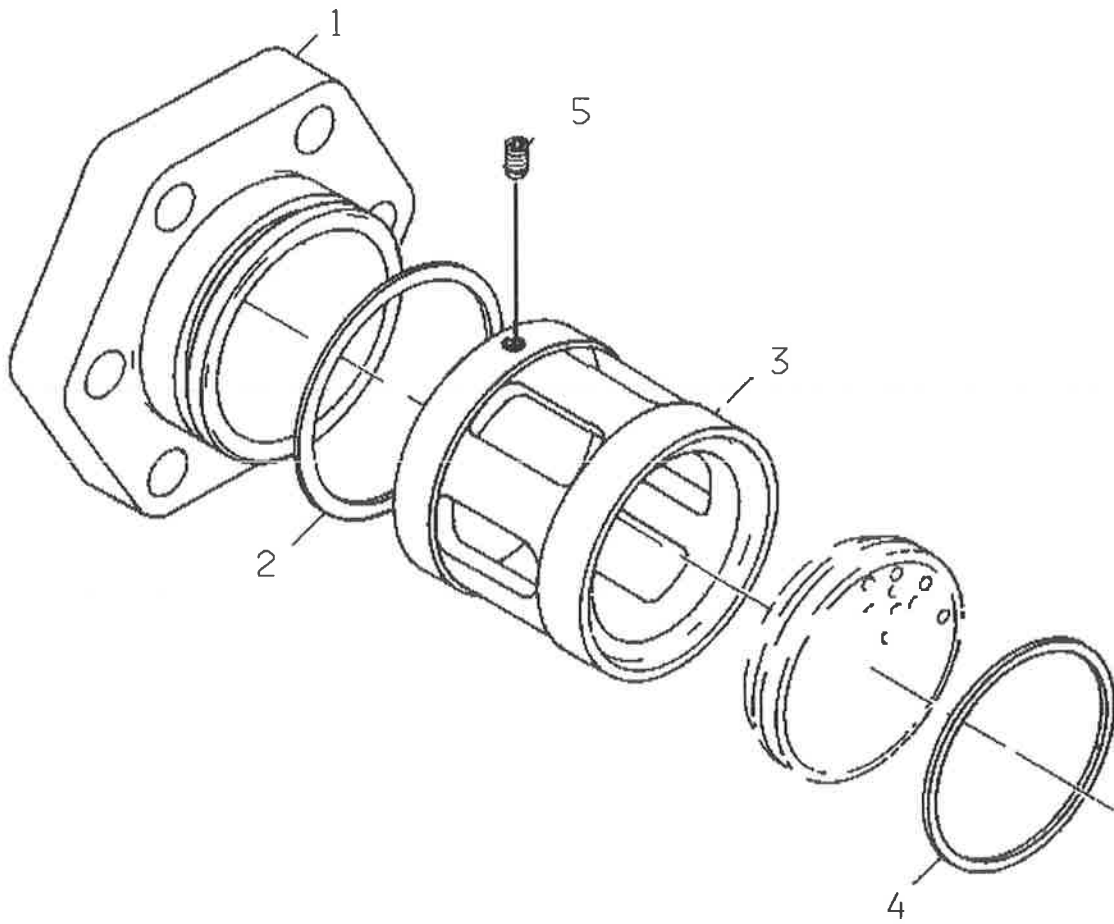
REV. 01

ILLUS. NO.	PART NUMBER	PART NAME	K I T	UNITS PER ASSEMBLY	UNITS	SPARES USAGE CODE
1	.F36933M	/.080 LIFT SEAT DISCHARGE		1.00		PCEM
2	.F36934WT3	STOPPLATE DISCHARGE		1.00		PC
3	.25A13C96	ROLLPIN		2.00		PCOEM
4	.25A13C67	ROLLPIN		1.00		PCOEM
5	.PP1344	SPRING		8.00		PCROCEM
6	.H56183AP1	PLATE VALVE		1.00		PCROCEM
7	.121A2A204	SCREW SKT SHLDR		1.00		PCOEM
		/USE LOCTITE #242				
		/TO ASSEMBLE ITEMS				
		/1 & 7				

\*SEE ACCESSORY LITERATURE SECTION

# D-R PARTS LIST

## VALVE ACCESSORIES



H50115

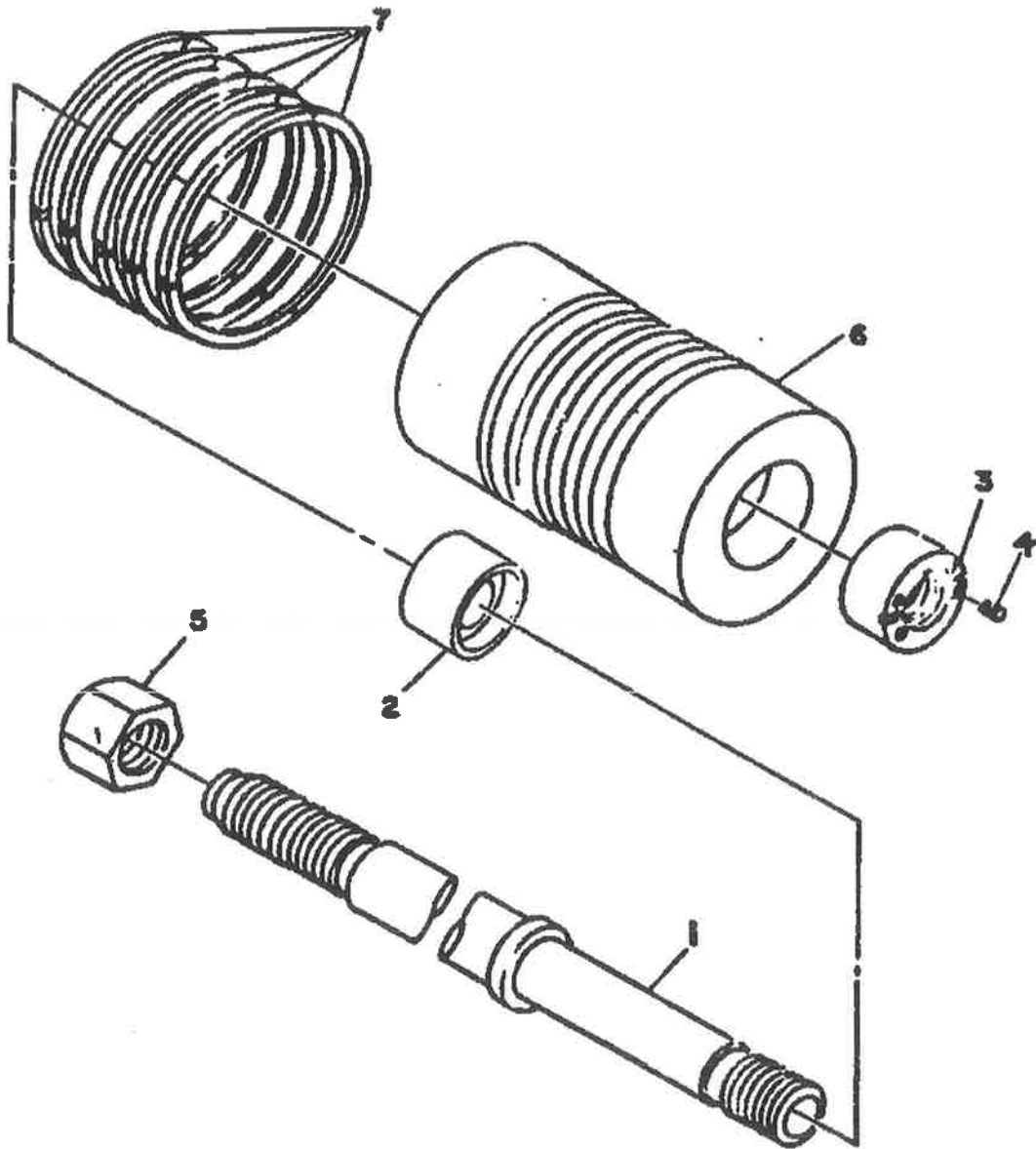
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH50115G2		ACCESS VALVE			OI	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
003	.R72082P1	CRAB VALVE	1.00	EA	EM	
004	.30A11F0540X12	GASKET, VALVE SEAT	1.00	EA	ROCEM	
005	.112A2A23	SETSCREW	1.00	EA	EM	

# PARTS LIST

## PISTON AND ROD ASSEMBLY



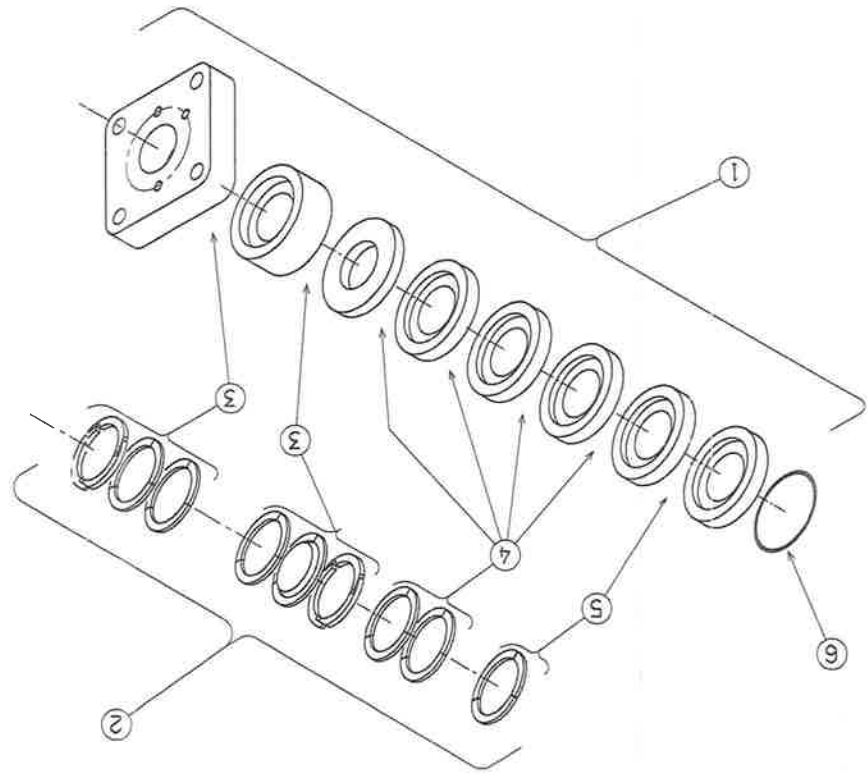
2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH50113G15		PISTON 6.00 & ROD 4142/TC3/18DP			OI
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE
001	.IEHM0204T1	ROD PISTON 4142/TC3/18"	1.00	EA	
002	.W139437	COLLAR, PISTON	1.00	EA	M
003	.W98966	NUT, PISTON	1.00	EA	M
004	.109A2S44	SETSCREW HEX SKT	1.00	EA	M
005	.X1010T12	NUT, ROD LOCKING (JAM NUT)	1.00	EA	M
006	.H50084P6	PISTON 6.00	1.00	EA	M
007	.11065687	RING 6.00 PISTON COMBO	5.00	EA	ROCEM

H59960

PACKING ROD COMPLETE ○



CHG TO: 16C, 29C, 80, 124C, 149C

ML ISSUED

**DR DRESSER-RAND**  
PRINTED POST. N. Y. 14870

SIZE	STROKE	TYPE
		HOS

DRAWN	DATE	NAME OF PART
	07/26/74	
CHECKED	DATE	PACKING ROD COMPLETE

APPROVED	DATE	SIZE	FEDERAL SUPPLY CODE	DRAWING NO.	ML	REV.
		C		H59960		-

SCALE	NTS	WT.	SHEET 1 OF 1

LTR	DESCRIPTION	DATE	APPROVED
REVISIONS			

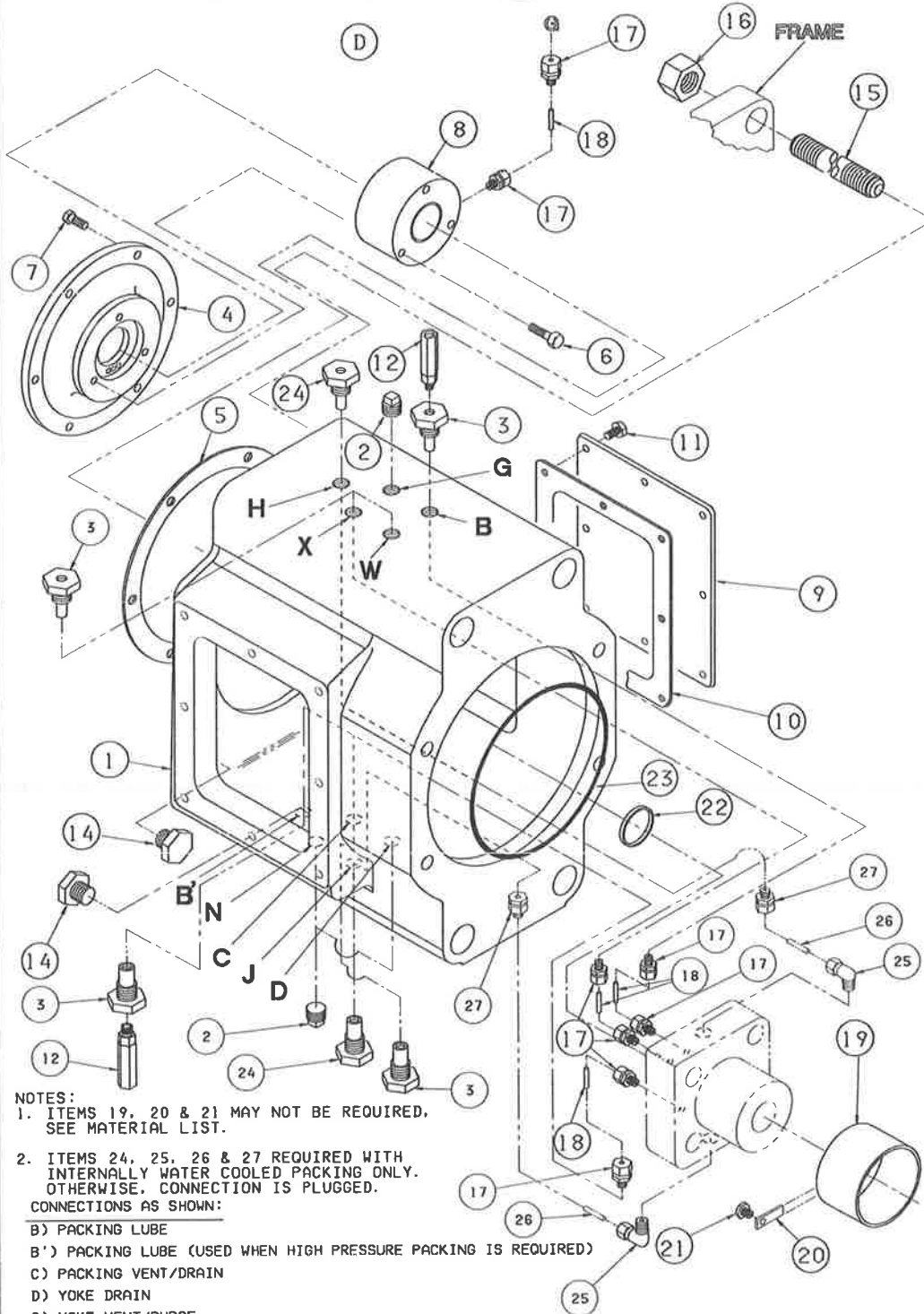
UNLESS OTHERWISE SPECIFIED,  
ALL DIMENSIONS ARE IN INCHES

2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH59960G1		PACKING ROD COMPL PURGED			OI
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE
001	.H59951	CASE PKG PURGED	1.00	EA	
002	.12475893	RING SET RENEWAL	1.00	EA	
003	.5A11J40	RING PACKING	2.00	EA	
004	.16A11JG40	RING PACKING	4.00	EA	ROCEM
005	.7A11G40G	RING PACKING	1.00	EA	ROCEM
006	.X1498T29F	GASKET, PKG CASE	1.00	EA	ROCEM

# 18" YOKE ASSEMBLY PURGED



- NOTES:
- ITEMS 19, 20 & 21 MAY NOT BE REQUIRED. SEE MATERIAL LIST.
  - ITEMS 24, 25, 26 & 27 REQUIRED WITH INTERNALLY WATER COOLED PACKING ONLY. OTHERWISE, CONNECTION IS PLUGGED. CONNECTIONS AS SHOWN:
- B) PACKING LUBE
  - B') PACKING LUBE (USED WHEN HIGH PRESSURE PACKING IS REQUIRED)
  - C) PACKING VENT/DRAIN
  - D) YOKE DRAIN
  - G) YOKE VENT/PURGE
  - H) PACKING COOLANT DISCHARGE (IF REQUIRED)
  - J) PACKING COOLANT INLET (IF REQUIRED)
  - N) SPARE CONNECTION(S)
  - W) WIPER PURGE
  - X) PACKING PURGE

**H51913BF**

MODIFIED NOTES AND LETTERING		DATE	BY
D	ECN 0080204	03/15/20	DDC/MAL
A	A WAS C; C WAS E; V WAS G; G WAS B;	1/12/00	WEC/MAL
C	B WAS R; X WAS F; ECN 0080024	01/17/97	MOK/SWT
B	REMOVED STREET ELL 90° ILLUS. 13	01/17/97	MOK/SWT
A	ADDED ILLUSTR. 23 ITEM	7/17/95	KAL/GRL
A	9580302		

REVISIONS		DATE	APPROVED
LTR	DESCRIPTION	DATE	APPROVED

CHG TO:	29C 109 124C 149C
ML ISSUED	
DR	DRESSER-RAND
TULSA, OKLAHOMA	79148

SIZE	18.00	STROKE	6.00	TYPE	HOS
NAME OF PART	YOKE ASSEMBLY				
SIZE FEDERAL SUPPLY CODE	H51913BF				
DISPATCH NO.	ML REV. D				
SCALE	NTS				
WT.	SHEET 1 OF 1				

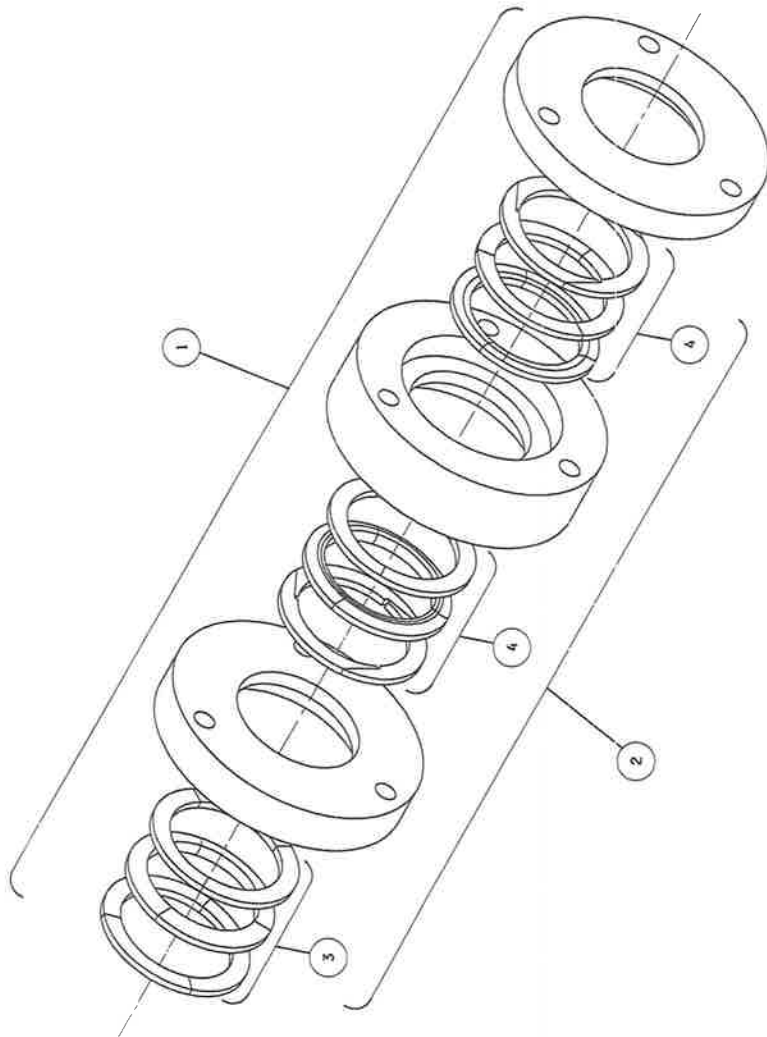


2000/09/21

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH51913BFG8		YOKE 18.00 PURGED WIPER			OI	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.F32243	YOKE 18.00, HOS	1.00	EA		
002	.30A7C6	PLUG PIPE	4.00	EA		
003	.W47886	ADAPTER, PIPE	4.00	EA		
004	.R70691P1	OIL STUFFER HOS	1.00	EA		
005	.W139350	GASKET,OIL STUFFER HOS	1.00	EA	ROCEM	
006	.35A2C230	CAPSCREW .500 X 3.75	3.00	EA		
007	.35A2C219	CAPSCREW	6.00	EA		
008	.MLH57758CG4	SCRAPER PURGE OIL	1.00	EA		
009	.W78603	COVER, YOKE RDS/HOS	2.00	EA		
010	.W78604	GASKET, YOKE COVER	2.00	EA	ROCEM	
011	.35A2C217	CAPSCREW	16.00	EA		
012	.33037417	VALVE, CHECK LUBR	1.00	EA	ROCEM	
014	.35A2C382	CAPSCREW	8.00	EA		
015	.R70754P1	TIEROD (18"YOKE)	4.00	EA		
016	.46A4K14	NUT 1.50X8UNC HEAVY HEX	4.00	EA		
017	.426A10C06	CONNECTOR 1/4 X 1/4	7.00	EA		
022	.300018AK9	SEAL OIL DEFLECTOR (2.50" ROD)	1.00	EA	M	
023	.20A11CM279	ORING	1.00	EA	ROCEM	

# PURGED OIL SCRAPER



ILLUS. NO. 2  
INCLUDES NO. 3 & NO. 4

## H57758C

CHG TO: 16C 29C 124C 149C

ML ISSUED

**DR DRESSER-RAND**  
TULSA, OKLAHOMA 79146

DRAWN	DATE
STLN	12/90
CHECKED	DATE
F KEMP	12/90
APPROVED	DATE

SIZE	STROKE	TYPE		
NAME OF PART				
SCRAPER PURGED OIL				
SIZE	FEDERAL SUPPLY CODE	DRAWING NO.	ML	REV.
C		H57758C		-

LTR	DESCRIPTION	DATE	APPROVED
REVISIONS			

UNLESS OTHERWISE SPECIFIED,  
ALL DIMENSIONS ARE IN INCHES

SCALE	NTS	WT.	SHEET	OF

12307781

1

2000/09/21

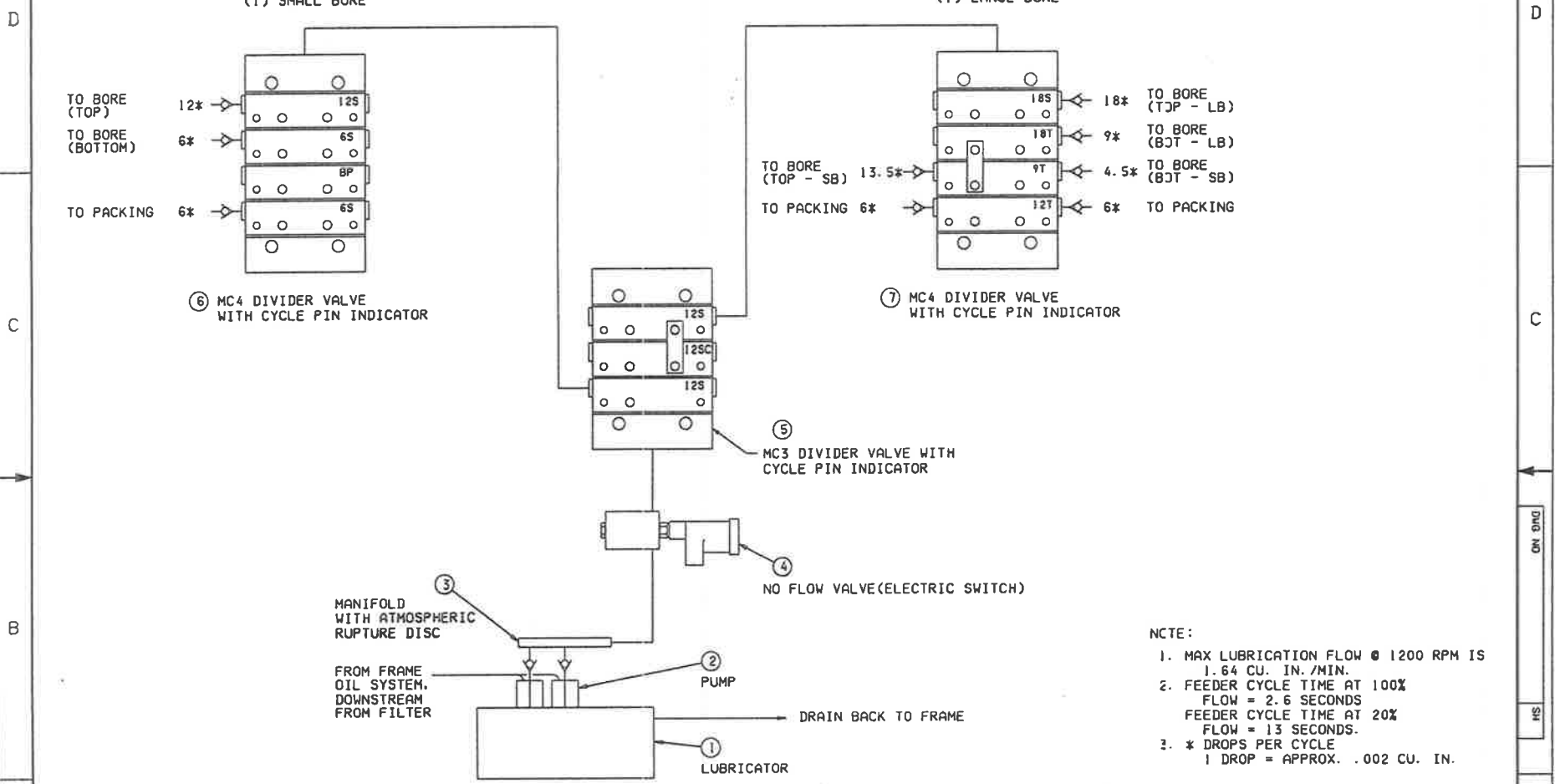
DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLH57758CG4		SCRAPER PURGE OIL			OI	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.LEZP0001T3	CASE OIL SCRAPER	1.00	EA		
002	.12475091	RING SET RENEWAL	1.00	EA		
003	.R79480T4G	RING OIL SCRAPER	1.00	EA		
004	.5A11J40	RING PACKING	2.00	EA		

# Cylinder Lubrication

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is intentionally  
blank.

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED



- NCTE:
1. MAX LUBRICATION FLOW @ 1200 RPM IS 1.64 CU. IN. /MIN.
  2. FEEDER CYCLE TIME AT 100% FLOW = 2.6 SECONDS  
FEEDER CYCLE TIME AT 20% FLOW = 13 SECONDS.
  2. \* DROPS PER CYCLE  
1 DROP = APPROX. .002 CU. IN.

ML ISSUED

CHG TO: 29C 109 124C 149C

THIS DRAWING CONTAINS CONFIDENTIAL AND TRADE SECRET INFORMATION. IS THE PROPERTY OF DRESSER-RAND COMPANY. AND IS PROVIDED TO THE RECEIVER IN CONFIDENCE. THE RECEIVER BY RECEPTION AND RETENTION OF THE DRAWING ACCEPTS THE DRAWING IN CONFIDENCE AND AGREES THAT, EXCEPT AS AUTHORIZED IN WRITING BY DRESSER-RAND COMPANY. IT WILL (1) NOT USE THE DRAWING OR ANY COPY THEREOF OR THE CONFIDENTIAL OR TRADE SECRET INFORMATION THEREIN; (2) NOT COPY THE DRAWING; (3) NOT DISCLOSE TO OTHERS EITHER THE DRAWING OR THE CONFIDENTIAL OR TRADE SECRET INFORMATION THEREIN; AND (4) UPON COMPLETION OF THE NEED TO RETAIN THE DRAWING, OR UPON DEMAND, RETURN THE DRAWING AND ALL COPIES THEREOF IN ANY FORM.

NOTE: THIS DRAWING CONFORMS TO ANSI STD Y14.5M-1982 UNLESS OTHERWISE SPECIFIED. ALL DIMENSIONS ARE IN INCHES

DIMENSION	TOLERANCE	MACHINING		SYMBOLS		MATERIAL
		DIMENSION	TOLERANCE	SYMBOLS	GEOMETRIC SYMBOLS	
UNDER 1"	+ .001" - .001"	2 PL.	3 PL.	FLATNESS		
1" TO 6"	+ .012" - .002"	UNDER 14"	± .010"	PERPENDICULARITY		
6" TO 6"	+ .012" - .002"	14" AND UP	± .010"	PARALLELISM		
6" TO 18"	+ .012" - .002"	ANGLES	± 30'	CONCENTRICITY		
18" TO 18"	+ .012" - .002"	UNSPECIFIED FILLETS AND RADII TO BE .125		POSITION		
18" AND UP	+ .012" - .002"			CIRCULAR RUNOUT	TOTAL RUNOUT	

UNLESS OTHERWISE SPECIFIED REMOVE ALL BURRS AND SHARP EDGES AND CHAMFER 5/16" TAPPED HOLES TO BODY SIZE

THIRD ANGLE PROJECTION		DRAWN		DATE	
DRAWN		WW FERRIER		2/8/00	
CHECKED		AL INGLE		DATE	
APPROVED		AL INGLE		DATE	
DATE		2/8/00		2/8/00	
SIZE		STROKE		TYPE	
4		THROW		6	
NAME OF PART		LUBRICATION SYSTEM			
FEDERAL SUPPLY CODE		DWG NO.		ML REV.	
C		QBHA0308		-	
SCALE		NTS		WT.	
SHEET		OF 1			

2000/09/22

DRESSER-RAND GAS FIELD COMPRESSORS  
PARTS LIST

MLQBHA0308G1		LUBRICATION SYSTEM 6HOS3 - 2SML/1L			2000B0099	
ILLUS NO.	PART NUMBER	PART NAME	QTY.	UM	SPARES USAGE CODE	
001	.735302	LUBRICATOR-PREMIER / 2-.38" P55U EXT PU	1.00	EA		
002	.91203	PUMP LUBRICATOR .375" EXT FEED	2.00	EA		
003	.91043-2	MANIFOLD LUBRICATOR - 2 PUMPS	1.00	EA		
004	.456060009	ALERT LUBE LINE LUBRIQUIP	1.00	EA		
005	.MCL3-011	MCL3 (12S/CPI-12SC-12S)	1.00	EA		
006	.MCL4-027	MCL4 (12S/CPI-6S-BP-6S)	1.00	EA		
007	.MCL4-009	MCL4 (18S/CPI-18TCL-9T-12T)	1.00	EA		







# **DRESSER-RAND**

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## How to order replacement parts...



The use of repair parts other than those included within the Dresser-Rand approved parts list may create hazardous conditions over which the company has no control. Such hazardous conditions can lead to accidents that may be life-threatening, cause substantial bodily injury, or result in damage to the equipment.

***When ordering replacement parts, please specify:***

1. The SERIAL NUMBER as stamped on the machine nameplate.
2. The QUANTITY desired and the PART NAME and PART NUMBER, exactly as listed.

***Careful observance of the following will help us to fill your order correctly and promptly:***

- THE MACHINE SERIAL NUMBER MUST BE GIVEN WITH EVERY ORDER FOR PARTS. This number will be found on a nameplate attached to the unit. It consists of a combination of letters and numerals (Example: YRS312, YRH590, Y6R565, A17922). The serial number is often permanently stamped in the metal near the nameplate location.
- DO NOT use such terms as "complete" and "sets" unless these words appear specifically in the Parts List. State quantity wanted and give the part number and part name exactly as shown in the Parts List. DO NOT use illustration numbers when ordering parts.
- When ordering spares for parts not manufactured by Dresser-Rand Company, such as Lubricators, Magnetos, Oil Pumps, Governors, etc., always give the serial or type numbers of these parts as well as the Dresser-Rand machine serial number. This will enable us to more quickly send the correct material, as manufacturers often make changes over which we have no control.
- If returning parts for inspection or repair, be sure to include the serial number of the machine from which the parts were removed.

# How to use approved parts lists...

## **PARTS LIST INDEX**

The assemblies and major subassemblies comprising the complete unit are listed in the index in the order in which they are displayed and broken down in the Parts List. The Part Number for each assembly and major subassembly listed in the index appears at the top right corner of the Parts List which lists the subassemblies and individual parts of that assembly.

## **PARTS LIST**

The Parts List contains the listings and illustrations of the parts for your unit. Interpretation of the Parts List is described on the next page.

### **NOTE**

Some illustrations may have illustration numbers which do not appear in the Parts List. This simply means those parts are not used on your unit.

A plus (+) sign next to a part name indicates that sub-manufacturer's literature for that part is available elsewhere in the Service Manual. A notation at the bottom of the parts list page calls attention to this fact.

## **RECOMMENDED SPARE PARTS DATA**

The spare parts data shown in the Spares Usage Code column of the Parts List identifies for you those Spare parts which you may require in the maintenance of the Dresser-Rand equipment.

It is desirable to forecast as accurately as possible your requirements for Spare Parts to assure that the necessary parts and materials will be available when needed to keep your equipment in efficient and continuous operating condition.

We feel that you are in a better position than we to decide how much you wish to invest in Spare Parts. The importance of minimizing shut-down time due to possible breakdowns in operation, together with the distance from source of supply and transportation facilities, should be considered when ordering spare parts.

**MAINTAIN THE MAXIMUM OPERATING CHARACTERISTICS AND DEPENDABILITY OF YOUR EQUIPMENT BY USING GENUINE DRESSER-RAND SPARE PARTS.**

# How to interpret parts list columns...

## ILLUSTRATION NUMBER COLUMN

The illustration number is the item number assigned to the part in the listing. This illustration number identifies the part on the associated illustration. When a parts list has no illustration this column is left blank.

## SPARES USAGE CODE COLUMN

This column identifies parts that are recommended under one or more of five classes of spare parts.

### Spare Usage Code

Code	Definition
R	Parts normally consumed during routine operation.
O	Parts normally used for overhaul.
C	Parts for convenience in minimizing down time at overhaul periods.
E	Insurance items normally consumed over an extended period.
M	Insurance items required for major failure, otherwise not likely to be consumed.

## PART NAME COLUMN

This column contains standard noun-names with major modifiers. When ordering an item, give the Part Name exactly as shown.

ILLUS. NUMBER	PART NUMBER	PART NAME	KIT	UNITS PER ASSEMBLY	UNITS OF MEASURE	SPARES USAGE CODE
	PISTON & ROD	MLH43705CG1				

## PART NUMBER AND NAME FOR THE TOTAL ASSEMBLY

Includes all parts listed.

## KIT CODE COLUMN

This column indicates parts that are included in one or more kits.

Code	Definition
G	Item included in a Gasket Set.

## PART NUMBER COLUMN

All numbers shown are Dresser-Rand Part Numbers. The relationship of a part to its next higher assembly is indicated by indenture in the Part Number column. An included item is denoted by indenture under the item with which it is included. For example:

PART NUMBER	PART NAME
1 H28571A	Liner
W54857A	O-Ring
W81556	Gasket

When ordering any part having an indented line or lines following the part, the indented items are always included with the part.

Indented items may also be ordered separately.

## UNITS PER ASSEMBLY COLUMN

The quantities specified in this column indicate the number of parts used per next-higher-assembly and are not necessarily the total number used in the complete unit.

## UNITS OF MEASURE COLUMN

This column designates what unit of measure is applicable for a particular part number. Examples of this are:

PC = piece	HA = halves
IN = inch	GA = gallons
FT = feet	QT = quarts
SI = square inch	LB = pounds
SF = square feet	

## **Sales Support Operation...**

**DRESSER-RAND**  
**Gas Field Compressors**  
5710 S. Garnett  
Tulsa, OK 74146-6843

Phone (918) 254-4099  
Fax (918) 252-9055

# **DRESSER-RAND**

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## **SUB-MANUFACTURER'S EQUIPMENT**

The instructions and replacement parts lists for sub-manufacturer supplied equipment are located in this section. The content of these instructions and parts lists are the responsibility of the particular sub-manufacturer. Prices that may be given in the literature are those of the manufacturer and not those of Dresser-Rand Company; no assurance can be given that these prices were current at the time this Service Manual was issued.

# **OPERATING INSTRUCTIONS**

## **BASCO TYPE "500" EXCHANGERS**

### **INSTALLATION**

Except when the hot fluid is dirty or is prone to fouling, it is preferable to pass the cooling medium through the tubes and the hot medium through the shell. Since the tubes can be mechanically cleaned it is sometimes advantageous to pass the hot dirty fluid through the tubes. When installing a single pass unit the shell inlet must be at the same end of the exchanger as the tubeside outlet.

When the BASCO Type "500" is used with steam as the heating medium, the steam must be in the shell. Either or both shell connections may be used as steam inlets.

### **OPERATION**

At start up or after maintenance inspection, both shell and tubeside should be carefully vented and full of liquid. Improper venting and fouling are the most common causes of heat exchanger malfunction.

To obtain maximum performance the following precautions should be taken:

1. Make sure all other equipment in the fluid circuits are functioning properly.
2. Maintain rated flow of both fluids but be sure flow rates are not excessive. Frequently tube failures can be directly traced to excessive fluid flow, causing tube erosion and corrosion. In the case of heavy oils high flow rates can reduce cooler efficiency.
3. A periodic venting program should be followed if air or vapor tends to accumulate in the system.
4. Observe a regular maintenance program.

### **INSPECTION**

A periodic inspection and maintenance program should be followed with any heat exchanger. To ensure continuous satisfactory performance of your Type "500" exchanger the following steps should be taken:

1. Inspect filters in system and replace or clean as required.
2. Remove bonnets from heat exchanger and inspect the zinc pencils for erosion or oxide deposits. Scrape to bright surface and replace if more than half corroded away.
3. Carefully examine tubes for scale and clean if necessary. After cleaning, examine for erosion or corrosion.

### **CLEANING**

The interior surfaces of the tubes can be cleaned in several ways. Many deposits can be removed by flushing a high velocity stream of water through them. For more stubborn deposits, wire brushes or rods can be used. If the special air or water gun is available rubber plugs can be forced through the tubes.

Both shell and tubeside can be cleaned chemically by circulating cleaning solutions through the exchanger. For most deposits a mild oakite solution is satisfactory. Circulate the cleaning solution until exchanger is clean. Be sure to wash out all chemicals thoroughly with clean water before returning the exchanger to service.



# AMERICAN PRECISION INDUSTRIES

Basco Division

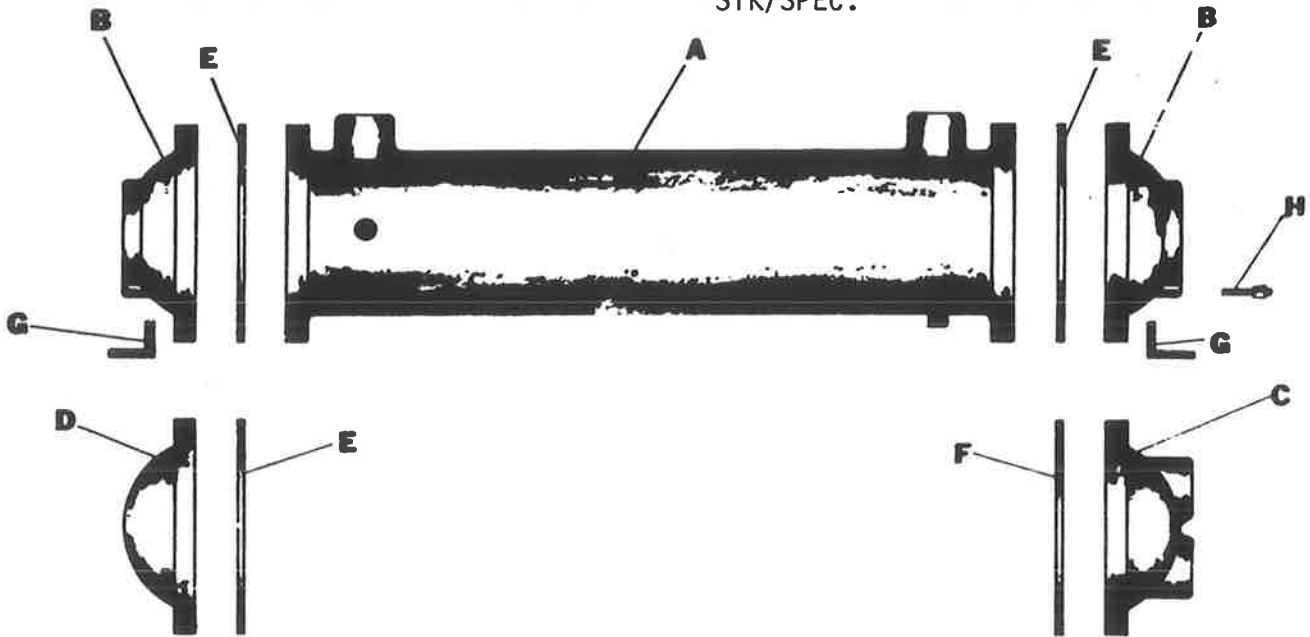
2777 Walden Ave, Buffalo, NY 14225 Tel: (716) 684-6700 • Fax: 684-2129

## PARTS LIST

Type "500" Heat Exchanger - Size 08036-L-4PASS

Customer DRESSER RAND  
Customer P.O. No. PGCG870320C  
Customer Part No. W106865

Basco Ct. No. 3-9510056  
Basco Serial No. 9510056-0101thru0103  
Basco Drawing No. 6A24A08036  
STK/SPEC.



A - Core Assembly 6A23C08036

B - Single Pass Bonnet \_\_\_\_\_

C - Inlet-Outlet Bonnet 32D02E8

D - Reversing Bonnet 33D02E8

E - Gasket 031G01A-8

F - Gasket 032G01A-8

G - Mounting Bracket 4501X-8

H - Zinc Pencil \_\_\_\_\_







# 8900/8910 Filter Series SERVICE INSTRUCTIONS

## 1. General Sources of Information:

Reference should be made to PIHC Low/Medium Pressure Filter Catalog for dimensions, operating parameters assembly and element part numbering, ordering information and notes and specifications. The Bulletin is available through your local Pall Industrial Hydraulics Distributor or directly from Pall Industrial Hydraulics Corporation, 2200 Northern Blvd., East Hills, New York 11548, Telephone number (516) 484-5400.

## 2. Specifications:

### Housing Materials:

Head: Gray Cast Iron  
Bowl: Carbon Steel  
Ring: Ductile Iron

Maximum Operating Pressure:  
600 psi (41 Bar)

Maximum Operating Temperature Range:  
-45°F to 225°F (-43°C to 107°C) with nitrile seals  
-20°F to 250°F (-29°C to 121°C) with fluorocarbon seals  
140°F (60°C) maximum in HWCF or water glycol fluids

Element Collapse Rating: 150 psid (10 Bar) minimum

### Bypass Valve Setting Options:

50 ± 5 psid (3.4 ± 0.34 Bar) cracking pressure  
25 ± 5 psid (1.7 ± 0.34 Bar) cracking pressure

Seals: Nitrile or Fluorocarbon standard O-rings.

The actual operating conditions should be checked by the user to ensure that the element, housing and all seals are compatible with the fluid and application, and are within local safety codes. Please contact Pall Industrial Hydraulics Corporation or approved distributor if further information is required.

**CAUTION:** Maximum surge flow should not exceed 1.3 times normal flow.

## 3. Installation of Housing:

3.1 The filter can be installed in any attitude, but for ease of servicing, it is recommended that it is installed vertically with the filter bowl pointing downwards. A minimum clearance of 2½" (64 mm) should be allowed beneath the bowl for installation and removal of filter element.

3.2 Flanged differential pressure devices, when fitted, must have screws torque tightened to 23 lb. in. (2.6 Nm). Threaded differential pressure devices, when fitted, must be torque tightened to 40 lb. ft. (54 Nm). All visual indicators must be clearly visible.

NOTE: Head has a machined port for a differential pressure warning device; flanged ports may be sealed with an H\*8630BL or threaded ports may be sealed with an HA9000-kit port plug kit. Never place the port plug kit in this port without first installing the lower O-ring in lower O-ring groove, otherwise a small bypass flow will result, allowing contaminant downstream of the filter element.

3.3 Mount the filter assembly in position using four bolts in the ½-UNC x 1" full threaded holes in the head assembly.

3.4 Use check valve on outlet if there is a possibility of reverse flow.

**CAUTION:** Reverse flow through filter element will cause damage.

3.5 Connect lines or hoses to ports.

**WARNING!** USE FITTINGS OR ADAPTERS COMPATIBLE WITH PORTS SUPPLIED AS SHOWN BY PART NUMBER ON NAMEPLATE AND NOTED IN DATA SHEETS: USE OF INCORRECT FITTINGS OR ADAPTERS CAN CAUSE FILTER HOUSING OR MANIFOLD FAILURE RESULTING IN LOSS OF PRESSURE AND POSSIBLE SYSTEM FAILURE OR PERSONAL INJURY.

3.6 Bleed filter prior to operation: open bleed plug, if fitted, one and one half turns. Jog system and fill filter until all air bleeds through plug, then tighten plug. Pressurize system fully and check for leaks; if leaks occur refer to Section 4.

**CAUTION:** Failure to bleed filter housing adequately will increase the dissolved air content of the system fluid which will shorten fluid life and may cause other problems in the system.

3.7 Painting of the filter is optional. The black coating on the filter is a suitable painting base.

Note: Cover the differential pressure warning device and nameplate if painting of assembly takes place.

#### 4. Routine Maintenance:

4.1 Pall filters do not normally require special attention except for periodic monitoring of the differential pressure warning device. Schedule replacement of filter element every six months or sooner, and have ample supply of spare elements available.

4.2 If external leakage is noted, replace O-ring at leak. For bowl seal leaks, replace O-ring (3). If leakage persists, check sealing surfaces for scratches or cracks; replace any defective parts.

4.3 Differential pressure devices actuate when the element needs changing or because of high fluid viscosity in "cold start" conditions. If "cold start" conditions exist, see Section 5.2 and 5.3.

**CAUTION:** Continued operation of 8900/8910 bypass filters (valve options A or B) with differential pressure device actuated can allow unfiltered flow downstream. Continued operation of 8900/8910 non-bypass filters (valve options W) may cause collapse or premature fatigue failure of the plugged filter element, which could allow contaminant and unfiltered flow downstream. Refer to element change instructions in paragraphs 6.1 through 6.7.

4.4 A dirty system can quickly plug a new filter element, especially with Pall silt removal grade media. It may require one or two initial element changes to stabilize element life. If element life is short or differential pressure excessive, filter may be undersized; refer to the sizing and selection section of the PIHC Low/Medium Pressure Filter Catalog.

4.5 Make sure element change labels are clean and undamaged. Replace illegible labels with the appropriate new labels.

#### 5. Differential Pressure Devices:

Reference should be made to Product Brochure for dimensions, operating parameters, part numbering, ordering information and specifications. The Bulletin is available through your local Pall Industrial Hydraulics Distributor or directly from Pall Industrial Hydraulics Corporation, 2200 Northern Blvd., East Hills, New York 11548. Telephone (516) 484-5400.

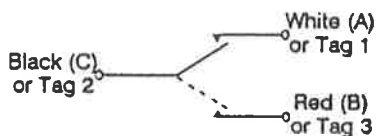
5.1 Differential pressure devices actuate when the element needs changing or because of high fluid viscosity in "cold start" conditions.

5.2 If visual indicator is fitted and actuates during "cold start" (orange sleeve or red button is visible), reset by depressing the button when the normal operating temperature is reached. If indicator actuates after resetting, replace element.

NOTE: Option "PL" or "PT" visual indicator has thermal lockout and manual reset. No signal below 32° F (0°C) signal above 80° F (29°C).

5.3 If electrical switch actuates (red light comes on) during cold start, continue operating until red light goes out as system warms to normal operating temperature (this feature can be used as "warm up" indication in operating procedures). If warning signal (red light) remains or appears when system is warm, replace element.

5.4 Use of both positive indication (green light) and negative indication (red light for dirty element) is recommended to effectively monitor filter element life.



Electrical Connections  
& Ratings for all differential  
pressure switch options

110 VAC = 4A (inductive),  
4A (resistive)  
220 VAC = 4A (inductive),  
4A (resistive)  
28 VDC = 3A (inductive),  
5A (resistive)  
48 VDC = 1A (inductive),  
1.5A (resistive)  
125 VDC = 0.25A (inductive),  
0.5A (resistive)

Maximum inrush - 24 amps  
UL, Inc. listed rating of Microswitch™  
4 amps at 250 VAC  
1/4 amp resistive at 110 VDC  
1/2 amp resistive at 110 VDC

Electrical Differential Pressure  
Switch Operation

When preset differential pressure is  
exceeded continuity switches from  
"C" - "A" to "C" - "B"

When differential pressure  
decreases continuity returns to  
"C" - "A"

™: Honeywell

## 6. Filter Element Servicing:

Refer to Figure 1 or Service Parts List (Section 8) for item numbers. Remove and replace element as follows:

6.1 Turn off and depressurize the system. Open bleed plug (if fitted) one and one half turns.

**WARNING! FAILURE TO DEPRESSURIZE THE FILTER BEFORE SERVICING THE ELEMENT COULD RESULT IN EXPLOSIVE LOSS OF FLUID, DAMAGE TO EQUIPMENT, AND POSSIBLE PERSONAL INJURY.**

6.2 Unscrew and remove filter bowl (2) from head assembly (1), counterclockwise when viewed from below. It may be necessary to use a lever on the "Rotolok Ring" of the filter bowl (2) to loosen the bowl initially.

6.3 Remove filter element (4) and carefully inspect the surface for visible contamination. Normally no dirt should show, but visible dirt or particles can be an early warning of system component breakdown and can indicate potential failure. Discard both the filter element and its o-ring. The filter element is NOT CLEANABLE. Any attempt to clean the filter element can cause degradation of the filter medium and allow contaminated fluid to pass through the filter element.

**WARNING! DO NOT ATTEMPT TO CLEAN OR RE-USE ELEMENT.**

6.4 DO NOT run the system without a filter element (4) installed. Check that the O-ring (3) on the head assembly (1) is not damaged. Use replacement filter element part number called for on the element change label.

6.5 Lubricate element O-ring (5) with clean system fluid and push open end of filter element (4) straight onto the nipple in the head assembly (1). Clean out filter bowl (2) interior and lightly lubricate threads of filter bowl with clean system fluid. Screw filter bowl onto head assembly until it bottoms. O-RING SEALING IS NOT IMPROVED BY OVER TIGHTENING.

**WARNING! DO NOT USE PIPE WRENCH, HAMMER OR ANY OTHER TOOL TO TIGHTEN BOWL.**

6.6 Bleed the system and check for leaks as per Section 4.

6.7 After element change ENSURE DIFFERENTIAL PRESSURE DEVICE IS RESET BY PUSHING IN THE BUTTON; electrical switches reset automatically. When system reaches normal operating temperature, check that the electrical switch has not actuated and/or the visual warning button has remained depressed. If visual indicator rises due to a cold start condition, reset again as per section 5.

## 7. Warranty, Limitation of Liability and Remedies:

THERE IS NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE WITH RESPECT TO ANY OF THE PRODUCTS, NOR IS THERE ANY OTHER WARRANTY EXPRESS OR IMPLIED, EXCEPT AS PROVIDED FOR HEREIN.

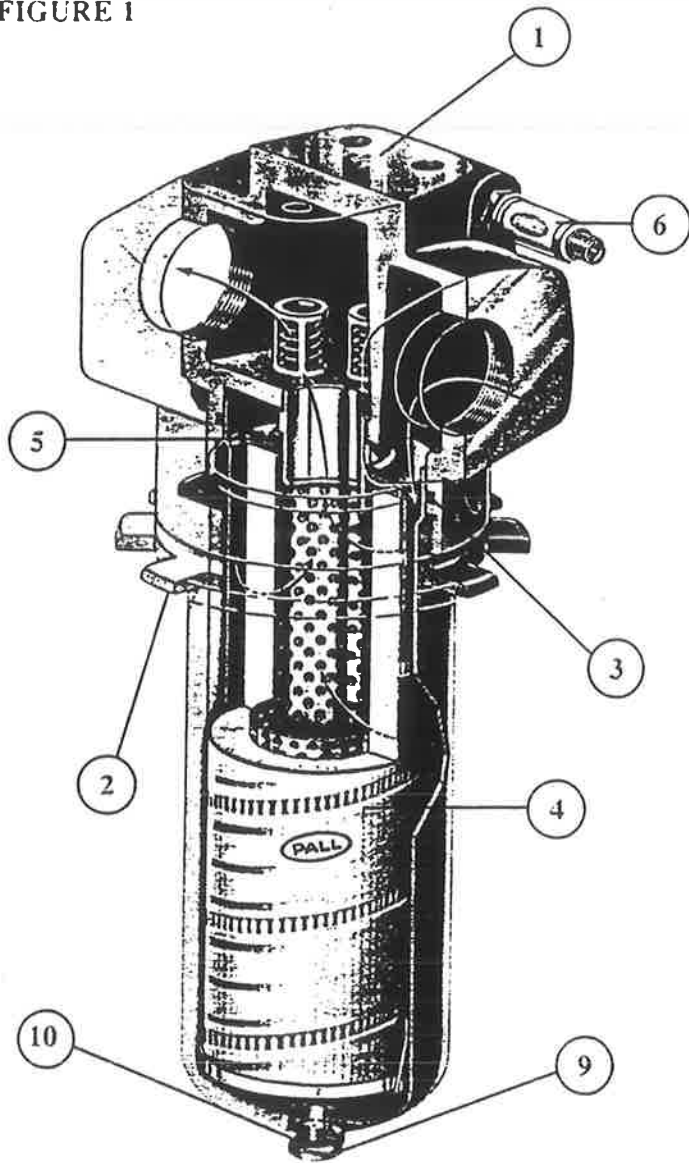
For a period of twelve months from the date of delivery from Seller or three thousand hours of use, whichever occurs first (the "Warranty Period"), Seller warrants that products manufactured by Seller when properly installed and maintained, and operated at ratings, specifications and design conditions, will be free from defects in material and workmanship. By way of explanation and not limitation, the Seller does not warrant the service life of the filter element as this is beyond the Seller's control and depends upon the condition of the system into which the filter is installed.

Seller's liability under any warranty is limited solely (in Seller's discretion) to replacing (FOB original ship point), repairing or issuing credit for products which become defective during the Warranty Period. Purchaser shall notify Seller promptly in writing of any claims and provide Seller with an opportunity to inspect and test the product claimed to be defective. Buyer shall provide Seller with a copy of the original invoice for the product, and prepay all freight charges to return any products to Seller's factory, or other facility designated by Seller. All claims must be accompanied by full particulars, including system operating conditions, if applicable.

Seller shall not be liable for any product altered outside of the Seller's factory except by Seller or Seller's authorized distributor, and then, as to the latter, only for products which have been assembled by the distributor in accordance with Seller's written instructions. Nor shall Seller be liable for a product subjected to misuse, abuse, improper installation, application, operation, maintenance or repair, alteration, accident or negligence in use, storage transportation or handling.

In no event will Seller be liable for any damages, incidental, consequential or otherwise, whether arising out of or in connection with the manufacture, packaging, delivery, storage, use, misuse, or non use of any of its products or any other cause whatsoever.

FIGURE 1



8. Service Parts List:

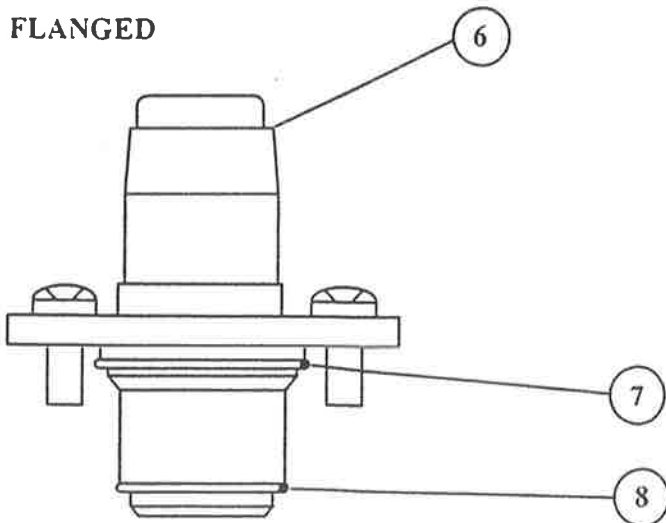
ITEM NO.	DESCRIPTION	PART NUMBER
1	Head Assembly	N/A
2	S-Length Bowl	1199343
	T-Length Bowl	1199521
	U-Length Bowl	1199344
3	Head To Bowl O-Ring	Size -248
4	Filter Element	See Brochure
5	Element O-Ring	Size -139
6	Indicator *	See Brochure
7	Indicator O-Ring	Threaded Size -908 Flanged Size -017
8	Indicator O-Ring	Threaded Size -014 Flanged Size -015
9	-6 Drain Plug	1128259
10	Drain Plug O-Ring	Size -906

NOTE: O-ring sizes are per SAE-ARP568 Uniform Standard Sizes.

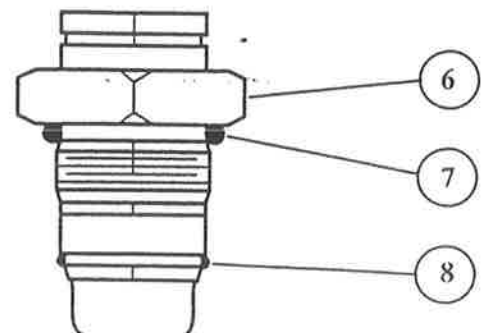
\* Flanged Indicator standard prior to December, 1992. Threaded Indicator standard after January, 1993.

Contact your local Pall Distributor when ordering service spare parts.

FLANGED



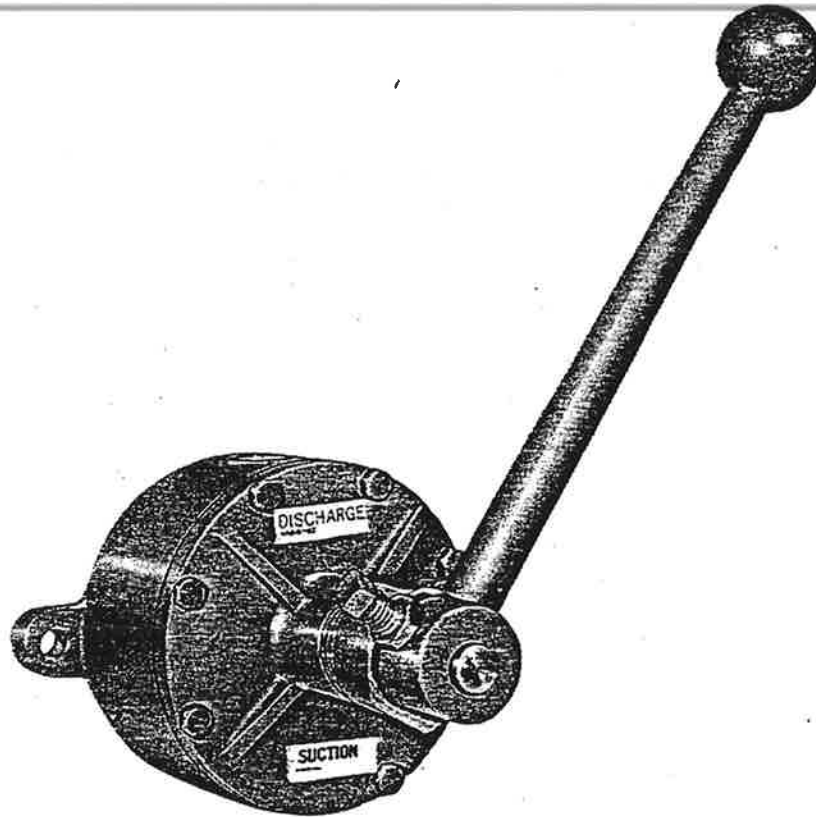
THREADED





**PUMP SPECIFICATION BULLETIN**

**HO SERIES  
 OSCILLATING HAND PUMP  
 ROTARY GEAR PUMP**



**FEATURES**

*COMPACT  
 SELF-PRIMING  
 AVAILABLE IN CAST IRON OR  
 ALL BRONZE  
 AVAILABLE IN 3/4", AND 1"  
 SUCTION PORTS*

**OPERATING RANGE**

CAPACITY	(GPM):	(6 TO 21)
	[LPM]:	[23 TO 79]
PRESSURE	(PSI):	(50)
	[BAR]:	[3.5]
VISCOSITY	(SSU):	(2500)
	[cSt]:	[541]
TEMPERATURE	(F) :	(120°)
	[C] :	[49°]

**APPLICATIONS**

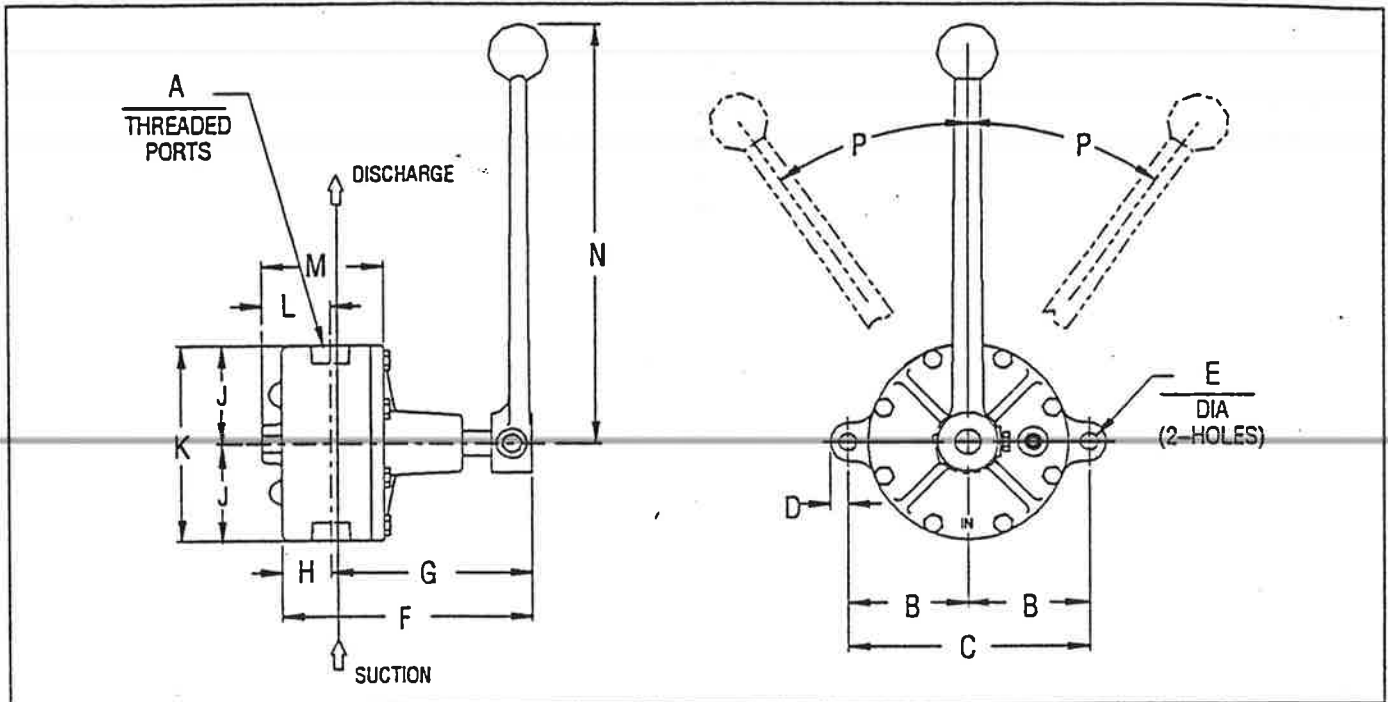
TRANSFER OF LIGHT TO  
 MEDIUM LIQUIDS,  
 COMPATIBLE WITH CAST  
 IRON AND BRONZE  
 OPTIONAL DRUM KIT  
 AVAILABLE

**THE GORMAN-RUPP COMPANY • MANSFIELD, OHIO**

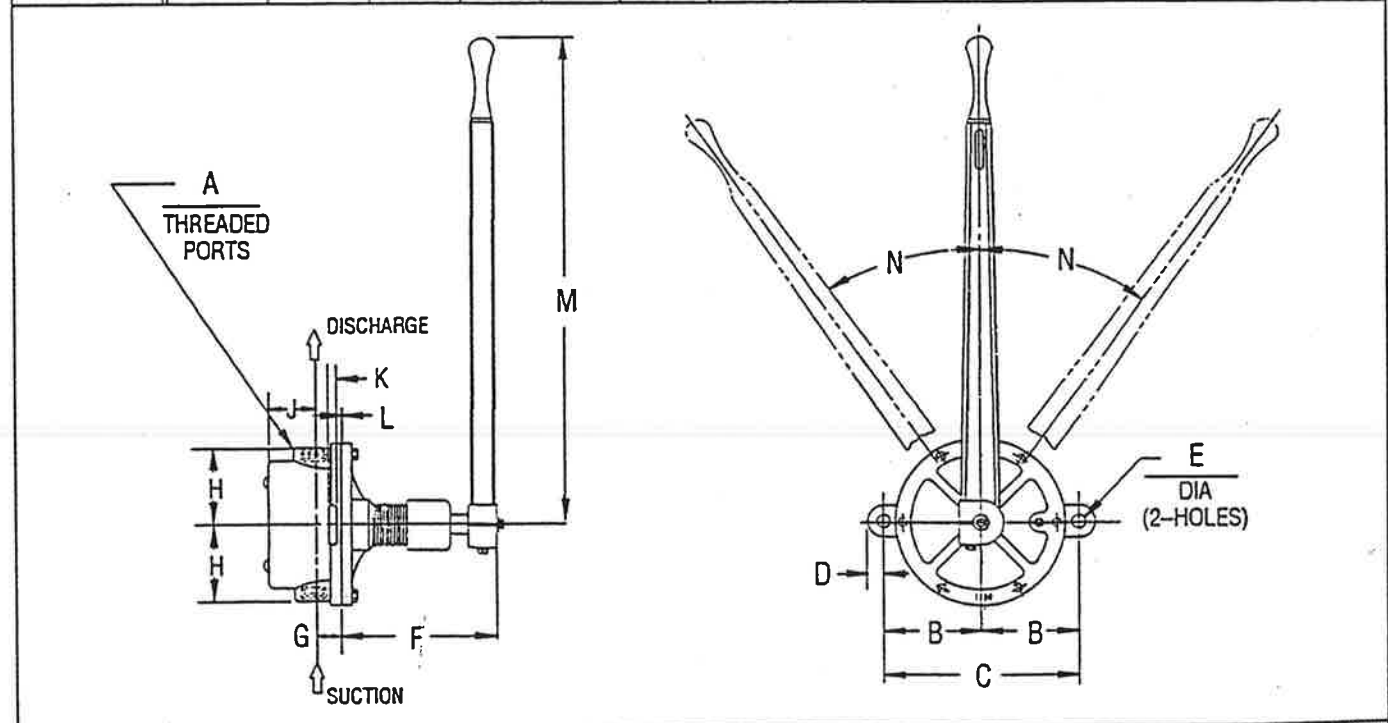




# Dimensions



MODEL NUMBERS	PUMP DIMENSIONS - INCHES [MILLIMETERS]													
	A	B	C	D	E	F	G	H	J	K	L	M	N	P
HO	3/4"	3.00 [76]	6.00 [152]	.76 [19]	.76 [19]	6.32 [161]	5.07 [129]	1.25 [32]	2.50 [64]	5.00 [127]	1.75 [44]	2.75 [70]	10.75 [273]	35°



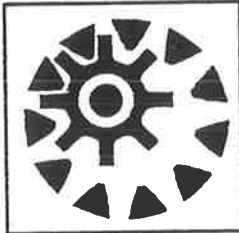
MODEL NUMBERS	PUMP DIMENSIONS - INCHES [MILLIMETERS]												
	A	B	C	D	E	F	G	H	J	K	L	M	N
HO	1"	4.63 [118]	9.26 [235]	.50 [13]	.50 [13]	6.81 [173]	1.25 [32]	4.00 [102]	2.16 [55]	.44 [11]	.12 [3]	24.00 [610]	35°

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ROTARY GEAR PUMPS

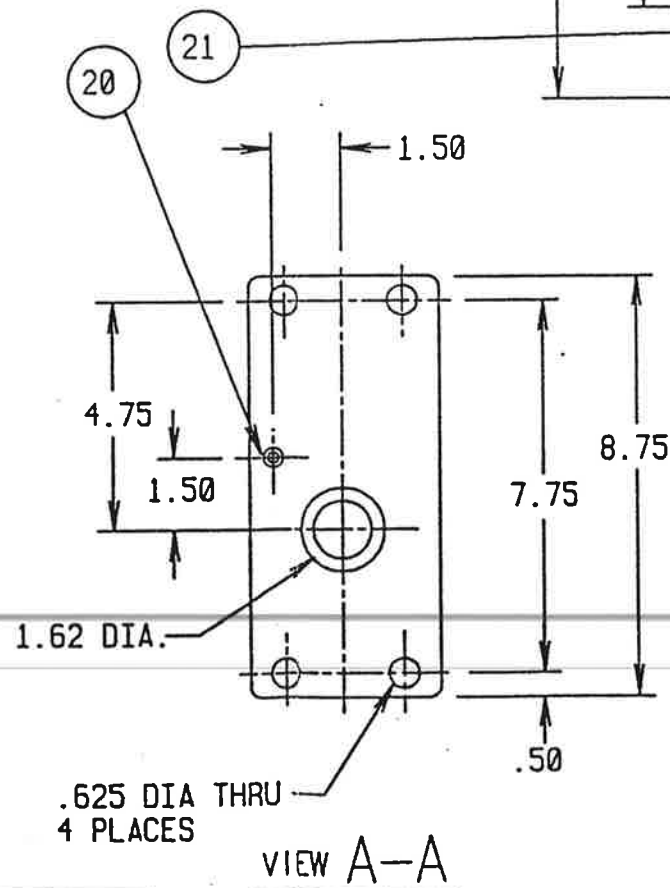
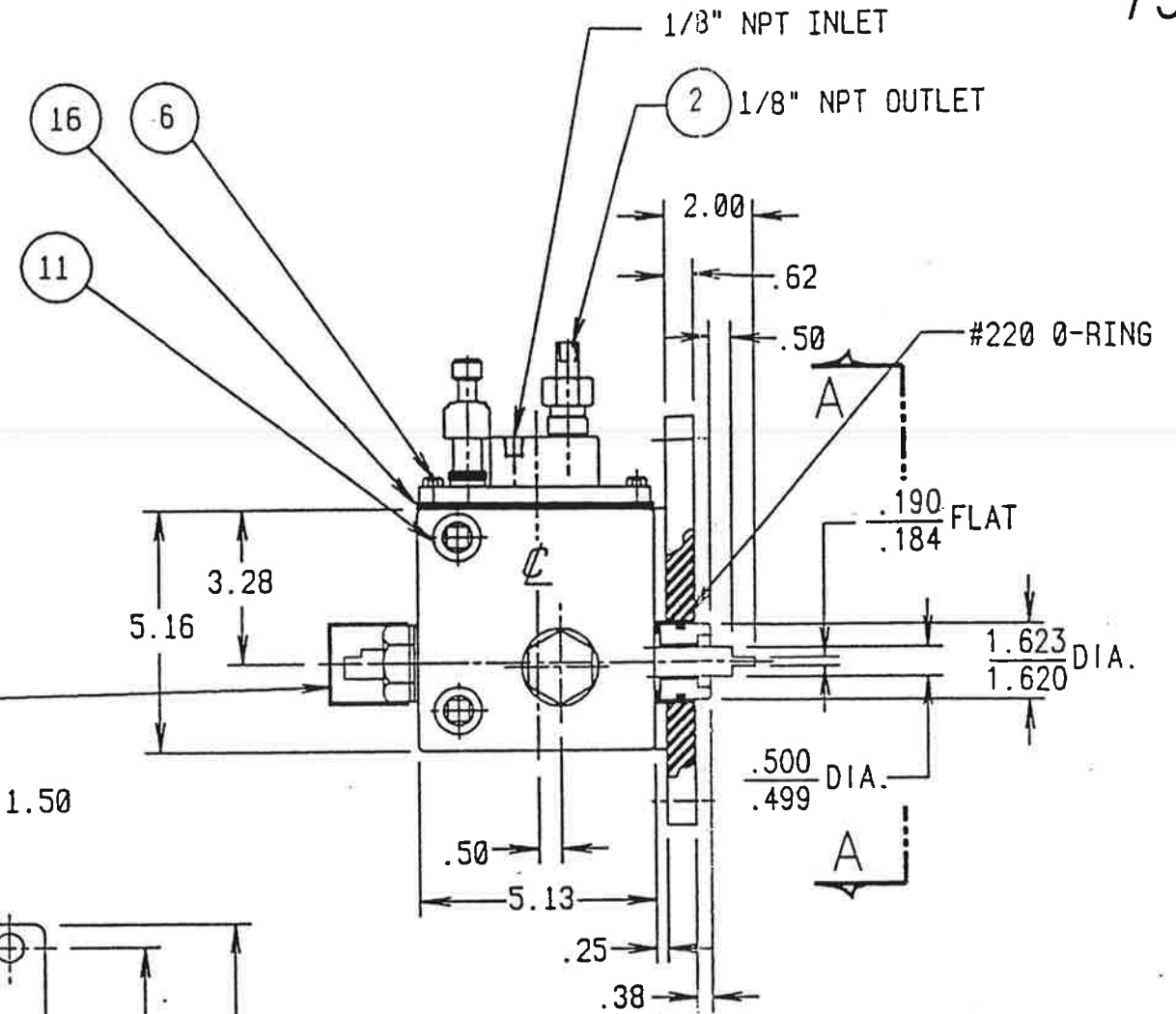
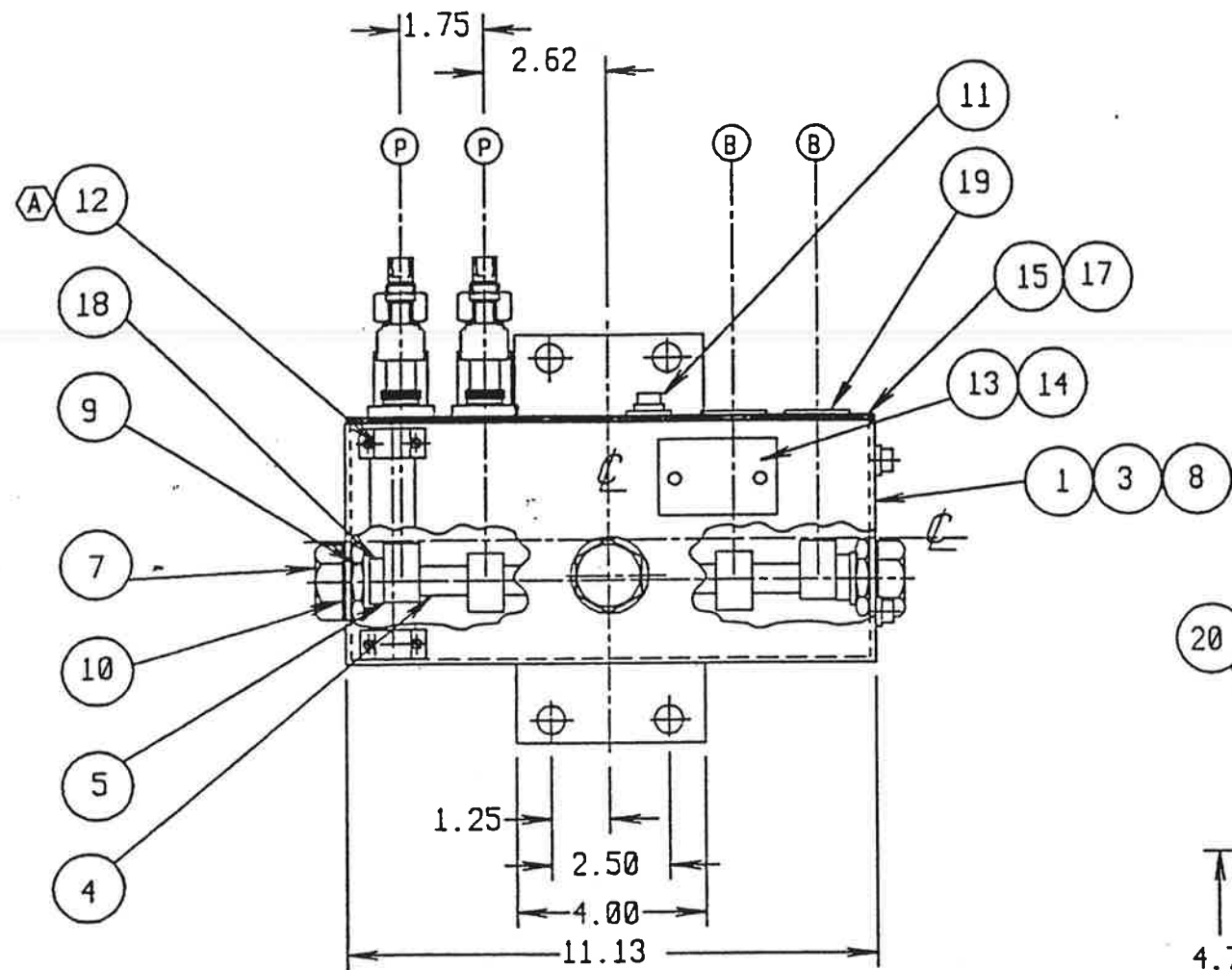


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70 Burwell Road  
St. Thomas, Ontario N5P3R7  
Phone: 519/631-2870 FAX: 519/631-4624



Ⓑ INDICATES BLANK PUMP LOCATIONS  
 ⒫ INDICATES PUMP LOCATIONS

RESERVOIR SIZE:	4 PINT
DRIVE TYPE:	CTR. REAR ROTARY
GEAR RATIO:	60:1
CAM QUANTITY:	4
PUMP SIZE:	3/8" PLUNGER
PUMP QUANTITY:	2

ITEM	QTY	PART NO.	DESCRIPTION
12	1	91392	GAUGE GLASS ASSEMBLY
11	3	90219	DRAIN PLUG
10	2	90224	WASHER
9	2	90087	NUT
8	1	91160	OPERATING INSTRUCTIONS
7	2	90210	END BEARING ASSEMBLY
6	12	90220	SCREWS
5	4	90279	CAM ASSEMBLY
4	2	90969	CAM SHAFT
3	1	91286	DRIVE ASSEMBLY (NOT SHOWN)
2	2	91203	PUMP MODEL P-55U 3/8" (BSF)
1	1	91378	ASS'Y - RESERVOIR & MTG. PLATE

ITEM	QTY	PART NO.	DESCRIPTION
21	1	90386	ASS'Y - DRIVE SHAFT COVER
20	1	90151	O-RING
19	2	90174	PLATE - BLANK PUMP
18	2	90230	SPACER - CAMSHAFT
17	1	91380	COVER PLATE
16	4	90175	PUMP GASKET
15	1	90177	COVER GASKET
14	2	90215	RIVETS
13	1	90214	NAME PLATE - PREMIER

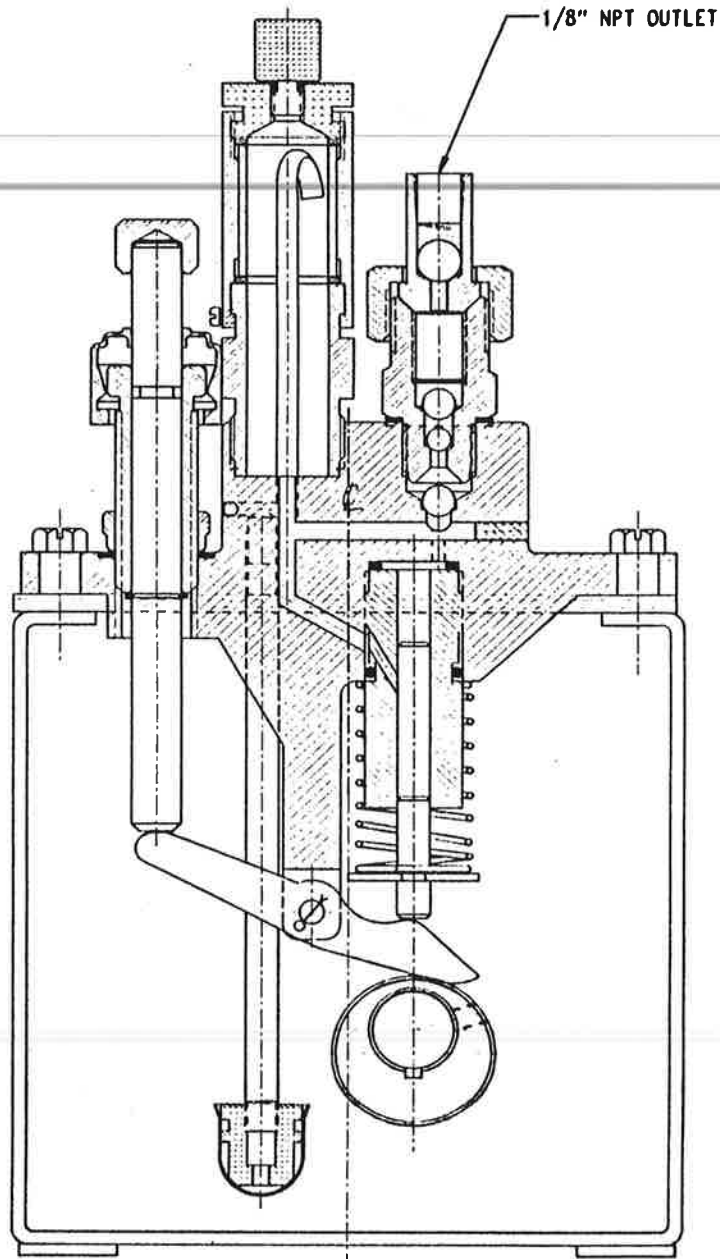
DRESSER - RAND RDS / HOS

ALL DIMENSIONS IN INCHES  
 REMOVE BURRS & BREAK EDGES  
 TOLERANCES NOT NOTED  
 CORNER RADIUS .03 MAX.  
 X.I (1 PLACE) +/- .020  
 X.II (2 PLACES) +/- .010  
 X.III (3 PLACES) +/- .005  
 CONCENTRICITY .010 T.I.R.  
 SURFACE TEXTURE 125 RMS  
 ANGLES +/- .5 DEG.

**PREMIER**  
 LUBRICATION SYSTEMS  
 14105 PACKARD ST. HOUSTON, TEXAS. 77040  
 TITLE LUBRICATOR - P-55U WITH  
 CTR. REAR DRIVE / MTG PLATE

REF: 732901	APPROVED:	DRAWN BY RDH	DATE 11-2-95	DRAWING NO. 735302	REV. A
SCALE: 1/4" = 1"	LET. REVISION	356	CAL 11-25-96		

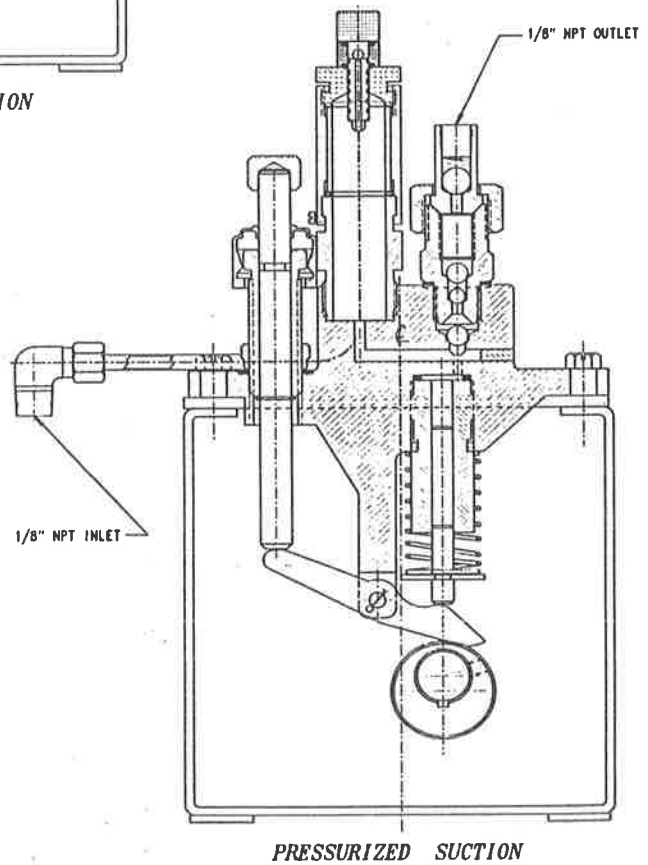
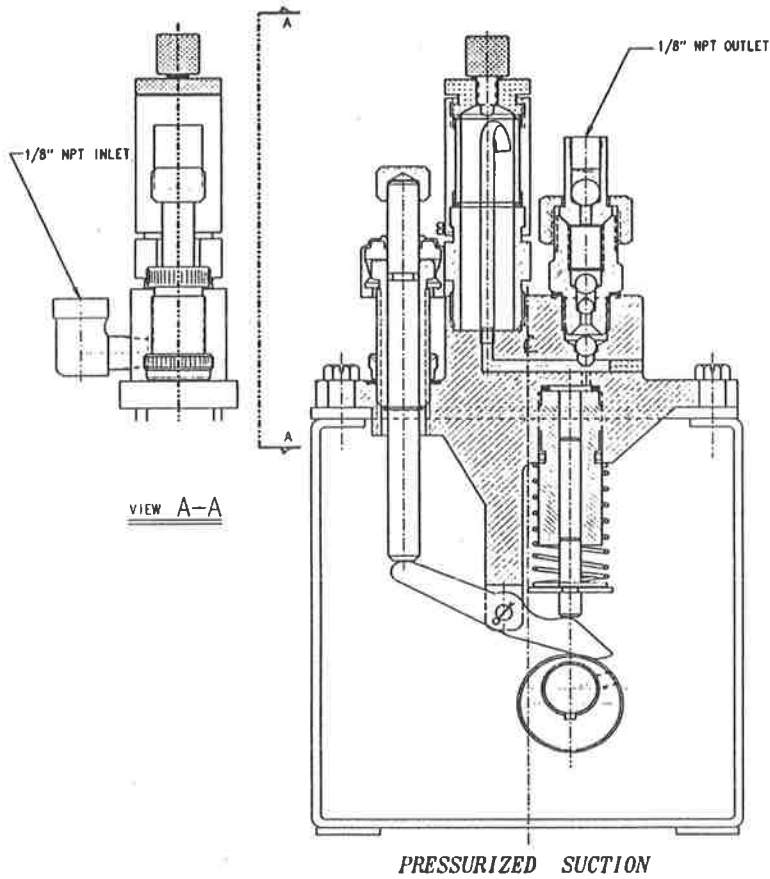
# PREMIER OPERATING INSTRUCTIONS



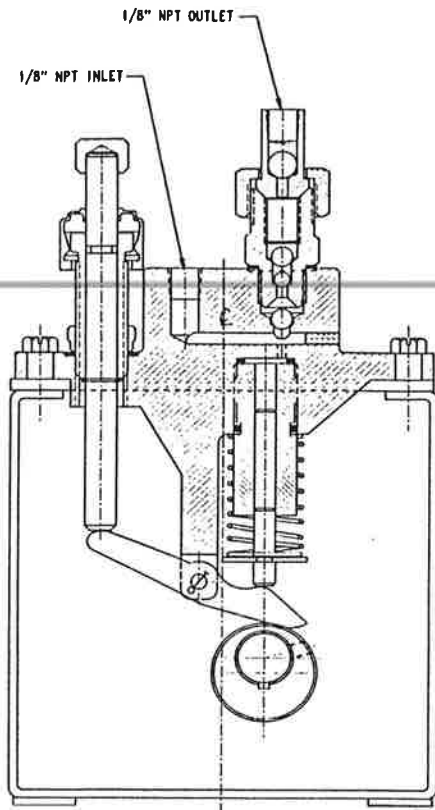
**BOX SUCTION**

PREMIER LUBRICATION SYSTEMS  
14105 PACKARD STREET  
HOUSTON, TEXAS 77040  
TELEPHONE: 713-462-5255  
FAX: 713-462-7919

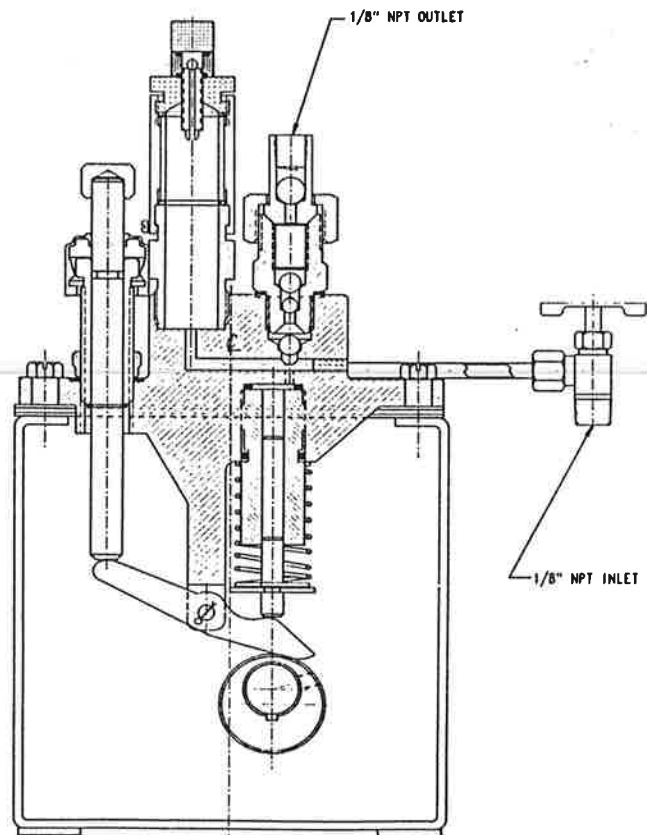
# PREMIER OPERATING INSTRUCTIONS



# PREMIER OPERATING INSTRUCTIONS



PRESSURIZED SUCTION



PRESSURIZED SUCTION

## BOX SUCTION PUMPS (VACUUM FEED)

1. Fill reservoir with oil.
2. Loosen union nut on pump outlet.
3. Remove vent screw and fill sight glass with oil. Prime by manually pumping flushing unit until air free oil is observed in drip tube and oil level drops in glass.
4. Replace vent screw and tighten union nut.
5. Maintain oil level in glass below drip tube so drops can be observed.

### FLOW RATE

1. Loosen lock nut on flushing unit.
2. Turn flushing unit counter-clockwise to increase flow.
3. Turn flushing unit clockwise to decrease flow.
4. Tighten lock nut when desired flow rate is achieved.

### SIGHT GLASS:

1. In a vacuum type sight feed, it is not uncommon for oil level in the sight glass to drop during operation. Absence of a level indicates air is being taken in with the oil and some oils, due to viscosity conditions, will release air faster than others. When the quantity of air becomes excessive, it can eventually air lock the pump.

### FOR THIS REASON IT IS RECOMMENDED AN OIL LEVEL IN THE GLASS BE MAINTAINED

When level drops, remove vent screw and fill sight glass to top; replace vent screw and operate flushing unit manually, observing that oil in sight glass is free from air. If air is not expelled, it may be necessary to loosen union nut (on pump outlet) and expel air at this point. It is desirable to maintain level below drip tube so drops can be seen during operation.

Due to viscosity conditions, some oils release air faster than others. For this reason, it is difficult to indicate how long sight glass level can be maintained before diminishing oil level occurs.

If reservoir runs low on oil (at a point below suction inlet of pump) it may be necessary to prime individual pumps after filling, using the procedure listed above.

The cubic volume for a pint of oil is 28.9 cubic inches and average drop size is .002 cubic inches. There are approximately 14,500 drops in a pint; however oil viscosity may vary size of drop.

Maximum output/stroke: (1/4" plunger) .018 cubic inches  
(3/8" plunger) .041 cubic inches

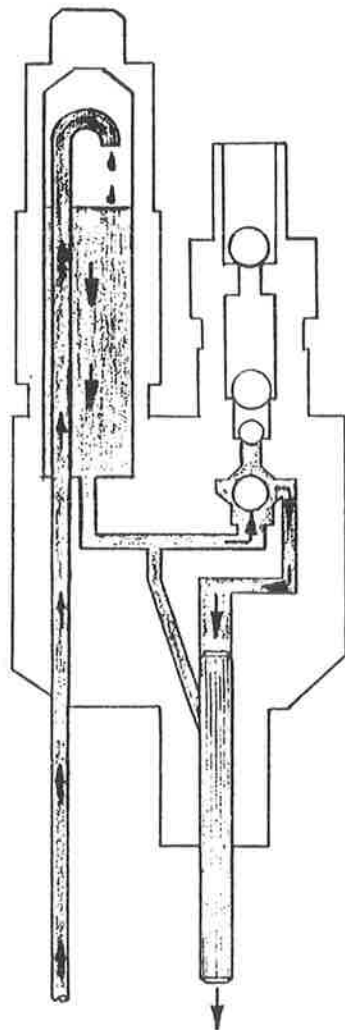
2. In a vacuum type sight feed, it is not uncommon to see a reverse action whereas sight glass fills with oil and the drops cannot be observed. Overfilling is caused by the oil absorbing air in the sight glass and normally does not affect the operating of the pump. Remove vent screw from sight glass and allow level to drop below drip tube. Tighten vent screw and check to see that air free oil from drip tube can be observed in sight glass. If overfilling continues, it may be caused by plunger wear and oil slippage is being drawn back to sight glass. If this is the problem, the feed setting in drops per stroke will automatically be reduced by the amount of slippage.

## INSTALLATION INSTRUCTIONS

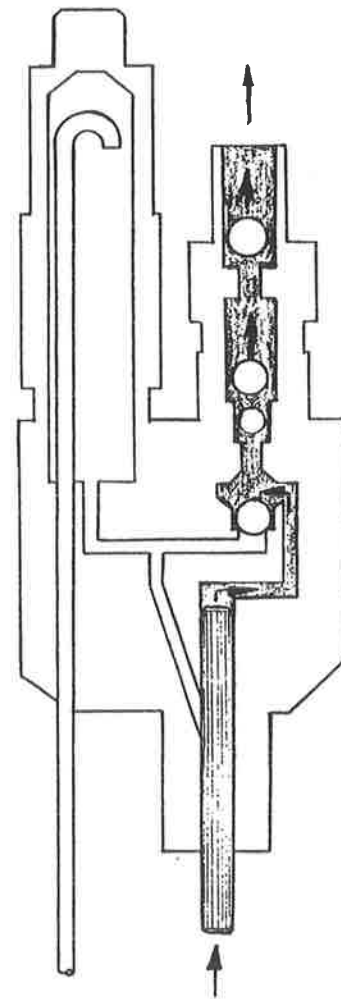
### #90670 SIGHT GLASS ASSY. WITH PYREX GLASS

1. Remove flushing unit assembly from pump to provide easy access to sight glass area.
2. Install new sight glass assembly over the drip tube and into the threaded hole in the block. Screw the assembly into the hole and tighten firmly with a wrench. Tighten by using the flats on Item #1.
3. Loosen the retainer, Item #5, one complete turn.

4. Loosen the lock screw, Item #6, one complete turn.
5. Turn the housing, Item #2, so that the window opening with the lock screw below is facing the front of the pump. Now tighten the lock screw with a small screwdriver.
6. Tighten the retainer, Item #5, firmly by hand.
7. Remove the vent screw, Item #4, and fill with oil to a visible level. Re-install the vent screw.
8. Re-install flushing unit assembly. The pump is now ready for operation.



**ON DOWNWARD STROKE ALL DISCHARGE VALVES CLOSE AND SUCTION VALVE REMAINS OPEN WHILE OIL IS DRAWN THROUGH SIGHT GLASS.**



**ON UPWARD STROKE SUCTION VALVE CLOSES AND DISCHARGE VALVES OPEN TO ALLOW OIL TO BE DISCHARGED THROUGH PUMP OUTLET.**



## PRESSURIZED SUCTION PUMPS

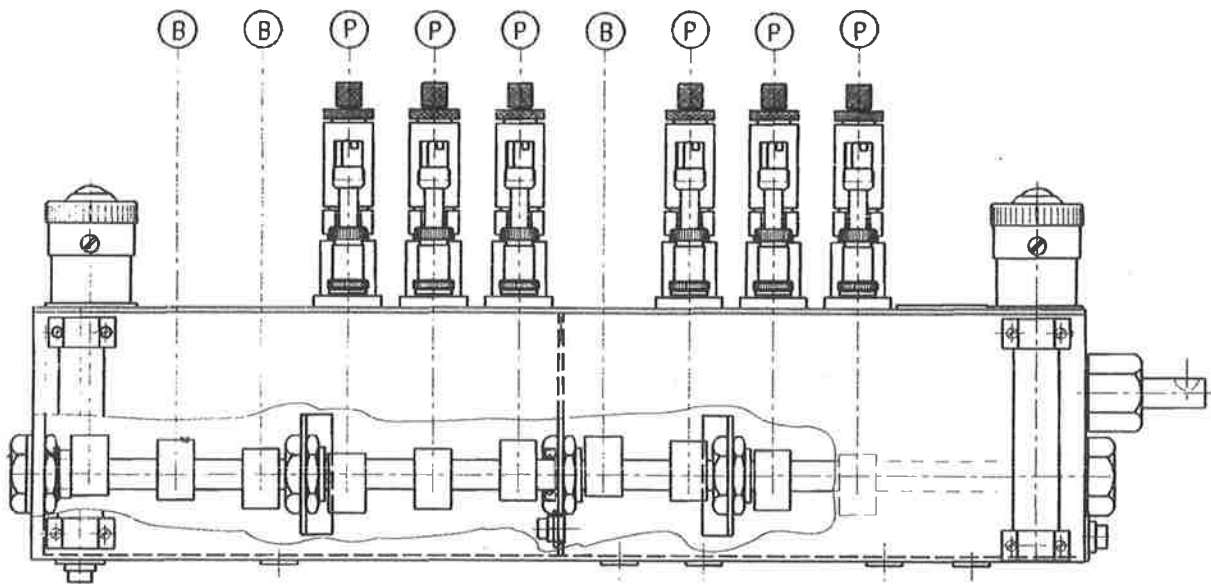
1. Fill reservoir with oil to approximately 1/2 full.  
DO NOT FILL TO TOP.
2. Loosen union nut on pump outlet.
3. Fill pumps with oil and prime by manually pumping flushing unit until air free oil is observed around union nut.
4. Tighten union nut.

**NOTE:** RESERVOIR WILL EVENTUALLY FILL TO TOP AND OVERFLOW IF OIL IS NOT PERIODICALLY DRAINED FROM RESERVOIR TO LEVEL INDICATED IN #1 ABOVE. THIS IS NOT UNCOMMON IN PRESSURIZED SUCTION PUMPS.

### FLOW RATE

1. Loosen lock nut on flushing unit.
2. Turn flushing unit counter clockwise to increase flow.
3. Turn flushing unit clockwise to decrease flow.
4. Tighten lock nut when desired flow rate is achieved.

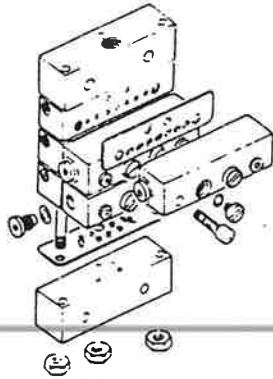
# PREMIER OPERATING INSTRUCTIONS



PREMIER LUBRICATION SYSTEMS  
14105 PACKARD STREET  
HOUSTON, TEXAS 77040  
TELEPHONE: 713-462-5255  
FAX: 713-462-7919

## SPECIFICATIONS:

Max. Operating Pressure	Seal Material	Lube Inlet	Lube Outlets	Indicator Ports	Mounting Screw Torque	Tie Rod Nut Torque
6000 Psi	Viton*	1/4 NPTF	1/8 NPTF	5/16"-24 UNF	108 in.-lb.	72 in.-lb.



## DESCRIPTION

MC Divider Valves are comprised of three to eight valve blocks fastened to a segmented baseplate with gasket plate seals between the valve blocks and the baseplate and between the baseplate segments. These divider valves are used in a single line, progressive lubrication system and can be used for dispensing oil or grease. MC valves and baseplate segments are supplied with viton seals.\*

Refer to the Modular Lube Planning Manual for system design information and an in-depth explanation of operation. An in-line filter should be installed between the pump and divider valves. Check valves should be installed at the inlets of all lube points. Refer to Service Page M50 Page 1 for check valve information.

\*Viton gasket plates are identified by a red stripe.

Valve blocks containing metering pistons discharge a predetermined amount of lubricant with each cycle. Valve blocks can be single or twin and can be externally singled or crossported with Model 87905 Single/Crossport Bar. Outlets not to be used when singling or crossporting must be plugged. Use 68645 pipe plug.

An 874000 By-Pass Block can be used in any position on the baseplate. The use of a by-pass block allows the addition or deletion of lubrication points without disturbing existing piping. Both outlets under a by-pass block must be plugged.

The valve blocks and by-pass blocks are fastened to a baseplate mounted on the machine to be lubricated. The baseplate contains the divider valve's inlet and outlet connections, interrelated passageways and built-in check valves. All piping of lubricant to and from the divider valve is connected to the baseplate.

The baseplate consists of one inlet block, three to eight intermediate blocks, one end block and three tie rods. Gasket plate seals are included with the baseplate segments. The valve block capacity of each baseplate is dependent upon the number of intermediate blocks in the baseplate. There must be a minimum of three working valves on each valve and baseplate assembly.

Optional cycle indicator pins provide positive identification of system operation. The indicator pin is an extension of the piston

in a valve block and will cycle back and forth as the piston moves.

Optional mounting brackets are shown below for mounting the valve assembly.



## ASSEMBLY INSTRUCTIONS

NOTE: The center tie rod in the baseplate is offset so that the intermediate blocks cannot be assembled backwards. If excessive force is encountered during assembly, make sure block is not backwards.

1. Screw three tie rods into inlet block until ends are flush with surface of block.
2. Slide inlet gasket onto tie rods.
3. Alternately slide an intermediate block and an intermediate gasket plate onto the tie rods until the last intermediate block is in place.
4. Discard remaining intermediate gasket plate.
5. Slide end gasket plate and end block onto tie rods.
6. Lay baseplate assembly on flat surface and torque nuts to 72 in.-lbs.
7. Mount divider valves with gasket plates onto baseplate and torque mounting screws to 108 in.-lbs.

## MC VALVE BLOCKS

	Single	Twin	Cycle Indicator Pin				Single (1 Outlet) Discharge/Outlet	Twin (2 Outlets) Discharge/Outlet
			Single-Right	Twin-Right	Single-Left	Twin-Left		
MC-6	874061	874062	-	-	-	-	.012 cu. in.	.006 cu. in.
MC-9	874091	874092	-	-	-	-	.018 cu. in.	.009 cu. in.
MC-12	874121	874122	874123	874124	874125	874126	.024 cu. in.	.012 cu. in.
MC-18	874181	874182	874183	874184	874185	874186	.036 cu. in.	.018 cu. in.
MC-24	874241	874242	874243	874244	874245	874246	.048 cu. in.	.024 cu. in.

## MC BASEPLATES

Baseplate Designation	Outlets	Inlet Block	Intermediate Blocks	End Block	Tie Rods
MC-3	2-6	87912	(3)87914	87913	(3)236640
MC-4	2-8	87912	(4)87914	87913	(3)236641
MC-5	2-10	87912	(5)87914	87913	(3)236642
MC-6	2-12	87912	(6)87914	87913	(3)236643
MC-7	2-14	87912	(7)87914	87913	(3)236644
MC-8	2-16	87912	(8)87914	87913	(3)236645

## OPERATION

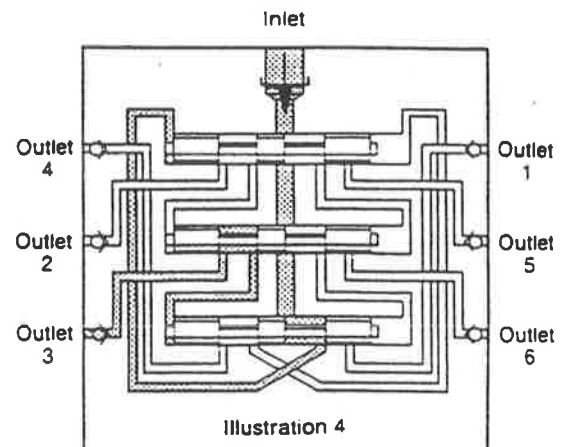
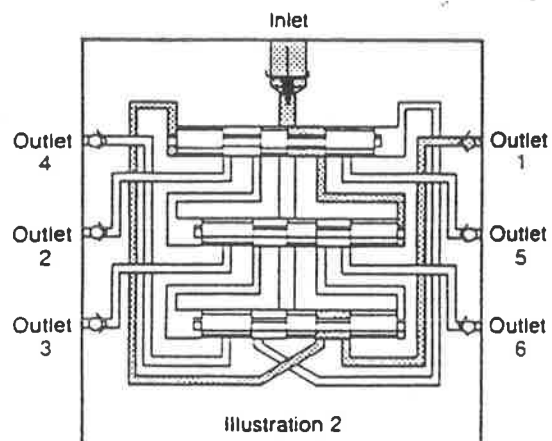
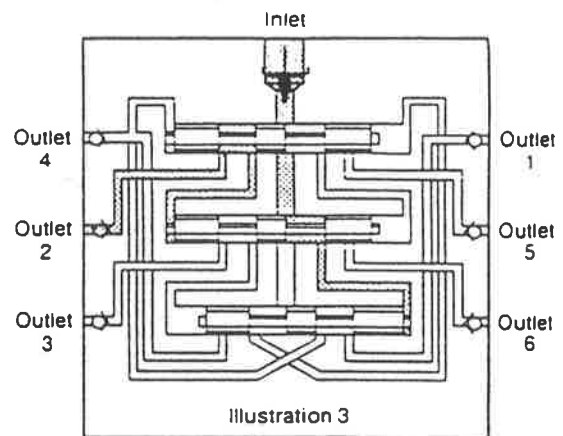
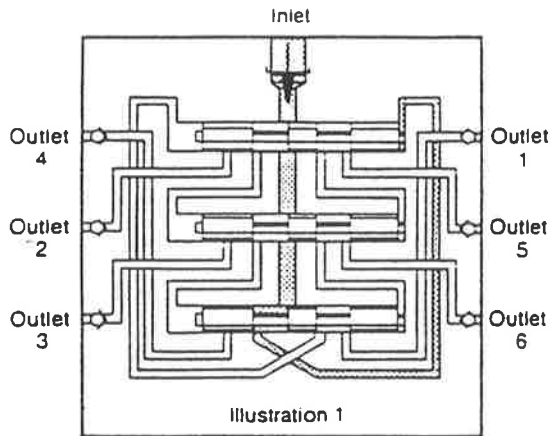
The inlet passageway is connected to all piston chambers at all times with only one piston free to move at any one time. With all pistons at the far right, lubricant from the inlet flows against the right end of piston 1. (See illustration 1)

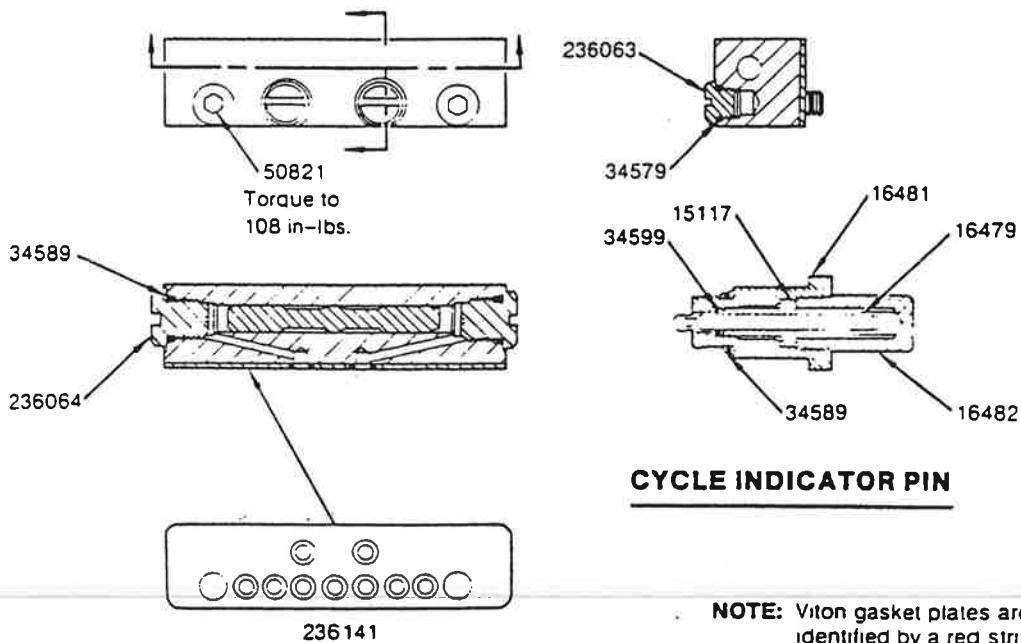
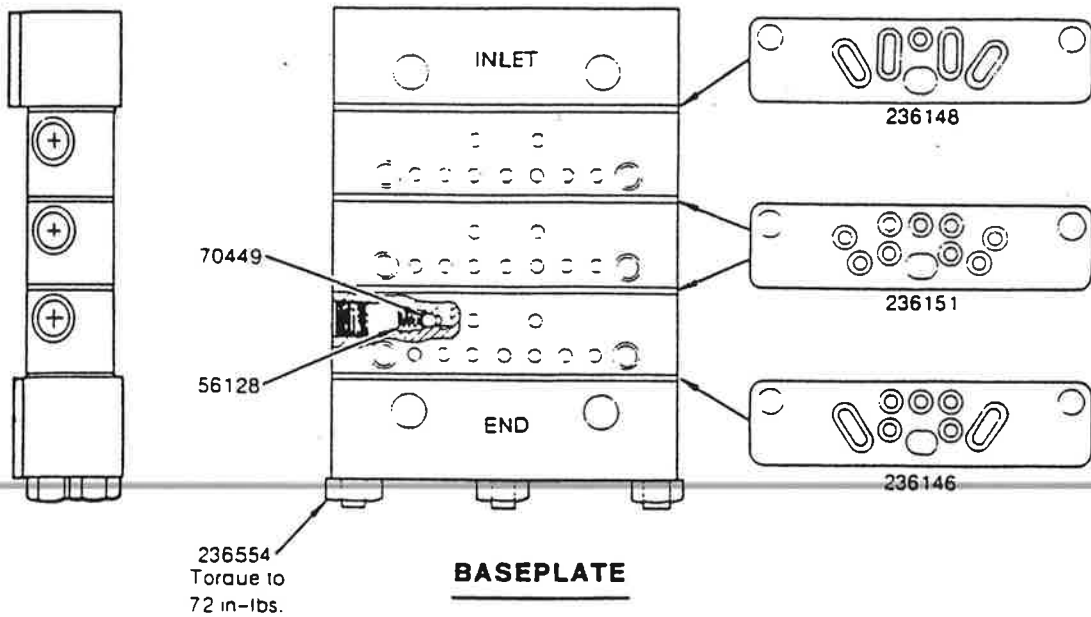
Lubricant flow shifts piston 1 from right to left dispensing piston 1 output through connecting passages to outlet 1. Piston 1 shift directs flow against right side of piston 2. (See illustration 2)

Lubricant flow shifts piston 2 from right to left dispensing piston 2 output through valve ports of piston 1 and through outlet 2. Piston 2 shift directs lubricant flow against right side of piston 3. (See illustration 3)

Lubricant flow shifts piston 3 from right to left dispensing piston 3 output through valve ports of piston 2 and through outlet 3. Piston 3 shift directs lubricant through connecting passage to the left side of piston 1. (See illustration 4)

Lubricant flow against left side of piston begins the second half-cycle which shifts pistons from left to right dispensing lubricant through outlets 4, 5 and 6 of the divider valve.



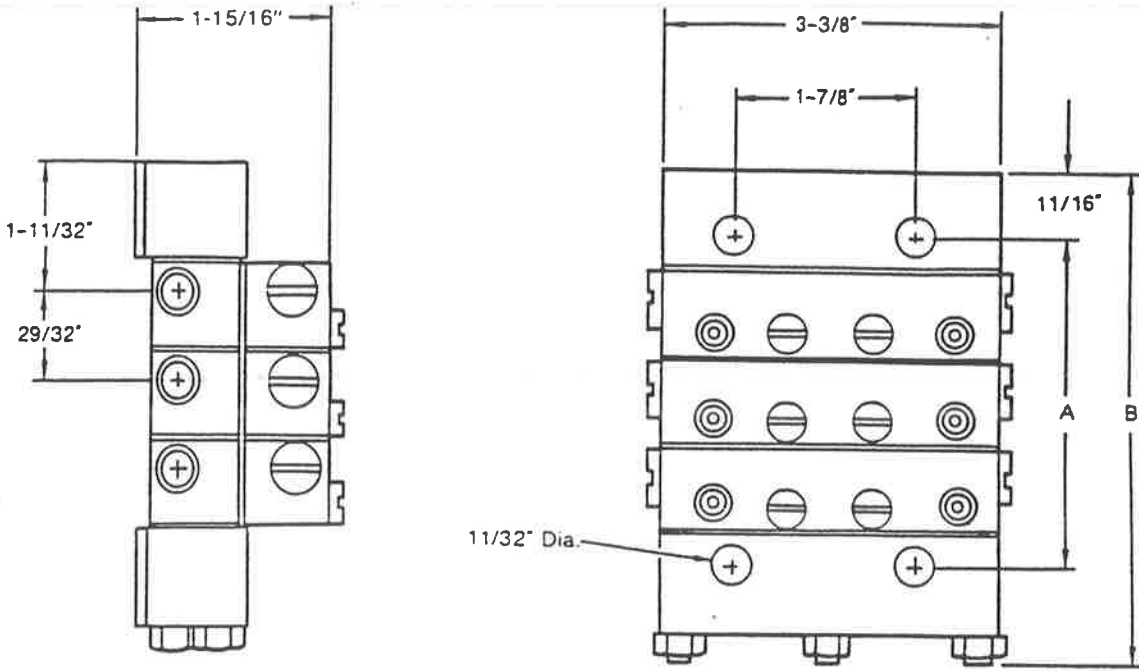


**DIVIDER VALVE**

**SERVICE PARTS**

Part	Description	Part	Description	Part	Description
15117	Bearing	34611	O-Ring	236141	Gasket Plate
16479	Indicator Pin	50821	Screw	236146	Gasket Plate
16481	Indicator Body	56128	Spring	236148	Gasket Plate
16482	Retaining Plug	70449	Ball	236151	Gasket Plate
34589	O-Ring	236063	Plug	236554	Nut
34599	O-Ring	236064	Plug		

## DIMENSIONS

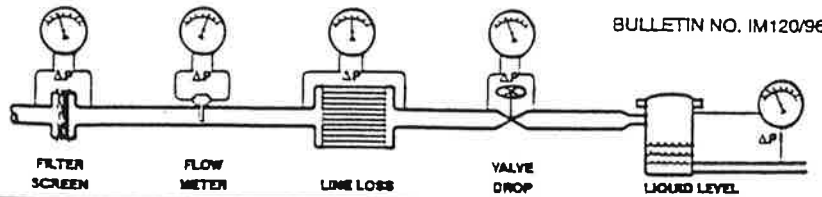


Baseplate	A	B
MC-3	$3-3/8''$	$5-3/32''$
MC-4	$4-9/32''$	$6''$
MC-5	$5-3/16''$	$6-29/32''$
MC-6	$6-3/32''$	$7-13/16''$
MC-7	$7''$	$8-23/32''$
MC-8	$7-9/32''$	$9-5/8''$

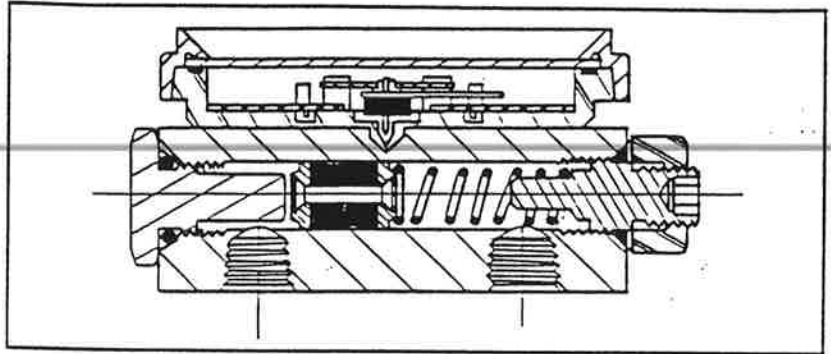
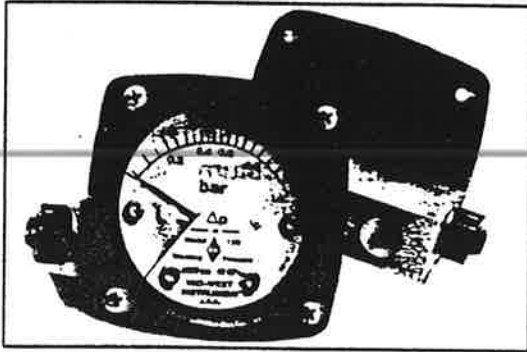
**RETAIN THIS INFORMATION FOR FUTURE REFERENCE**

When ordering replacement parts, list: Part Number, Description, Model Number, and Series Letter.

LINCOLN provides a Distributor Network that stocks equipment and replacement parts.



## Model 120 "Filter Minder"<sup>®</sup> Installation and Operating Instructions



### INSPECTION

Before installation check the nameplate on each instrument against the receiving paperwork and the intended application for correct part number, materials of construction, working pressure, dial range, etc. If equipped with switches, check electrical rating, type of enclosure, etc. Inspect for shipping damage and, if damaged, report it immediately.

**NOTE - Before attempting repairs contact your local Mid-West Representative or our factory. Failure to do so will void any warranty.**

### PRODUCT DESCRIPTION

The Model 120 "Filter Minder"<sup>®</sup> is a rugged, medium-range differential pressure instrument available as a switch, a gauge, or both. See "Part Numbering System". (Fig. 6) for available options.

Differential pressure is sensed by the movement of a floating piston magnet against a calibrated spring. The magnetically coupled gauge pointer outside the pressure housing follows the movement of the piston magnet and indicates differential pressure on the dial scale.

When equipped with switches, a contact is made or broken by the magnetic field of the piston magnet. See Bulletin Elec. IM 120/96 for gauges with switches.

The unit provides full over-range protection to the rated working pressure of the housing in either direction.

The precise piston/bore fit allows minimal leakage from high to low sides. This leakage is only 5 to 15 SCFH air at ambient conditions and a pressure differential of 100 PSID.

### INSTALLATION

Model 120 "Filter Minder"<sup>®</sup> is calibrated and tested prior to shipment and is ready for immediate installation. Use of the following installation procedures should eliminate potential damage and provide optimum trouble-free operation.

#### 1. CONNECTIONS

1/4" FNPT are provided as standard but check paperwork for connections ordered. There are two connections on the housing identified as "hi" and "lo" for high pressure and low pressure (Fig. 2). Be sure these get plumbed to the proper connections on your system. Improper connection will not damage the instrument, but it will not function properly. Flexible tubing is recommended to minimize the effect of any vibration that may exist.

#### 2. INSTRUMENT LOCATION

On liquid service the instrument should be mounted **below** the process connections to facilitate self-bleeding. On gas service it should be located **above** the process connections to promote self-draining. If the process contains particulates, a "pigtail" loop or drop leg (manometer "U-tube" configuration) in the tubing will minimize the possibility of it migrating into the instrument.

### 3. PANEL MOUNTING

Gauges with 2-1/2" dials can **only** be mounted through the **rear** of the panel. Make the proper panel cutout as indicated in (Fig.1). Remove the (4) bezel screws. Insert the gauge front through the rear of the panel and reinstall the bezel screws through the **front** of the panel and into the gauge bezel. Tighten the screws securely, alternating in a **diagonal** pattern.

Gauges with 4-1/2" dial should be mounted from the **front** of the panel. Make the cutout as indicated in (Fig. 1). Insert the (4) panel mounting studs, finger tight, into the metal inserts located in the rear of the bezel. Insert the gauge through the panel, aligning the panel mounting studs with the holes in the panel. Install the (4) #8-32 nuts onto the studs and tighten securely.

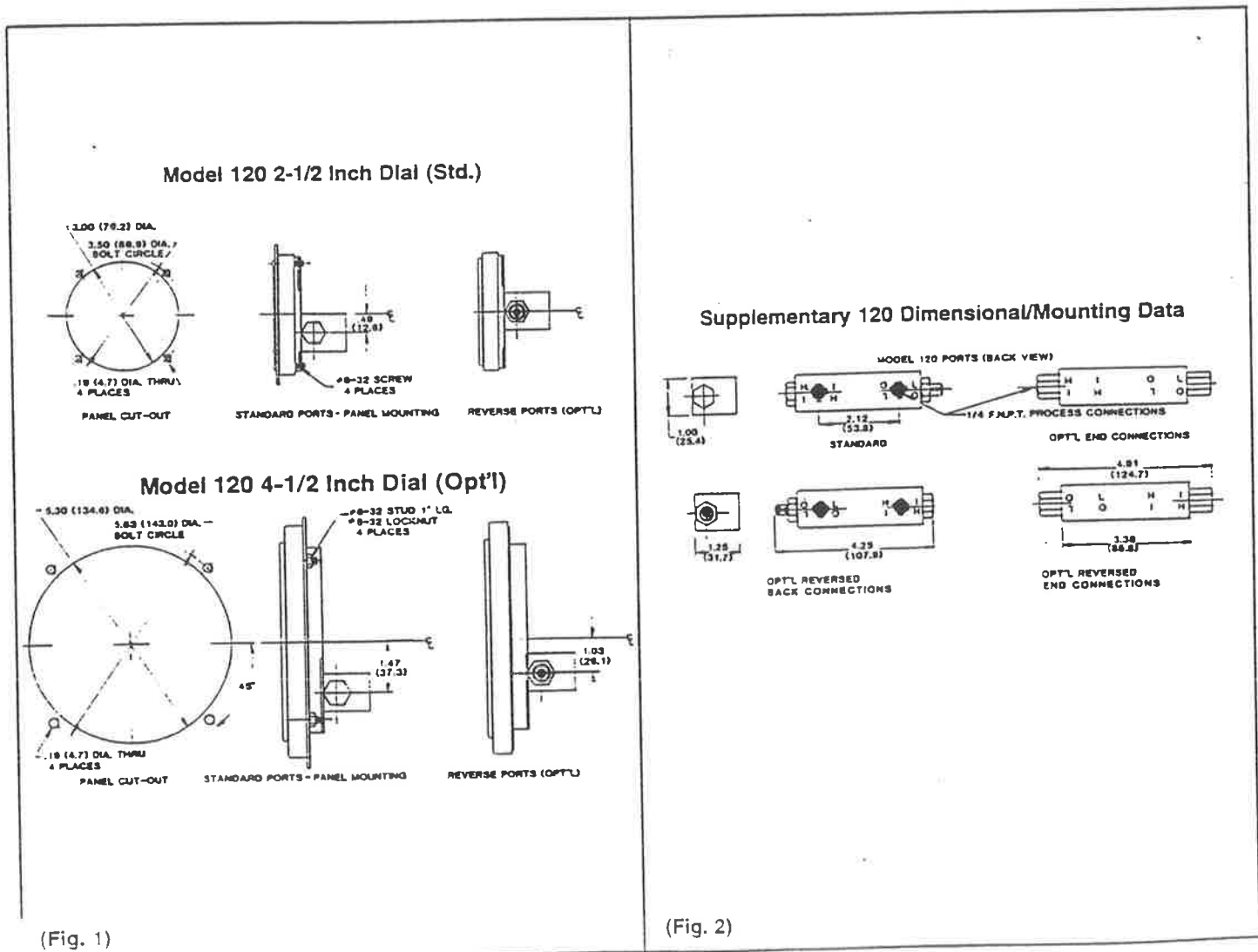
### 4. PIPE MOUNTING

An optional pipe mounting kit is available for mounting the gauge to a 2" vertical or horizontal pipe (Fig. 3).

### TROUBLE SHOOTING

#### 1. Gauge does not indicate differential.

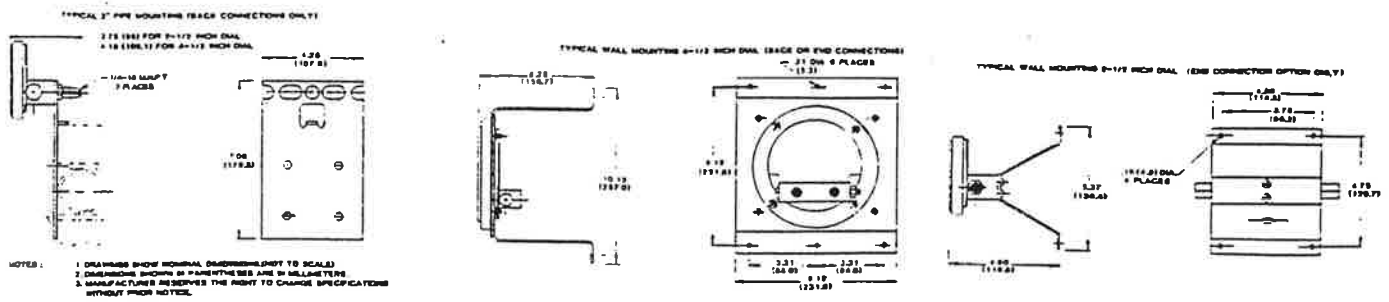
- A. Check for proper hook up, high to "hi" and low to "lo".
- B. Make certain block valves are open and, if using a 3-valve manifold, that the equalizer (balance) valve is closed.
- C. If A & B check out correctly, loosen or disconnect the high pressure line to determine if there is pressure to the instrument.
- D. If there is pressure to the instrument, check to determine that there is differential across the unit being monitored. If so, contact the factory for assistance and/or an "RGA" (return goods authorization) number to return the instrument for repair or replacement.



(Fig. 1)

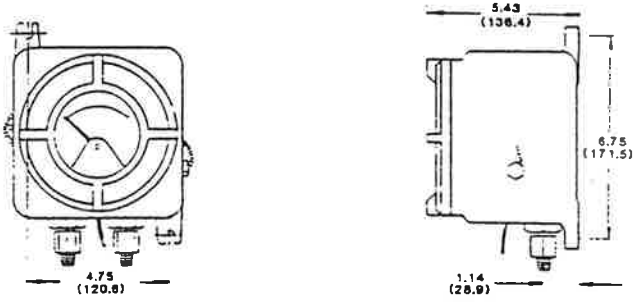
(Fig. 2)



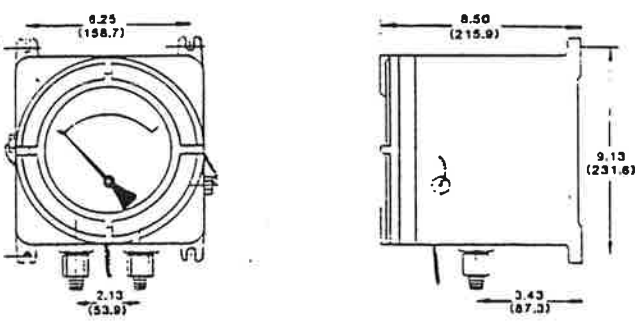


(Fig. 3)

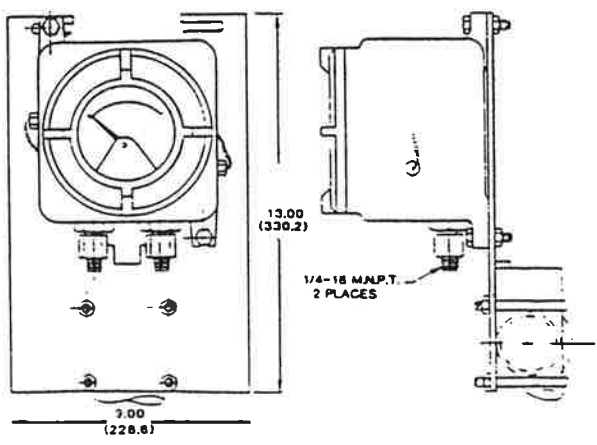
**Explosion-Proof Enclosures Class I, Groups D, Class II, Groups E, F & G. 2-1/2 Inch Dial**



**4-1/2 Inch Dial**

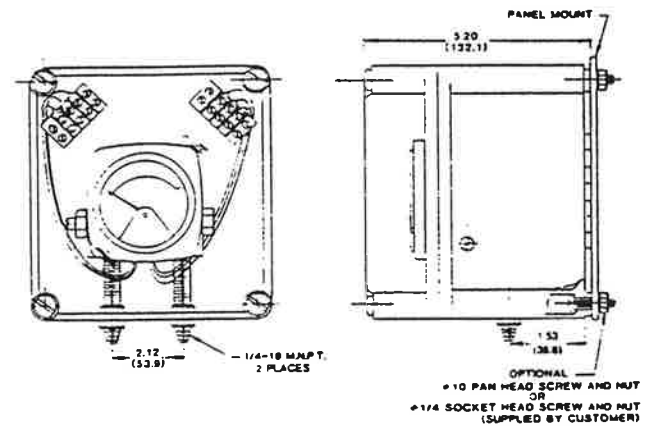


**Typical 2" Pipe Mounting - Weather Proof/Explosion Proof Models**

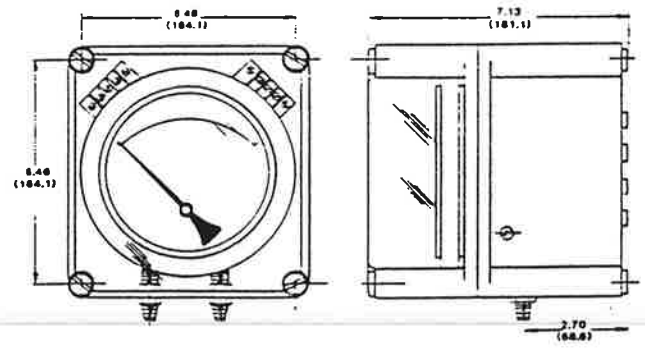


(Fig. 4)

**NEMA 4X Enclosures (2-1/2 Inch Dial)**



**4-1/2 Inch Dial**



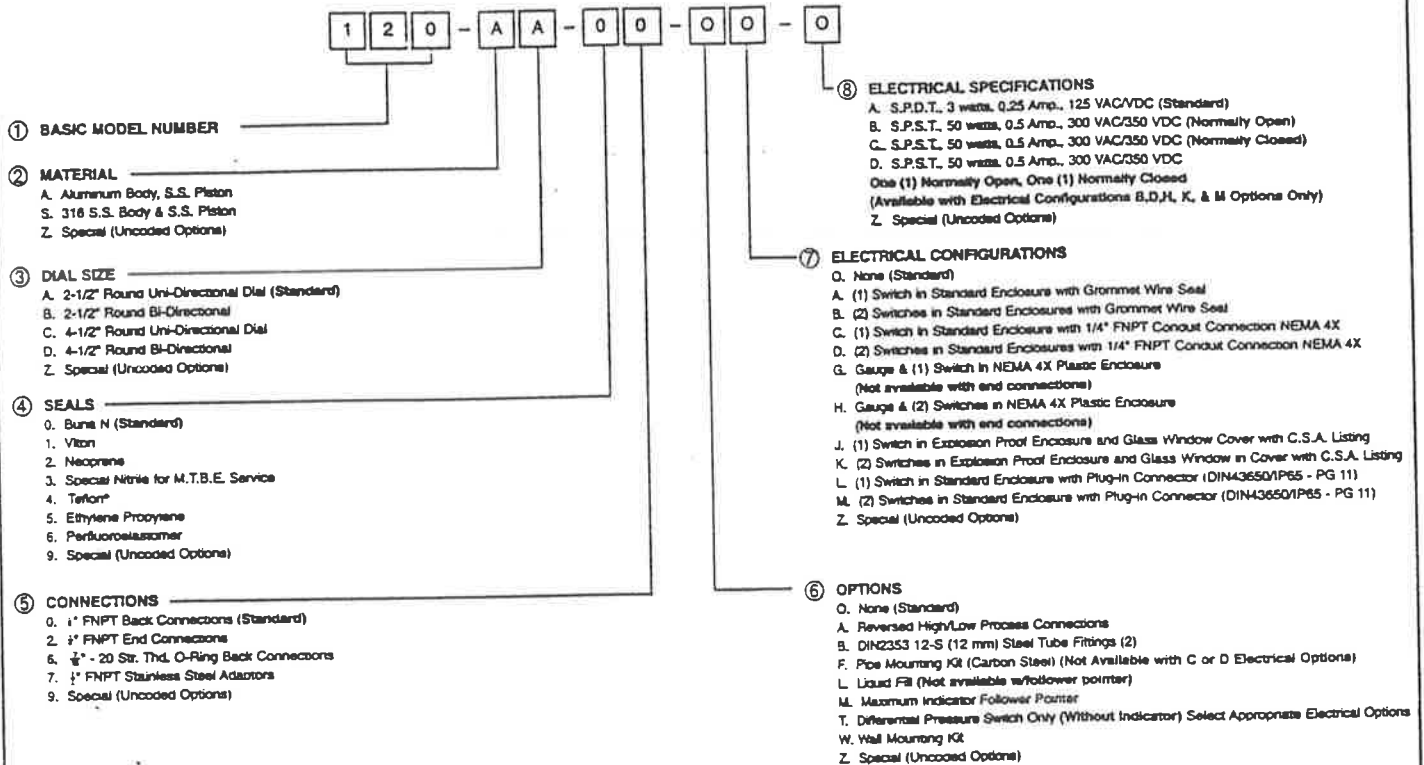
(Fig. 5)

## STANDARD MODEL SPECIFICATIONS

### 120-AA-00-00

6000 P.S.I.G. Working Pressure Aluminum Body, Stainless Steel Piston, Ceramic Magnets, Buna N Seals, 2-1/2" Engineering Plastic Case with Shatter-Resistant Lens. 1/4" FNPT Back Connections.  
Accuracy  $\pm 3-2-3\%$  Full Scale (Ascending).

### PART NUMBERING SYSTEM



(Fig. 6)

Manufacturer reserves the right to change specifications without prior notice.

PROOF PRESSURE: 12,000 PSI.

TEMPERATURE LIMITS: -40°F(-40°C) to +200°F(+93°C) - These limits are based on the entire instrument being saturated to these temperatures. System (process) temperatures may exceed these limitations with proper installation. Contact our customer service representative for details.

REPRESENTED BY:

# Mid-West<sup>®</sup>

## Instrument

6500 Debry Dr. □ Sterling Heights, MI 48314  
(810) 254-6500 □ FAX (810) 254-6509

Printed in U.S.A.

### A Positive Safeguard — Indicates lubricant flow or no flow

#### DESCRIPTION

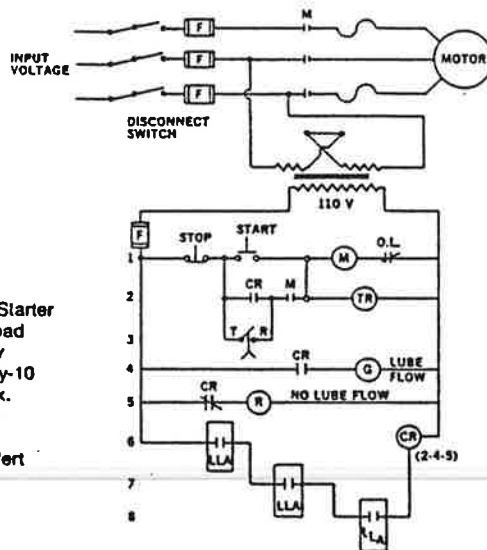
The Manzel Lube-Line Alert is an easily installed device providing positive protection for compressors, pumps, engines and equipment employing any make or type of force feed lubrication system. Installed as close to each point of lubrication as possible, the unit acts as a sentinel to indicate flow or no-flow at any point in the system ahead of the Lube-Line Alert inlet.

**One Lube-Line Alert per Pumping Unit** will warn of flow stoppage for any reason including low reservoir lubricant level; shaft rotation stoppage; broken lubricant lines; dirt under pump valves and worn plungers.

**A single Lube-Line Alert per Lubricator** will warn of low reservoir lubricant level or shaft rotation stoppage.

For complete protection, there should be as many Lube-Line Alert units in your installations as there are points of lubrication.

The Manzel Lube-Line Alert provides low-cost, dependable protection for costly machinery



- F - Fuse
- M - Main Motor Starter
- OL - Motor Overload
- TR - Timing Relay
- CR - Control Relay-10 watt coil max.
- G - Green Lamp
- R - Red Lamp
- LLA - Lube Line Alert

Typical wiring diagram for fail safe operation using Lube-Line Alerts assembled in N.O. normally open position. Alerts installed in a 110V control circuit side of motor starter to provide positive system protection through automatic system shut down.

#### FEATURES

**Indicates Flow or No-Flow** at any point in the system ahead of the Lube-Line Alert inlet. Not affected by discharge pressure.

**Operates under continuous or Intermittent low-flow rates.**

**Universal use** — operates in any air free force feed lubrication system — any make lubricator.

**Sensitive to a wide range of flow** — from .006 cubic inches to 190 cubic inches per minute.

**Many type lubricants and viscosities** — mineral or synthetic.

**Time delay adjustment** — to compensate for viscosity and/or flow rate. Quick and easy to adjust.

**Pressures** — for operation up to 10,000 psi.

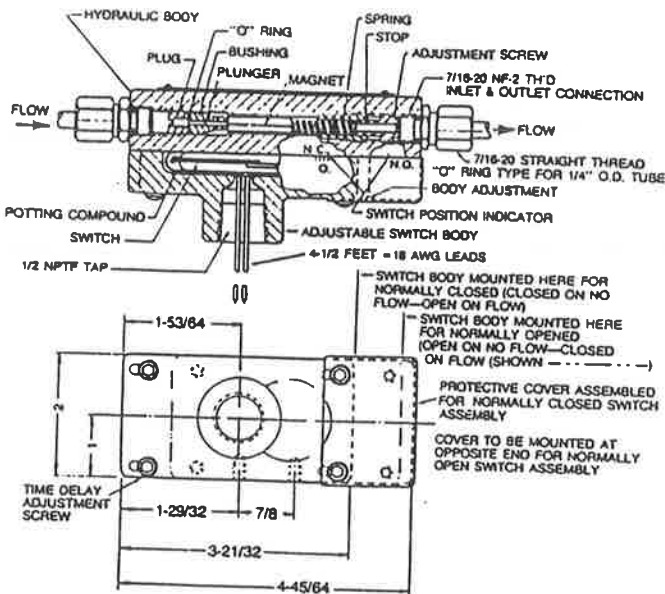
**Explosion-proof** — UL and CSA Listed for Class I Groups C & D and Class II Groups E, F & G, Division 1 & 2 when installed as per National Electrical Code.

**For connection to any electrical warning system** — lights, sound devices, machinery shutoff relays, telephones, etc.

**A low-level and shaft rotation indicator** — equip one pumping unit per reservoir with Lube-Line Alert.

#### SPECIFICATIONS

Electrical.....	Single pole, single throw magnetically operated switch
.....	115 VAC, 60Hz, 10 Watt, 1 Amp load
.....	28 VDC, .5 Amps resistive, .5 Amps inductive (L/R .026)
Operating Pressure.....	10,000 psi (Max.)
Pressure Drop Across Alert.....	150 psi (Min.)
Flow Range.....	.006 cu. in. to 190. cu. in. per minute at 100 SUS at 100° F.
.....	.006 cu. in. to 75.0 cu. in. per minute at 2,000 SUS at 100° F.
Fluid Viscosity.....	min., 100 SUS at 100° F., max., 2,000 SUS at 100° F. *
Weight.....	1.6 pounds



**OPERATION**

The Manzel Lube-Line Alert is composed of a separate hydraulic body and a switch body bolted together. The hydraulic body consists of a plunger, a magnet, a spring, and an adjustable plug. The switch body consists of a hermetically sealed magnetically-actuated switch set in a potting compound. The switch body can be mounted in one of two alternate positions: one for (N.O.) normally open contacts (during no flow), the other for (N.C.) normally closed contacts (during no flow) to accommodate various alarm or shut down circuits.

Lubricant flowing through the Alert moves the plunger and magnet until the plunger has opened the cross port in the bushing. This movement of the magnet opens the contacts for the (N.C.) normally closed switch position and closes the contacts on the (N.O.) normally open switch position, thus breaking or making the electrical circuit. The lubricant then moves through the cross port, around the magnet, through the hole in the plug and on to the point of lubrication. This path is shown in grey.

When flow stops, the spring returns the magnet and plunger toward their original position. When this movement is sufficient, the magnet closes the contacts for the (N.C.) normally closed switch position or opens the contacts for the (N.O.) normally open switch position, making or breaking the alarm or shut down circuit.

There is a built-in external time delay to adjust for various flow rates and/or viscosities, which can be easily varied by sliding the switch body "O" mark in relation to the N.C. or N.O. mark on the hydraulic body. With the N.C. or N.O. mark opposite the "O" mark, the longest time delay — from flow stoppage to indication — will be obtained. An internal screw adjustment provides an additional time delay adjustment range. This can be varied by removing the Alert outlet connection and turning the slotted screw clockwise, to decrease the delay time and counter clockwise, to increase the delay time. These adjustments should be made in 1/4 turn increments and with the N.C. or N.O. mark opposite the "O" mark.

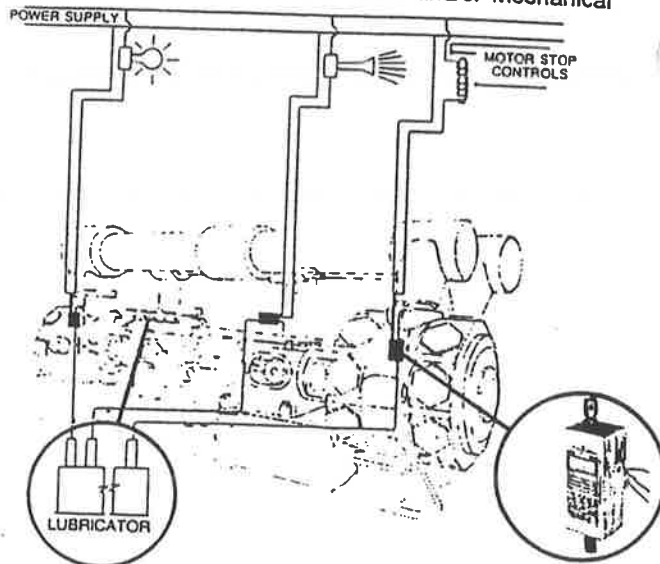
A light spring is included (loose) with the Lube Line Alert (P/N 456-060-009 only). This spring is to be used in low flow applications where the unit fails to actuate.

**INSTALLATION**

Cut the line as close to the point of lubrication as practical. Install the Alert with proper flow direction as shown on the nameplate. Straight or elbow fittings are available in most tubing or pipe thread sizes for the 7/16-20 NP straight thread "O" ring Alert ports.

The electrical switch housing should be set at the proper switch position — N.O. opposite "O" for normally open circuitry (during no flow) or N.C. opposite "O" for normally closed circuitry (during no flow). Lead wires from the switch are ready for connection through the 1/2" conduit connections to a suitable alarm circuit.

**WARNING—Visual and/or Audio and/or Mechanical**



Fail safe circuitry can only be provided by using the N.O. (normally open) switch position. Multiple Alerts must be wired in series or through separate circuits.

For the N.C. (normally closed) switch position multiple Alerts should be wired in parallel or through separate circuits.

The loose cover must be assembled over the exposed machined face of the Alert hydraulic body to meet Underwriters' Laboratory listing. To reduce the risk of ignition of hazardous atmospheres, conduit runs must have a sealing fitting connected within 18 inches of the enclosure.

Installation at point of lubrication provides complete protection, including detection of broken lines up stream of Alert.

**ORDERING INFORMATION**

Order Part Number

**Lube Line Alert**

- N.C. configuration with check valves for 1/4" O.D. tube, standard spring (installed), with light spring (loose)\* . 456-060-009
- N.O. configuration with check valves for 1/4" O.D. tube, light spring (installed), with standard spring (loose)\* . 456-060-181
- N.O. configuration with check valves and fittings for 1/8" NPTF connections, standard spring (installed)... 456-060-109

**Accessory Parts**

**Inlet Check Valves**

- With 1/4" O.D. tube inlet (supplied with 456-060-009 and 456-060-181)..... 463-001-211
- With 7/16-20 straight female thread inlet (supplied with 456-060-109)..... 463-001-201

**Outlet Check Valves**

- With 1/4" O.D. tube outlet (supplied with 456-060-009 and 456-060-181)..... 463-001-251
- With 7/16-20 straight female thread outlet (supplied with 456-060-109)..... 463-001-221

**Fittings (use with check valves 463-001-201 and 463-001-221)**

- 7/16-20 straight male thread X 1/8" NPTF (2 supplied with 456-060-109)..... 435-050-040

**Springs**

- Standard Spring (installed at factory in 456-060-009 and 456-060-109)..... 458-005-440
- Light Spring for low flow applications (supplied loose with 456-060-009, installed in 456-060-181)\* ..... 458-005-220

**Repair Parts**

- Switch Assembly..... 456-060-049
- Plunger & Bushing Assembly..... 456-060-029

\* When using the light spring (458-005-220) fluid viscosity should not exceed 350 SUS.

**LUBRIQUIP®**  
Centralized Lubrication Systems

Registered Trademarks of LUBRIQUIP, INC., A Unit of IDEX Corporation. Printed in U.S.A.



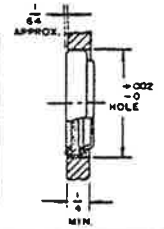
**DESCRIPTION:** Bijur Window-Units are flush-mounted, preserving the clean lines of the machine. Installation is economical, requiring only a simple press fit into a reamed hole . . . no bosses to face . . . no holes to tap . . . no loose parts to assemble. One piece construction features a corrosion resistant chrome plated brass frame, holding a clear, hard, unbreakable plastic, or a crystal clear glass window, with an oil proof gasket between the frame and window, assuring permanent oil tightness.

**INSTALLATION DATA:** All units are simply pressed into a reamed hole in the wall of reservoir. To insure tightness cover the surface of the hole with a thin coat of Glyptal,

shellac or other sealing material before pressing Window-Unit into place. Hole diameters and Assembly Punches are given below according to Window size.

WINDOW SIZE "A"	HOLE DIAMETER	ASS'Y PUNCH PART NO. BIJUR
3/8"	.875	B-5026
1"	1.250	B-5049
1 1/4"	1.500	B-5051
1 3/4"	2.000	B-5179

Assembly Punches are shown on Data Sheet 2900

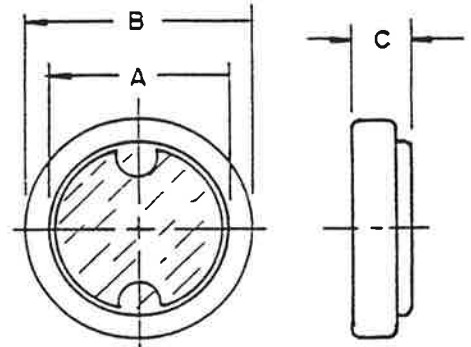


**MAXIMUM PRESSURE OR SUCTION 10 lbs./sq. in.**  
**MAXIMUM TEMPERATURE 120°F.**

### STANDARD TYPE (PLASTIC WINDOW)

Used to indicate level of oil or other non-corrosive liquid in reservoir. A clear window together with a reflecting background provides good visibility.

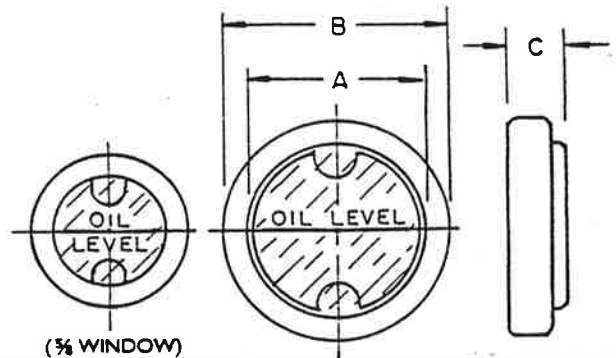
A	B	C	NAME	PART NUMBER	
				BIJUR	
3/8"	7/8"	1 1/64"	WINDOW-UNIT, ST'D TYPE	B-4900	
1"	1 1/4"	1 1/32"	WINDOW-UNIT, ST'D TYPE	B-4904	
1 1/4"	1 1/2"	3/8"	WINDOW-UNIT, ST'D TYPE	B-4908	
1 3/4"	2"	3/8"	WINDOW-UNIT, ST'D TYPE	B-5171	



### LEVEL TYPE (PLASTIC WINDOW)

Arranged to indicate a definite level of oil or other non-corrosive liquid in reservoir. Wording is on back of a clear window. Reflecting background assures good visibility.

A	B	C	NAME	PART NUMBER	
				BIJUR	
3/8"	7/8"	1 1/64"	WINDOW-UNIT, LEVEL TYPE	B-5095	
1"	1 1/4"	1 1/32"	WINDOW-UNIT, LEVEL TYPE	B-5093	
1 1/4"	1 1/2"	3/8"	WINDOW-UNIT, LEVEL TYPE	B-5091	
1 3/4"	2"	3/8"	WINDOW-UNIT, LEVEL TYPE	B-5175	

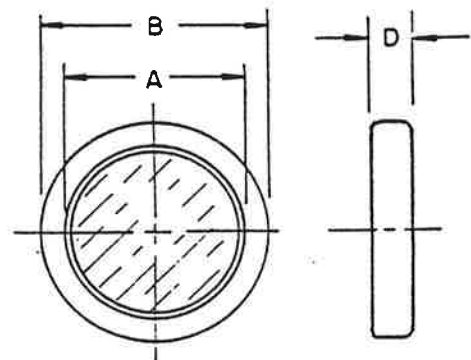


(3/8" WINDOW)

### OPEN TYPE (PLASTIC WINDOW)

Has no reflecting background thus permitting observation of liquid flow or internal parts through a clear window.

A	B	D	NAME	PART NUMBER	
				BIJUR	
3/8"	7/8"	1 3/64"	WINDOW-UNIT, OPEN TYPE	B-5104	
1"	1 1/4"	1/4"	WINDOW-UNIT, OPEN TYPE	B-5102	
1 1/4"	1 1/2"	1/4"	WINDOW-UNIT, OPEN TYPE	B-5100	
1 3/4"	2"	1/4"	WINDOW-UNIT, OPEN TYPE	B-5177	



(See reverse side for glass windows)



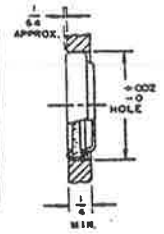
# WINDOW UNITS (GLASS WINDOWS)

**INSTALLATION DATA:** All units are simply pressed into a reamed hole in the wall of the reservoir. To insure tightness cover the surface of the hole with a thin coat of heat-resisting sealing material before pressing Window-Unit into place.

Hole diameters and Assembly Punches are given below according to Window size.

WINDOW SIZE "A"	HOLE DIAMETER	ASSY PUNCH PART NO.	
		BIJUR	
3/8"	.875	B-5026	
1"	1.250	B-5049	
1 1/4"	1.500	B-5051	
1 3/4"	2.000	B-5179	

Assembly Punches are shown on Data Sheet 2900

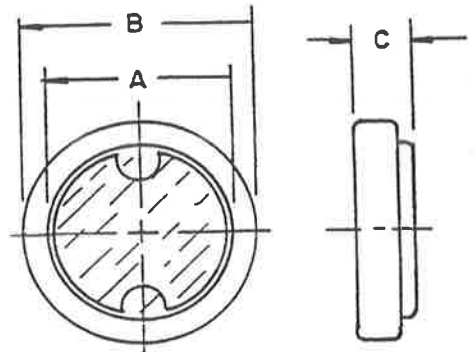


**MAXIMUM PRESSURE 50 lbs./sq. in.    MAXIMUM TEMPERATURE 300°F.**

## STANDARD TYPE (GLASS WINDOW)

Used to indicate level of oil or other non-corrosive liquid in reservoir. A clear window together with a reflecting background provides good visibility.

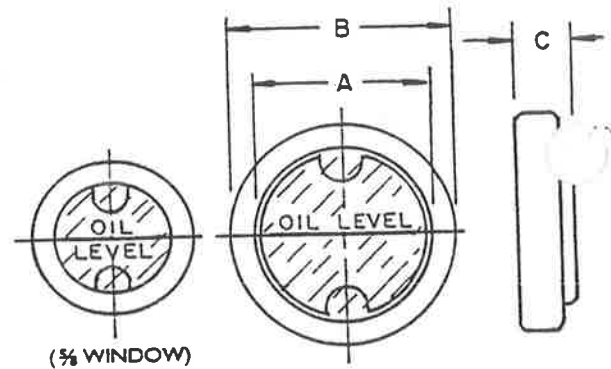
A	B	C	NAME	PART NUMBER	
				BIJUR	
3/8"	3/8"	19/64"	WINDOW-UNIT, ST'D TYPE	B-5184	
1"	1 1/4"	11/32"	WINDOW-UNIT, ST'D TYPE	B-5108	
1 1/4"	1 1/2"	3/8"	WINDOW-UNIT, ST'D TYPE	B-5145	
1 3/4"	2"	3/8"	WINDOW-UNIT, ST'D TYPE	B-5582	



## LEVEL TYPE (GLASS WINDOW)

Arranged to indicate a definite level of oil or other non-corrosive liquid in reservoir. Wording is on back of a clear window. Reflecting background assures good visibility.

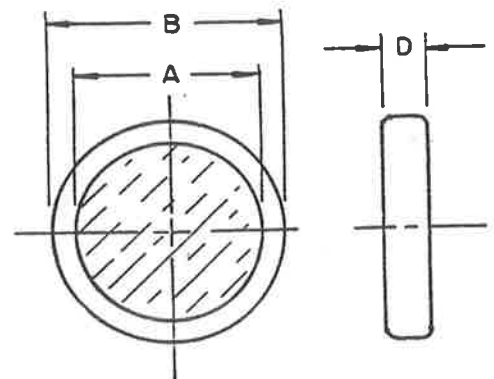
A	B	C	NAME	PART NUMBER	
				BIJUR	
3/8"	3/8"	19/64"	WINDOW-UNIT, LEVEL TYPE	B-5944	
1"	1 1/4"	11/32"	WINDOW-UNIT, LEVEL TYPE	B-5631	
1 1/4"	1 1/2"	3/8"	WINDOW-UNIT, LEVEL TYPE	B-5734	
1 3/4"	2"	3/8"	WINDOW-UNIT, LEVEL TYPE	B-5191	



## OPEN TYPE (GLASS WINDOW)

Has no reflecting background, thus permitting observation of liquid flow or internal parts through a clear window.

A	B	D	NAME	PART NUMBER	
				BIJUR	
3/8"	3/8"	13/64"	WINDOW-UNIT, OPEN TYPE	B-5602	
1"	1 1/4"	1/4"	WINDOW-UNIT, OPEN TYPE	B-5603	
1 1/4"	1 1/2"	1/4"	WINDOW-UNIT, OPEN TYPE	B-5604	
1 3/4"	2"	1/4"	WINDOW-UNIT, OPEN TYPE	B-5605	

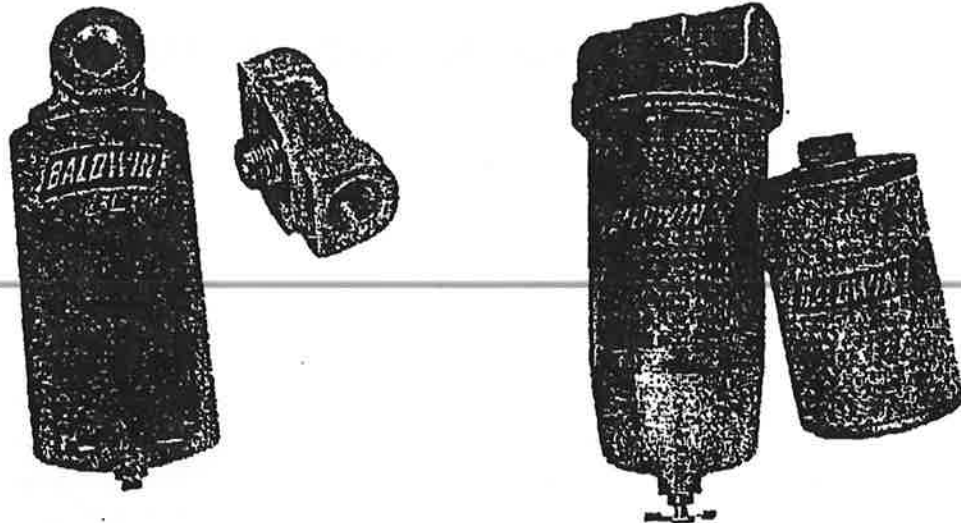


**Bijur Lubricating Corporation**

112 Bauer Drive, Oakland, New Jersey 07436 (201) 337-1600







The **BF914** combines a BF915 spin-on (with drain) and a FB1307 mounting head. The BF915 is about 1-1/2 inches longer than most competitive spin-on filters. The greater length and the use of a high capacity paper filter media provides longer life and greater contaminant capacity.

The **B10-AL** is our only element-style storage tank unit. It comes complete with PF10 filter element, a see-through amber collection bowl and its own mounting head. When it's time to drain, the unit has an easy-to-open petcock for fast, efficient draining.

**Spin-on Style Fuel Storage Tank Filter**  
 Complete Filter .....**BF914**  
 Spin-on Only .....**BF915**  
 Mounting Head .....**FB1307**

**See-Through Style Fuel Storage Tank Filter**  
 Complete Filter .....**B10-AL**  
 Filter Element .....**PF10**  
 Bowl Only .....**B10-AL Bowl**  
 Filter Element  
 w/Corn Starch Media .....**PF10-CS**

Baldwin gives you a choice of many different storage tank filters. Whether you use diesel, gasoline or gasohol, a Baldwin storage tank filter is the proven way to insure your fuel is clean when it leaves the tank. Each one is designed to meet the varying needs on our nation's farms. You need to make the choice of which Baldwin filter meets your particular requirements. Refer to the chart on the preceding page to help you make this choice.

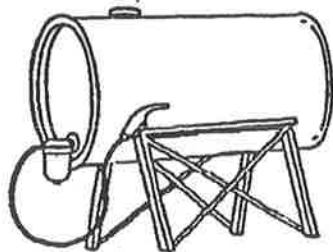


# BALDWIN STORAGE TANK FILTERS

YOUR CHOICES FOR CLEANER FUEL . . .

IT'S UP TO YOU.

If you own or operate farm equipment, you know the importance of using clean fuel. That's why it's wise to filter your fuel at the source - your fuel storage tank.



The Baldwin storage tank filters will help prevent water, rust, fungus, bacteria, scale and grit from damaging your equipment. All Baldwin filters offer the proven filtering efficiency of our special Microlite® filter media. This unique media traps harmful contaminants, without removing the important additives in your fuel.

The outstanding feature of Baldwin's BF956 spin-on is its highly absorbent material that removes moisture as well as other contaminants. If there is significant water contamination, the filter's media will swell and block fuel flow. The fuel delivery rate then drops from 15 gallons per minute to one-half gallon per minute.

STORAGE TANK FILTER	LONGEST LIFE	GREATEST EFFICIENCY	GPM FLOW	DRAIN	BASE	SPECIAL FEATURES
B10-AL Hsg. & Ele.	●	■	25	Yes	B10-AL Cap	See-Through Collection Bowl
BF914 Base & Spin-on	▲	▲	25	Yes	FB1307	BF915 Spin-on
BF955 Spin-on	■	■	15	No	FB1307	Standard 5-3/8" Long Spin-on
BF956 Spin-on	●	●	15	No	FB1307	Water Absorbent Media
BF958 Spin-on	▲	■	15	Yes	None	Replacement for Amoco A05, A08
BF971 Spin-on	■	■	20	No	FB1307	Hi Performance 7-1/8" Long Spin-on

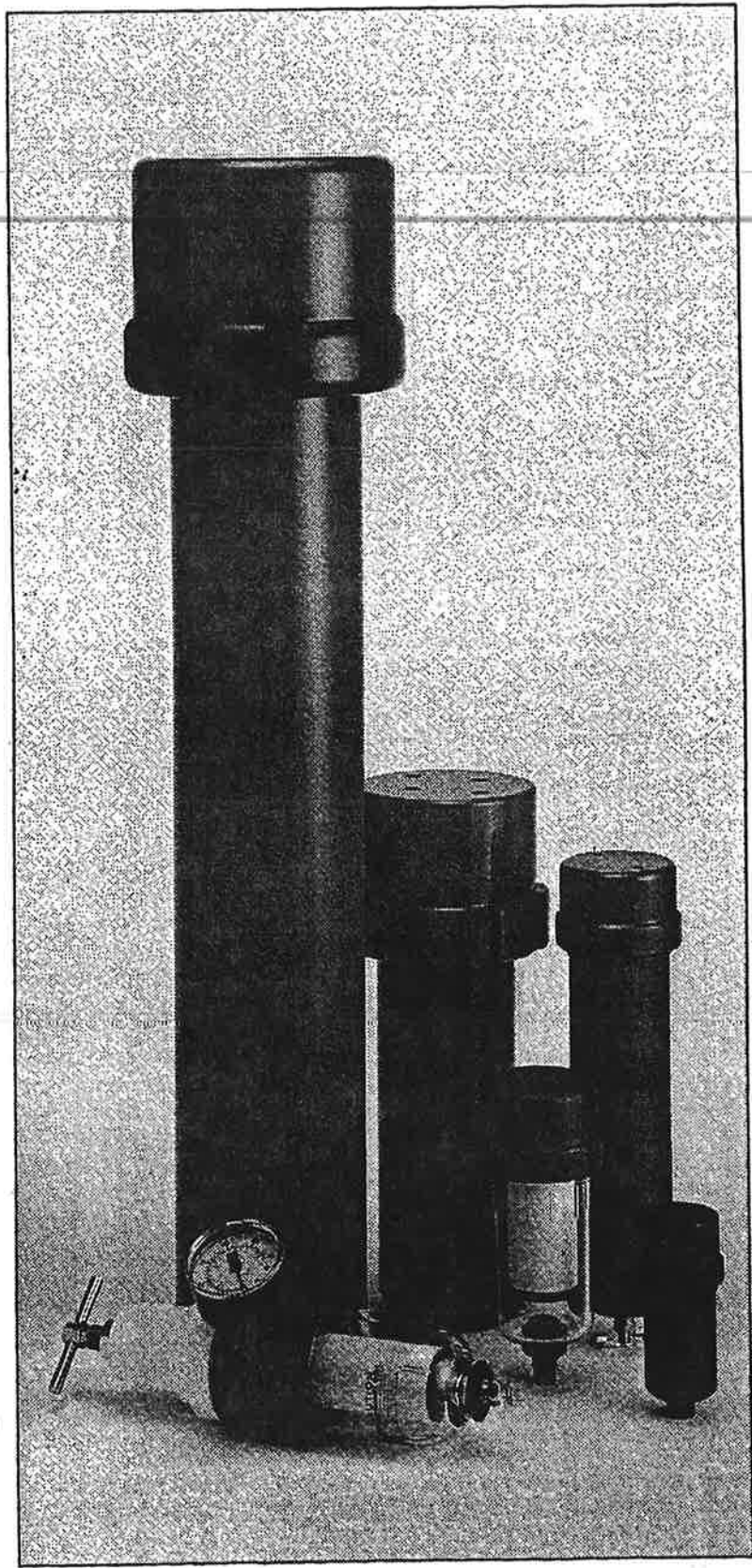
● Good

▲ Very Good (Better)

■ Excellent (The Best)

**H** HEADLINE  
FILTERS

F-220



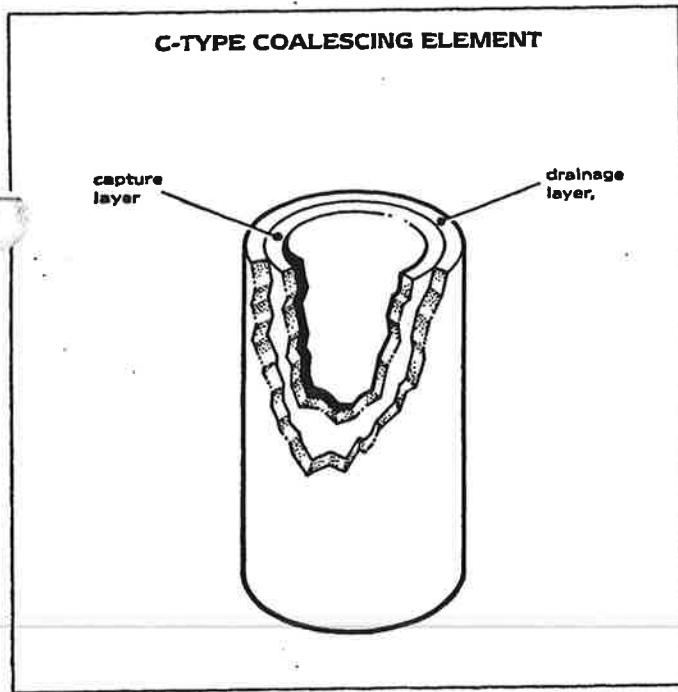
**COMPRESSED AIR FILTER SYSTEMS**



## COALESCING FILTRATION – HOW IT WORKS

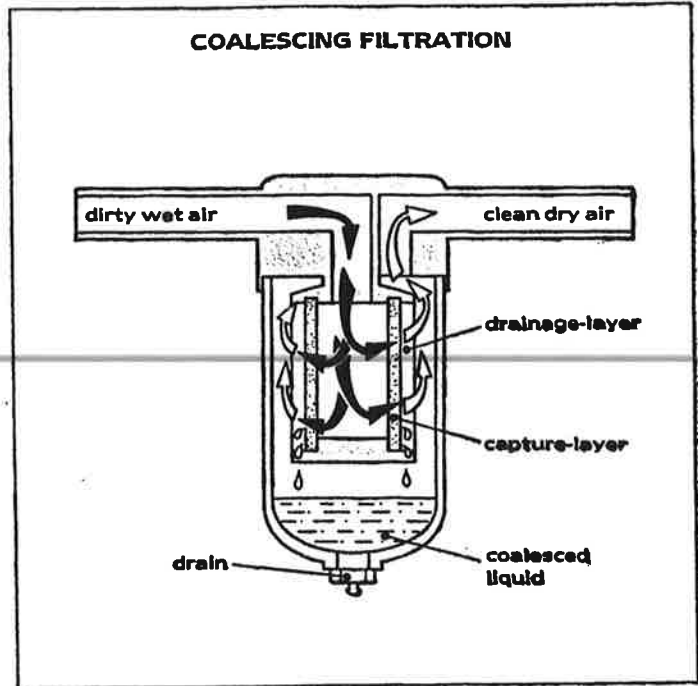
Compressed air, even from a new installation, is a heavily contaminated product. Dirt is ingested through the compressor inlet, oil is carried over from the piston, and water condenses out at the higher air pressure. The demand for more sophisticated and more reliable pneumatic systems can only be met by ultra-clean compressed air.

Ultra-clean compressed air is most conveniently produced in the production plant by the installation of a well-designed Coalescing Filtration System. This system will remove essentially all solid and liquid contamination, with minimum maintenance and low operating costs. Headline Coalescing Filters remove up to 99.99% of solid and liquid particles down to 0.1 micron, producing truly clean compressed air.



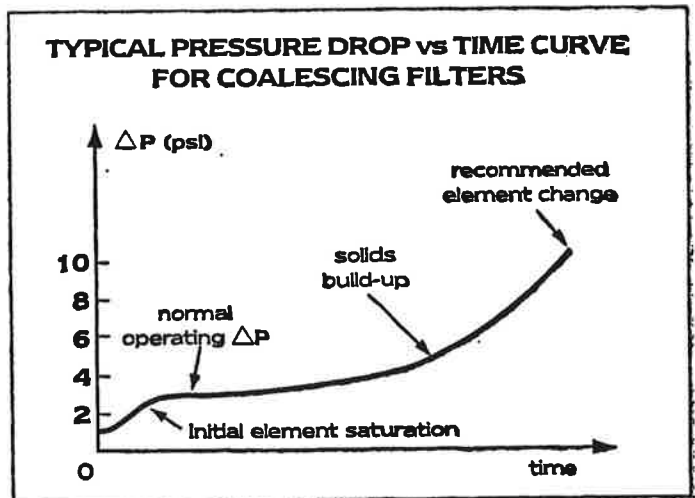
At the heart of the Headline Coalescing Filter is the completely disposable C-type coalescing element. Made entirely from borosilicate glass microfiber and fluorocarbon binder, it is compatible with all compressor lubricants and will operate at temperatures up to 300°F.

The C-type element has a two-layer structure, an inner particle capture-layer and an outer drainage-layer. Liquid droplets remain mobile once captured and travel through the fine-pored capture-layer, along the intersecting microfibers, growing in size as they progress. These coalesced droplets are transferred to the large-pored drainage-layer, from where they drain by gravity into the filter bowl. Liquid collected in the filter bowl can be removed by a manual or fully automatic drain.



Headline C-type elements are completely self-supporting and are sealed into the filter housing simply by tightening a retaining nut. No end caps, gasketing materials or support cores are required. At element change only the filtering material itself is discarded, and this complete disposability keeps replacement element costs down.

Headline Coalescing Filters are designed to have an initial dry pressure drop of less than 2 psi. Thereafter the pressure drop will increase very slowly as solid particles are captured and retained in the capture-layer of the element. Headline recommends changing the filter element when the pressure drop reaches 10 psi. The optional differential pressure indicator will give a visual warning of the need to change the filter element.





## HEADLINE BENEFITS

- COMPLETE REMOVAL OF OIL, WATER AND SOLIDS
- HIGH FLOW RATES, LOW PRESSURE DROPS
- LOW COST, COMPLETELY DISPOSABLE MICROFIBER FILTER ELEMENTS
- COMPATIBLE WITH ALL COMPRESSOR LUBRICANTS
- WIDE VARIETY OF HOUSING SIZES & OPTIONS AVAILABLE
- CHOICE OF MANUAL OR FULLY AUTOMATIC DRAINS

### HOW TO SELECT THE CORRECT GRADE OF FILTER ELEMENT

#### GRADE 70C - COALESCER

has an efficiency rating of 95% against 0.1 micron particles and aerosols and should be specified for all general purpose applications requiring clean compressed air e.g. Protection of valves, cylinders, air tools, air motors and pumps etc.

#### GRADE 50C - COALESCER

has an efficiency rating of 99.99% against 0.1 micron particles and aerosols and should be specified for the most demanding applications requiring the highest quality of air cleanliness e.g. air bearings, spray coating, instrumentation, laser systems, food contact etc. For best performance a grade 70C coalescer should be used as a prefilter to the grade 50C.

#### GRADE CC - VAPOR ADSORPTION

Coalescing filters can only remove the oil and water present in compressed air lines as liquid aerosols. They cannot remove the small fraction of oil present as a true vapor or water vapor. Headline manufactures a range of vapor adsorption filter cartridges which will remove such gaseous contamination when used in conjunction with coalescing filters. These grade CC cartridges fit the complete range of Headline Compressed Air Housings and are described in detail on page 6. Please remember grade CC Vapor Adsorption Cartridges must always be protected by a grade 50C coalescing prefilter.

### HOW TO SELECT THE CORRECT FILTER HOUSING

First select the correct grade of element using the guidelines above. Next estimate the maximum air flow and line pressure expected at the filter. Now turn to page 8 of this bulletin and select which housings have the necessary flow capacity for the grade of element chosen. Then refer to the specification tables on pages 4 & 5 to select the housing which has the necessary pressure and temperature capability, and the required drain option.

#### LARGER HOUSINGS

Details of larger Headline Filters are available on request.

#### INSTALLATION GUIDE

- Never install a filter with ports smaller than the existing air line size.
- Always install the filter as close as possible to the equipment being protected.
- Never exceed the maximum rated flow of the filter, or it's efficiency will be jeopardized.
- Never install polycarbonate bowls where synthetic lubricants or solvents may contact them.
- Always use a grade 70C prefilter before a grade 50C final filter.
- Always protect grade CC vapor adsorption cartridges with a grade 50C coalescer.

### HOW TO ORDER

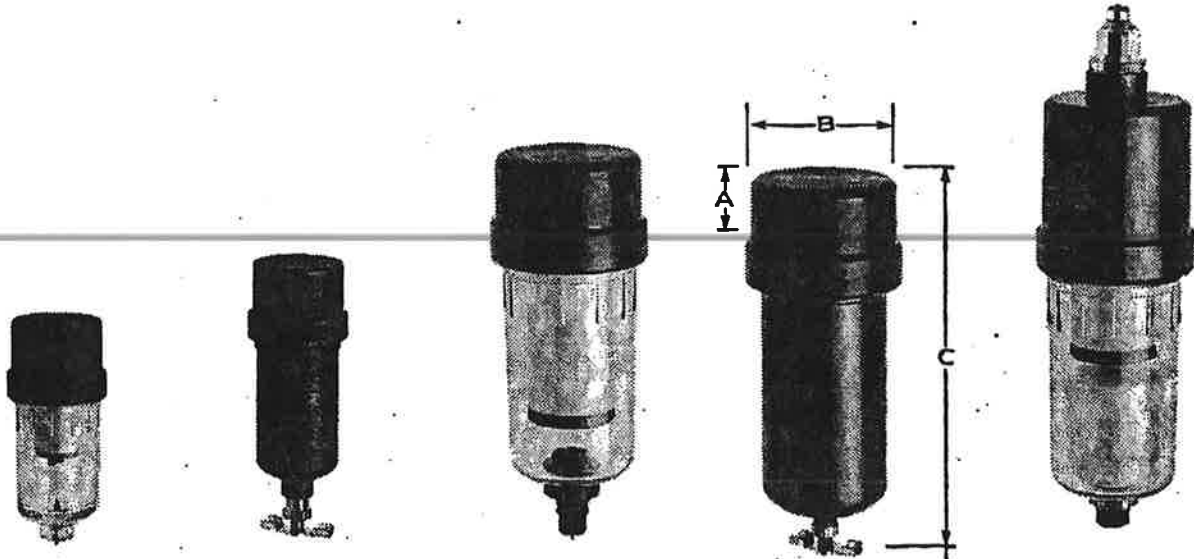
**FILTER HOUSINGS** - Please specify model no., port size and element grade required. e.g. 360A-50C-1/4"  
Each housing comes complete with filter element, ready for installation.

**ACCESSORIES** - For your convenience please order accessory items at the time of ordering the filter housing.  
Please check the exact order codes in the table on page 4, 5, 6 & 7. |

**REPLACEMENT ELEMENTS** - Coalescing elements are sold in packs of 3 or 10. Please refer to tables on pages 4 & 5 for the exact order codes. Please specify the grade required.  
Adsorption cartridges are sold individually.



# HIGH EFFICIENCY COALESCING FILTERS 1/8" THROUGH 1/2"



MODEL 315

MODEL 315A

MODEL 360

MODEL 360A

MODEL 360FI

## PRINCIPAL SPECIFICATIONS

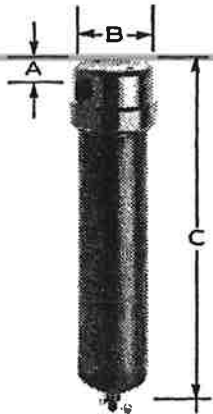
HOUSING MODEL	315	315A	360	360I	360FI	360A	360AF	370	370I	370FI
PORT SIZE (NPT)	1/8" or 1/4"	1/8" or 1/4"	1/4" or 1/2"	1/4" or 1/2"	1/4" or 1/2"	1/4" or 1/2"	1/4" or 1/2"	1/2"	1/2"	1/2"
DRAIN TYPE	manual	manual	dump valve	dump valve	automatic	manual	automatic	dump valve	dump valve	automatic
MAXIMUM TEMPERATURE (°F)	120	200	120	120	120	200	200	120	120	120
MAXIMUM PRESSURE (psig)	150	250	150	150	150	250	250	150	150	150
PRINCIPAL DIMENSIONS - A (Inches)	0.39	0.39	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
- B	1.57	1.57	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
- C	3.82	4.45	6.14	7.84	8.66	6.30	7.17	10.28	11.97	11.97
FILTER ELEMENT CODES (1)	12-32-□	12-32-□	25-64-□	25-64-□	25-64-□	25-64-□	25-64-□	25-178-□	25-178-□	25-127-□
MAXIMUM PRESSURE DROP - (psi)	100	100	100	100	100	100	100	100	100	100
MAXIMUM PRESSURE DROP AT ELEMENT CHANGE - (psi)	10	10	10	10	10	10	10	10	10	10
MATERIALS OF CONSTRUCTION (2)										
- Head	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
- Bowl	Pc	Al	Pc	Pc	Pc	Al	Al	Pc	Pc	Pc
- Internals	Nylon	Nylon	Nylon	Nylon	Nylon	Nylon	Nylon	SS/Al	SS/Al	SS/Al
- Seals	Buna-N	Buna-N	Buna-N	Buna-N	Buna-N	Buna-N	Buna-N	Buna-N	Buna-N	Buna-N
- Others	Brass	Brass	Plastic/Brass	Plastic/Brass	Plastic/Brass	Brass	Plastic/Brass	Plastic/Brass	Plastic/Brass	Plastic/Brass
OPTIONAL ITEMS										
Mounting bracket	MB315	MB315	MB360	MB360I	MB360I	MB360	MB360	MB360	MB360I	MB360I
Bowl Guard	BG315	-	BG360	BG360	BG360	-	-	BG360	BG360	BG360
gasket seal set	GV315	GV315	GV360	GV360	GV360	GV360	GV360	GV370	GV370	GV370
DPI Kit	-	-	-	Included	Included	-	-	-	Included	Included

(1) Enter grade required - 50C or 70C or CC. CC cartridges are not used in housings with automatic drains.

(2) Material abbreviations: Al=Anodized aluminum, Pc=Polycarbonate, SS=Stainless Steel.



# HIGH EFFICIENCY COALESCING FILTER 1/2" THROUGH 3"



MODEL 370A



MODEL 380AF



MODEL 385AF



MODEL 390AF



MODEL 395AF

## PRINCIPAL SPECIFICATIONS

HOUSING MODEL	370A	370AF	380A	380AF	385A	385AF	390A	390AF	395A	395AF
PORT SIZE (NPT)	1/2"	1/2"	3/4" or 1"	3/4" or 1"	1 1/2"	1 1/2"	2"	2"	3"	3"
DRAIN TYPE	manual	automatic	manual	automatic	manual	automatic	manual	automatic	manual	automatic
MAXIMUM TEMPERATURE (°F)	200	200	200	200	200	200	200	200	200	200
MAXIMUM PRESSURE (psig)	250	250	250	250	250	250	250	250	250	250
PRINCIPAL DIMENSIONS - A (inches)	0.61	0.61	1	1	1.85	1.85	1.85	1.85	2.56	2.56
- B	2.44	2.44	3.94	3.94	5.51	5.51	5.51	5.51	7.48	7.48
- C	10.28	10.28	11.61	11.61	14.57	14.57	25	25	38.19	38.19
FILTER ELEMENT CODES (1)	25-178-□	25-127-□	38-152-□	38-152-□	51-230-□	51-230-□	51-476-□	51-476-□	63-762-□	63-762-□
MAXIMUM PRESSURE DROP - (psi)	100	100	100	100	100	100	100	100	100	100
MAXIMUM PRESSURE DROP AT ELEMENT CHANGE - (psi)	10	10	10	10	10	10	10	10	10	10
MATERIALS OF CONSTRUCTION (2)										
- Head	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
- Bowl	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
- Internals	SS/Al	SS/Al	SS/Al	SS/Al	SS/Al	SS/Al	SS/Al	SS/Al	SS/Al	SS/Al
- Seals	Buna-N	Buna-N	Buna-N	Buna-N	Buna-N	Buna-N	Buna-N	Buna-N	Buna-N	Buna-N
- Others	Brass	Plastic/Brass	Brass	Plastic/Brass	Plastic	Plastic/Brass	Plastic	Plastic/Brass	Plastic	Plastic/Brass
OPTIONAL ITEMS										
Mounting bracket	MB360	MB360	MB380	MB380	MB385	MB385	MB390	MB390	MB390	MB390
Bowl Guard	-	-	-	-	-	-	-	-	-	-
Viton seal set	GV360	GV360	GV380	GV380	GV385	GV385	GV390	GV390	GV395	GV395
DPI Kit	-	-	DP380	DP380	DP380	DP380	DP380	DP380	DP380	DP380

(1) Enter grade required - 50C or 70C or CC. CC cartridges are not used in housings with automatic drains.

(2) Material abbreviations: Al=Anodized aluminum, Pc=Polycarbonate, SS=Stainless Steel.

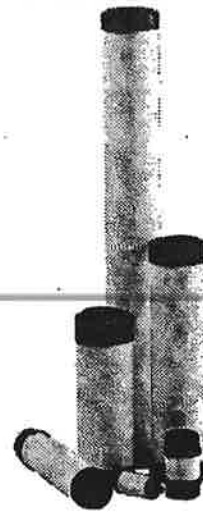


# VAPOR ADSORPTION FILTERS 1/4" THROUGH 2"

## REMOVE LAST TRACES OF OIL VAPOR AND ODOR FROM COMPRESSED AIR.

Headline grade CC vapor Adsorption Cartridges fit the standard range of compressed air housings described on pages 4 & 5 and are designed to remove the last traces of oil vapor and odor from compressed air. The cartridge consists of a cylinder of activated carbon cloth sandwiched between two filter tubes providing the most effective known adsorption of organic vapors. Carbon cloth is up to 20 times more efficient in the removal of organic vapors than granulated carbon, giving Headline cartridges exceptional flow and life characteristics.

GRADE CC ADSORPTION CARTRIDGES



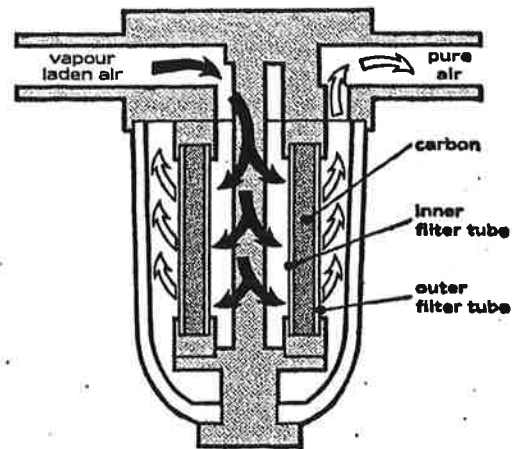
### ADSORPTION CHARACTERISTICS

EXCELLENT ADSORPTION - HYDROCARBONS C<sub>4</sub> & LARGER

- FREONS
- OIL VAPOR
- ALCOHOLS
- ALDEHYDES & KETONES
- AROMATIC HYDROCARBONS

LITTLE ADSORPTION

- METHANE
- CARBON MONOXIDE
- CARBON DIOXIDE
- ACETYLENE
- AMMONIA
- AMINES
- HYDROCARBONS C<sub>3</sub> & LOWER



GRADE CC ADSORPTION CARTRIDGE HOW IT WORKS

## RECOMMENDED PREFILTER/ADSORBER COMBINATIONS

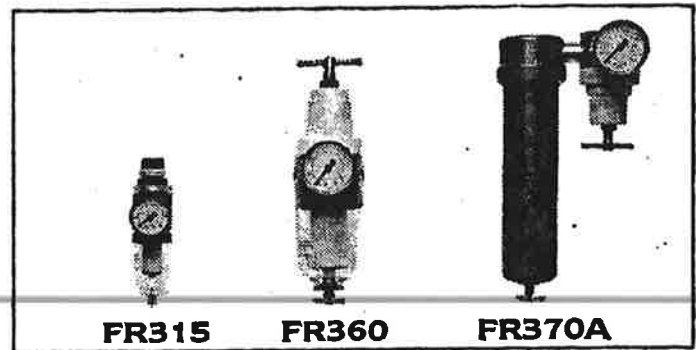
Line Size	Maximum flow rate at 100 psig	Prefilter Housing (use 50C element)	Adsorber Housing and cartridge code
1/4"	5 scfm	315, 315A	315, 315A + 12-32-CC
1/2"	15 scfm	360F, 360AF	360, 360A + 25-64-CC
1/2"	40 scfm	370F, 370AF	370A + 25-178-CC
3/4", 1"	80 scfm	380AF	380A + 38-152-CC
1 1/2"	125 scfm	385AF	385A + 51-230-CC
2"	250 scfm	390AF	390A + 51-476-CC
3"	560 scfm	395AF	395A + 63-762-CC

# COALESCING FILTER REGULATORS 1/4" THROUGH 1/2"



## HIGH EFFICIENCY COALESCING FILTRATION + HIGH QUALITY PRESSURE REGULATION

In one convenient piggy-back unit. Headline coalescing filter regulators combine all the advantages of coalescing filtration using grade 50C filter elements with a high performance pressure regulator. The regulator is placed downstream of the coalescer to provide clean, dry air at constant pressure, irrespective of the pressure drop across the coalescer.

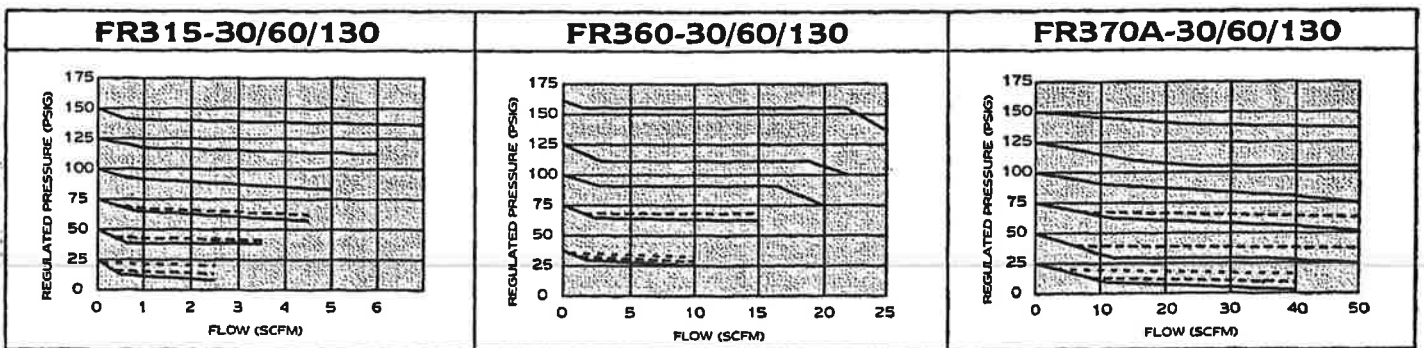


## PRINCIPAL SPECIFICATIONS

MODEL NO.	FR315	FR315A	FR360	FR360A	FR370A
PORT	1/4"	1/4"	1/4"	1/4"	1/2"
GAUGE PORTS	1/8"	1/8"	1/4"	1/4"	1/4"
FILTER ELEMENT CODE	12-32-50C	12-32-50C	25-64-50C	25-64-50C	25-178-50C
MATERIALS OF CONSTRUCTION (1)					
- Head	Al	Al	Al	Al	Al
- Bowl	Pc	Al	Pc	Al	Al
- Internals	Nylon & Buna-N	Nylon & Buna-N	SS & Buna-N	SS & Buna-N	SS & Buna-N
Maximum Temperature (°F)	120	220	120	220	220
Maximum Inlet Pressure (psig)	150	250	150	250	250
Regulated Range	FR315 - 30	FR315A - 30	FR360 - 30	FR360A - 30	FR370A - 30
5-60 psig	- 60	- 60	- 60	- 60	- 60
10-130 psig	- 130	- 130	- 130	- 130	- 130
% Drop at maximum flow rate	8	8	8	8	8

(1) Material abbreviations: Al=Anodized aluminum, Pc=Polycarbonate, SS=Stainless Steel.

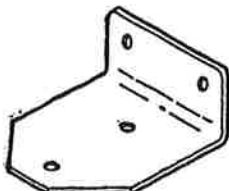
## FLOW CHARACTERISTICS



## ACCESSORIES

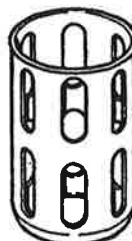
### MOUNTING BRACKETS

Filter Mounting Brackets are available for most Headline Filters. The model no. for each housing is given in the tables on pages 4 & 5.



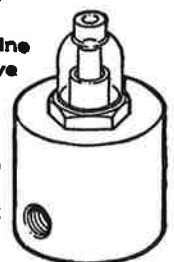
### BOWL GUARDS

Available for all filters with polycarbonate plastic bowls to protect against impact damage. Headline recommends that, in the interest of safety, bowl guards always be installed.



### DIFFERENTIAL PRESSURE INDICATORS

Differential Pressure Indicators can be installed on all Headline Filters to give positive visual indication of the need to change elements. Differential Pressure Indicators can also be built into the head on many models.







# COMPRESSED AIR FILTER SYSTEMS

## AIR FLOW RATES in SCFM at 2 psi Pressure Drop

HOUSING MODEL	LINE SIZE	ELEMENT GRADE	AIR LINE PRESSURE (psig)								
			2	20	40	60	80	100	150	200 <sup>(1)</sup>	250 <sup>(1)</sup>
315, 315A	1/4"	70C	4.4	9.0	14	20	25	30	43	56	69
		50C	1.3	2.7	4.3	5.9	7.4	9.0	13	17	21
		CC	0.7	1.5	2.4	3.3	4.1	5.0	7.2	9.4	12
360, 360I 360FI 360A, 360AF	1/4" or 1/2"	70C	9.5	20	31	42	54	65	93	122	150
		50C	3.6	8	12	16	21	25	36	47	58
		CC	2.2	4.5	7.2	10	12	15	22	28	35
370, 370I 370FI 370A, 370AF	1/2"	70C	22	45	72	98	125	150	215	280	345
		50C	8.7	18	29	39	50	60	86	112	138
		CC	5.8	12	19	26	33	40	57	75	92
380A, 380AF	3/4" or 1"	70C	58	120	190	260	330	400	570	750	920
		50C	15	30	48	65	83	100	144	187	230
		CC	12	24	38	52	66	80	115	150	185
385A, 385AF	1 1/2"	70C	116	240	380	520	660	800	1150	1500	1850
		50C	25	53	83	114	144	175	250	330	405
		CC	18	38	60	81	103	125	180	235	290
390A, 390AF	2"	70C	205	425	670	910	1160	1400	2010	2620	3230
		50C	51	106	167	230	290	350	505	655	810
		CC	36	76	120	163	205	250	360	470	580
395A, 395AF	3"	70C	400	835	1320	1800	2300	2800	4320	5900	7200
		50C	115	240	380	520	665	795	1226	1710	2100
		CC	80	170	270	365	470	560	864	1200	1450

(1) Airline pressures above 150 psig apply only to housings with aluminum bowls.  
Housings with polycarbonate bowls are limited to 150 psig.

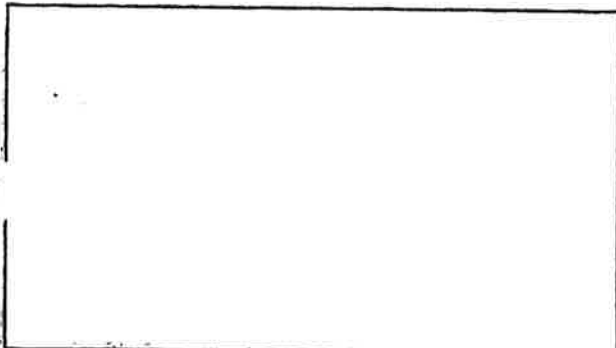
### WARRANTY

HEADLINE FILTERS WARRANTS their products against defects in material and workmanship for a period of one year from the date of purchase, providing use was in accordance with Headline Filters recommendations. If product fails to perform as warranted, Headline Filters will replace the product free of charge. The company will not be liable for incidental or consequential damages, labor charges, delays, or any other charges. We make no other warranty, expressed or implied.

The user through his own analysis and testing is solely responsible for product selection and ensuring all reasonable safety and warning requirements of the application are met.

HEADLINE FILTERS reserves the right to make design changes and improvements in our products at any time without notice.

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## HEADLINE FILTERS

Headline North America Inc.  
34062 James J. Pompo Drive  
Fraser MI 48026  
Phone: (810) 296-8007  
Fax: (810) 296-8081





# RUFFNECK<sup>®</sup> Heaters

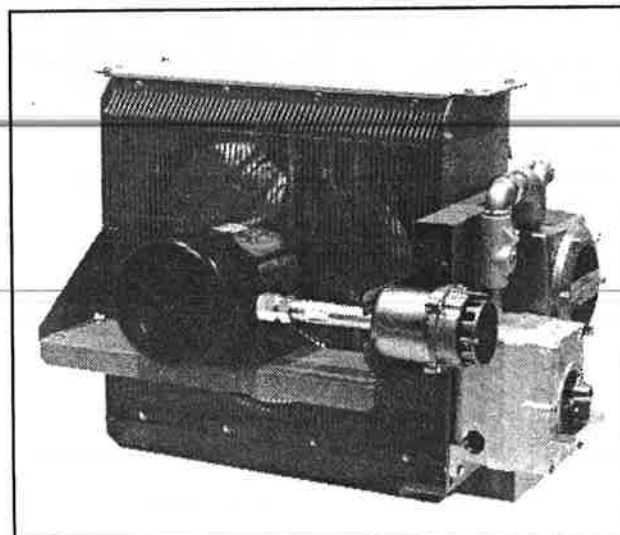
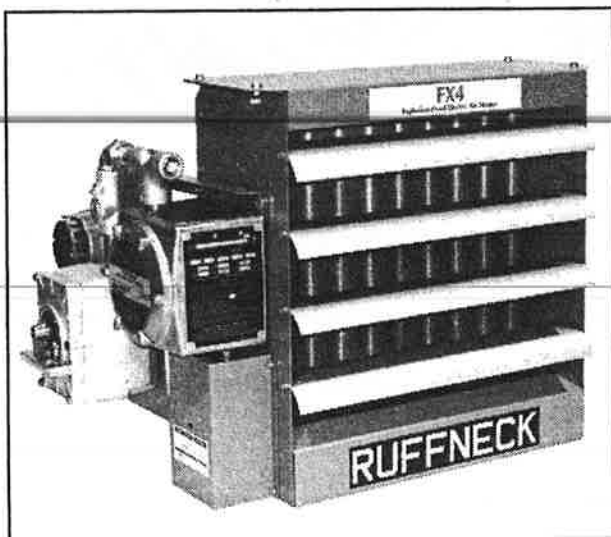
H-240B

Owner's Manual



## FX4 Series

Electric Forced Air Heaters for Hazardous Locations



This manual covers the installation, maintenance, repair and replacement parts.

### APPROVED LOCATIONS

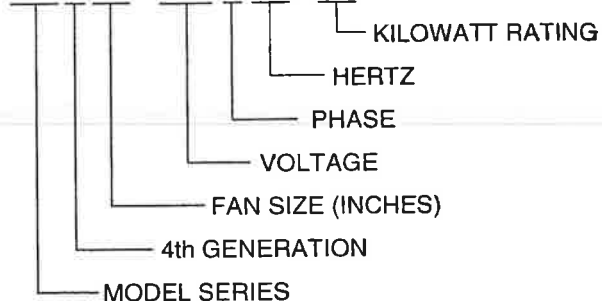
The Electric Forced Air Heaters are CSA certified and/or UL listed for the following locations:

Class I, Divisions 1 & 2, Groups C & D;  
Class II, Division 1, Groups E, F, & G;  
Class II, Division 2, Groups F & G;  
Class I, Zones 1 & 2, Groups IIA & IIB;  
Temperature Code T3B 165°C (329°F)  
(50 Hz & 60 Hz Models)

For details of hazardous locations with potential for explosion, refer to the Canadian Electrical Code, Part 1, Section 18 or National Electrical Code articles 500-516.

### MODEL CODING

**FX 4 20 - 480 3 60 - 35**



**WARNING!**  
READ ALL IMPORTANT NOTICES ON PAGE 3.

Part No. 5031-10

Printed in Canada



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# HEATER MAINTENANCE CHECKLIST

For Electric Forced Air Heaters

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this page  
for reuse.

Heater Model: \_\_\_\_\_ Serial No.: \_\_\_\_\_

Date of Maintenance: \_\_\_\_\_ Maintenance Done By: \_\_\_\_\_

Comments: \_\_\_\_\_

## WARNING

Disconnect heater from power supply at integral disconnect or fuse box before opening enclosures or servicing heater.  
Lock the switch in the "OFF" (open) position and/or tag the switch to prevent unexpected power application.  
IF INTEGRAL DISCONNECT IS BEING SERVICED, verify that power has been disconnected at fuse box or main panel.  
Lock the switch in the "OFF" (open) position and/or tag the switch to prevent unexpected power application.  
This heater should only be serviced by personnel with heating and hazardous location equipment experience.

## PERIODIC (before and as required during heating season)

- |          |                                       |          |   |
|----------|---------------------------------------|----------|---|
| 1. CLEAN | <input type="checkbox"/> Finned Tubes | 2. CHECK | <input type="checkbox"/> Motor for smooth, quiet operation        |
|          | <input type="checkbox"/> Fan          |          | <input type="checkbox"/> Louvers for proper angle and tightness   |
|          | <input type="checkbox"/> Fan Guard    |          | <input type="checkbox"/> All explosion-proof covers for tightness |
|          | <input type="checkbox"/> Motor        |          |   |
|          | <input type="checkbox"/> Louvers      |          |   |

**Remove dust using compressed air. Do not spray with water or solvents.  
Do not immerse in water or solvents.**

## ANNUAL (before heating season)

- ELECTRICAL
  - Check all terminal connections and conductors.** Tighten loose connections. Conductors with damaged insulation must be replaced.
  - Inspect contactor contacts.** If badly pitted, burned or welded shut, replace with factory supplied contactor.
  - Check fuses.** Fuse rating and type are on printed circuit board. Correct fuse must be in the active fuse clip. It is recommended that a spare fuse be stored in the spare fuse clip.
  - Check all explosion-proof conduits.** Replace damaged conduits. All threaded conduit connections must have a minimum 5 turns engagement. Straight threaded conduit must protrude a minimum of 1/16" (1.6mm) inside enclosures. Taper threaded connections must be at least hand tight.
  - Check electrical resistance on all load side legs.** Reading should be balanced ( $\pm 5\%$ ).
- MECHANICAL
  - Check for fluid leakage.** The heater core is vacuum charged and contains ethylene glycol which is **poisonous**. If any fluid leakage occurs from the heater, disconnect it from the power supply and have the core replaced. A factory supplied exchange core can be shipped immediately from stock. Refer to the "Repair and Replacement" section for details.
  - Check all enclosures.** Interior of enclosures must be clean, dry and free of foreign materials. Threaded covers must be installed and hand tight.  
**Note:** Enclosure joints are metal to metal. Do not use gasket material or sealant in joints. A grease is applied to the joints at the factory and should be left intact.
  - Check motor shaft bearing play.** Replace motor if play is excessive, or if motor does not run quietly and smoothly. Motor bearings are permanently lubricated.
  - Check fan.** Replace immediately if cracked or damaged.
  - Check louvers.** Louver screws should be tight. Louvers shall not be fully closed or override stops.
  - Check the tightness of all hardware.** All nuts and bolts, including mounting hardware, must be tight.
  - Turn heater on for a minimum of five minutes.** Check for warm air exiting heater through louvers. Crackling or pinging noises within heater during start-up are normal.



For assistance, please call  
Toll Free: 1-800-661-8561 (24 hrs)  
U.S. & Canada

# IMPORTANT NOTICES

## WARNING

Read and adhere to the following. Failure to do so may result in severe or fatal injury.

1. Read and follow all instructions in this manual.
2. Heater is to be used only in atmospheres having an ignition temperature higher than the heater's maximum rated operating temperature as shown on the heater data plate. Refer to applicable electrical codes for additional information.
3. Heater to be used only in the hazardous locations indicated on the heater's data plate.
4. Heater is for dry indoor use only. Do not immerse in water. Do not store or use in areas exposed to rain or snow.
5. ~~Heater is to be connected and serviced only by a~~ qualified electrician experienced with hazardous location equipment.
6. Installation and wiring of the heater must adhere to all applicable codes.
7. Disconnect heater from power supply at integral disconnect or fuse box before opening enclosures or servicing heater. Lock the switch in the "OFF" (open) position and/or tag the switch to prevent unexpected power application. IF INTEGRAL DISCONNECT IS BEING SERVICED, verify that power has been disconnected at fuse box or main panel. Lock the switch in the "OFF" (open) position and/or tag the switch to prevent unexpected power application.
8. This heater is equipped with a single bimetal overtemperature high-limit. It is of the automatic reset type and therefore the heater may restart without warning. The heater is not to be operated with the high-limit disabled or disconnected from the control circuit.
9. Venting pressure of the pressure relief valve is factory set. Do not tamper with lock nut.
10. Operate the heater only while it is permanently mounted in an upright position. Refer to the "Installation - Mechanical" section for details.
11. Heater must be kept clean. When operating in a dirty environment, regularly clean the finned tubes, fan, and fan guard. Follow the recommended maintenance procedures. Refer to the "Heater Maintenance Checklist" section for details.
12. The heater core is vacuum charged and contains ethylene glycol which is **poisonous**. If any fluid leakage occurs from the heater, disconnect it from the ~~power supply and have the core replaced with a~~ factory supplied core. Refer to the "Repair and Replacement" section for details.
13. Do not operate the heater with any of the louvers fully closed or overriding their stops.
14. Do not operate the heater in atmospheres corrosive to steel or aluminum.
15. Do not operate heater in ambient temperatures above 40°C (104°F).
16. Use factory approved replacement parts only.
17. See applicable electrical codes for seal requirements in field installed conduits. Factory installed conduits require no further sealing.
18. Crackling or pinging noises within the heater core during start up may occur. This is normal.
19. Air discharge near the bottom of the heater may be warmer than the top. This is normal.
20. If there are any questions or concerns regarding the heater, contact the factory. Refer to the last page of this manual for details.

**WARRANTY WILL BE VOID  
IF INSTRUCTIONS ARE NOT FOLLOWED**

## INSTALLATION

The installation instructions provide a general guideline for the installation and wiring of the heater. All applicable codes must be adhered to.

## MECHANICAL

### LOCATION

For optimum heating, the heater should be installed as follows:

1. There are no obstructions that may impede the heater's air inlet or discharge.
2. The air discharge is directed into open areas and not at occupants.
3. The air discharge is not directed at a thermostat.
4. The air discharge is directed across areas of heat loss, such as doors and windows (see Figure 1).
5. The air discharge is directed along and at a slight angle toward exterior walls (see Figure 1).
6. If equipment freeze protection is important, direct air discharge at equipment.
7. Air discharge streams support each other and create a circular air flow. It is not required that the heater's air throw reaches the next heater (see Figure 1).

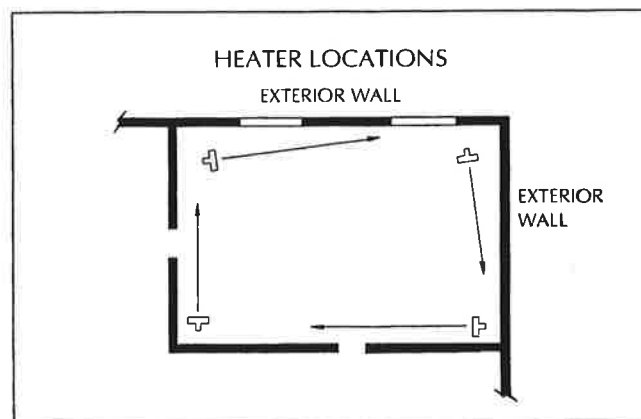


FIGURE 1

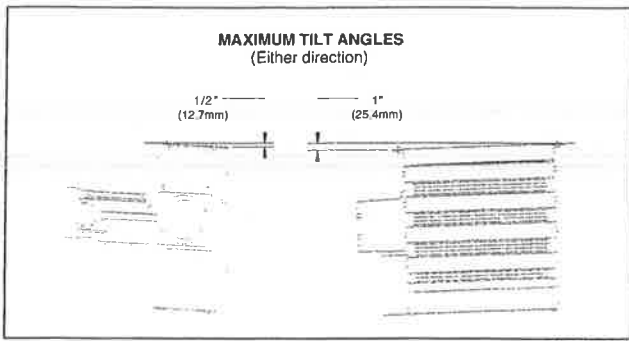


FIGURE 2

## MOUNTING

- The heater must be permanently mounted in a level, upright position for operation. See Figures 2, 3, and 4 for maximum tilt angles, installation clearances, and physical dimensions. For ease of installation, a variety of mounting kits are available from the factory.
- The mounting structure must be strong enough to:
  - support the heater's weight, refer to the "Specifications" section,
  - provide sufficient stiffness to prevent excessive vibration, and
  - withstand harsh situations such as transportable installations.

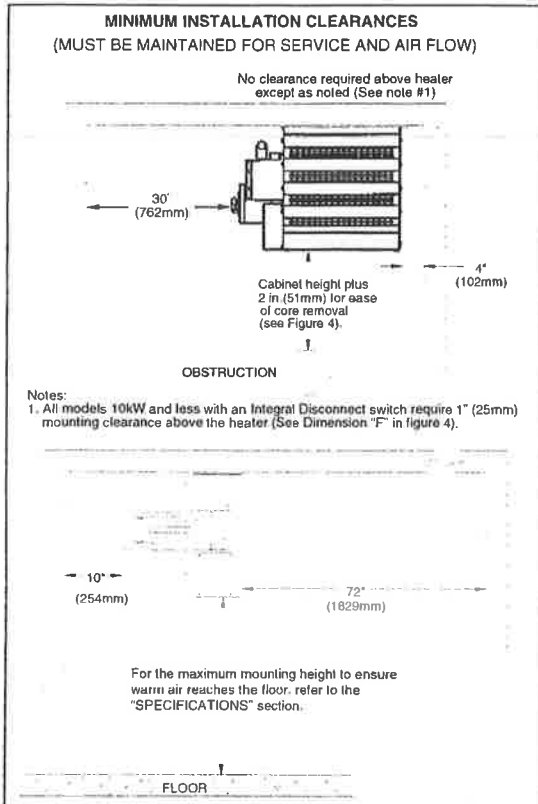


FIGURE 3

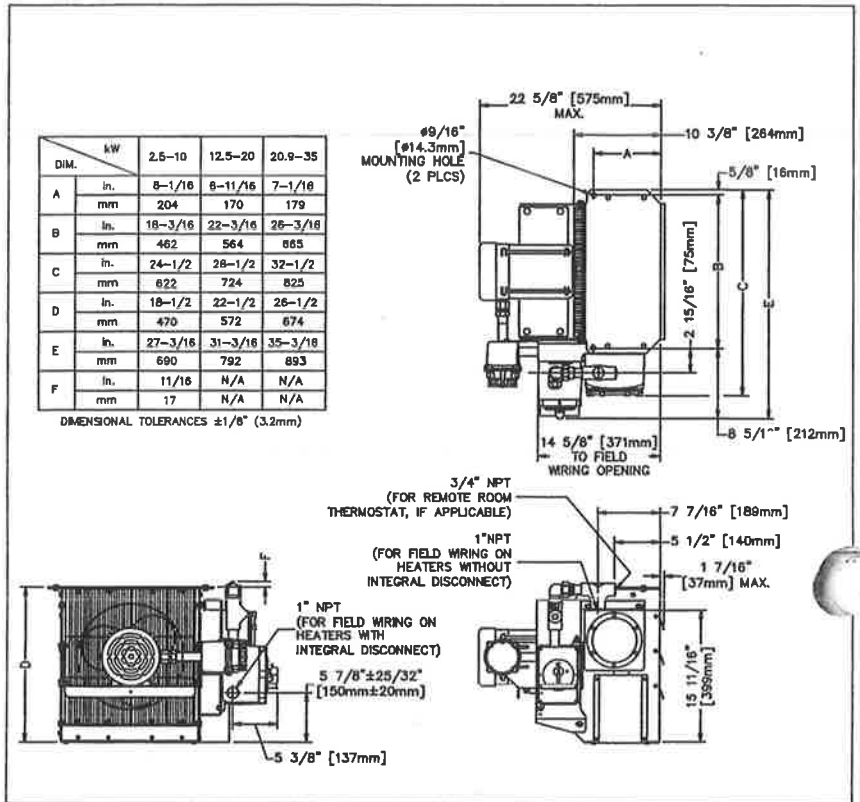


FIGURE 4

## ELECTRICAL

### WARNING

Disconnect heater from power supply at integral disconnect or fuse box before opening enclosures or servicing heater. Lock the switch in the "OFF" (open) position and/or tag the switch to prevent unexpected power application. IF INTEGRAL DISCONNECT IS BEING SERVICED, verify that power has been disconnected at fuse box or main panel. Lock the switch in the "OFF" (open) position and/or tag the switch to prevent unexpected power application. Installation and wiring of the heater must adhere to all applicable codes.

### GENERAL

- Use only copper conductors and approved explosion-proof wiring methods during installation. Refer to the "Technical Data" table and heater data plate for conductor rating.
- External overcurrent protection is required. Refer to the "Technical Data" table and heater data plate for voltage, frequency, amperage, and phase. Supply voltage is to be within 10% of the data plate voltage.

### FIELD WIRING

- The supply conductors, ground conductor, and room thermostat conductors (see point 2, page 4) all pass through the 1" NPT opening (see Figure 5) and are to be wired into the control enclosure (see Figure 6A).

- Heater may be supplied with a factory installed built-in room thermostat (see Figure 7). On heaters not supplied with this option, it is recommended that a remote room thermostat be used. Connect the remote room thermostat conductors to the printed circuit board terminal block marked "TSTAT". Any thermostat used with this heater must:
  - be of an explosion-proof type,
  - be rated 125 V minimum,
  - have a minimum 2 amp capacity, and
  - open on temperature rise.
 Appropriate hazardous location room thermostats are available from the factory.

3. Heater may be supplied with a factory installed built-in integral disconnect. (See Figure 6B)

**Field Wiring for Integral Disconnect:**

- Power Supply conductors and Ground conductor pass through 1" NPT opening of Disconnect Enclosure (see Figure 6B). Supply conductors to be wired to Disconnect Switch inside. Ground conductor to be wired to Ground Lug fastened to inside of Disconnect Enclosure.
- If applicable, Remote Room Thermostat conductors pass through 3/4" NPT opening of Tee fitting (see Figure 6B) and are to be wired to printed circuit board terminals marked "T'STAT".
- To reduce risk of ignition of hazardous atmospheres, conduit runs must have a sealing fitting connected within 18 inches (457 mm). Factory installed conduits require no further sealing. Integral Disconnect is sealed at factory.

**FINAL INSPECTION**

- Before application of electrical power:
  - Check that all connections are secured and comply with the applicable wiring diagram (see Figure 8) and code requirements,
  - Confirm that the power supply is compatible with the data plate rating of the heater,
  - Remove any foreign objects from the heater,
  - Install all covers and verify that all enclosures are well secured, and
  - Ensure that the fan rotates freely. See Figure 5 for proper direction of fan rotation.

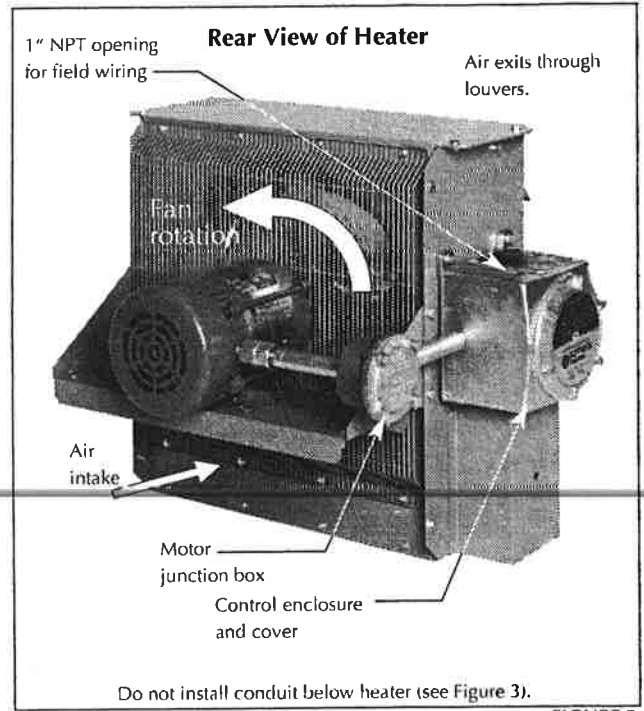


FIGURE 5

**Control Enclosure & Field Wiring**

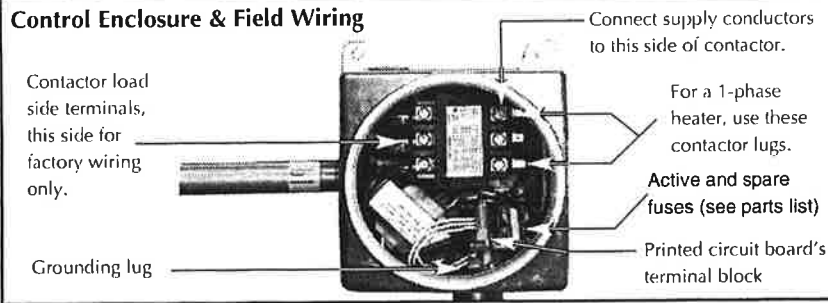


FIGURE 6A

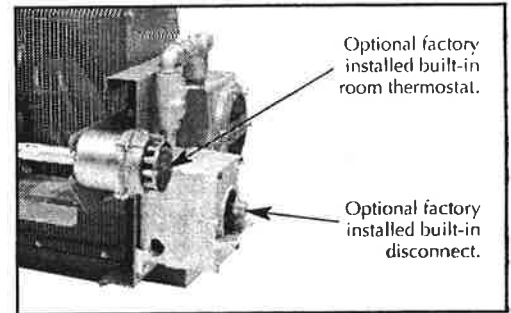


FIGURE 7

**Optional Built-in Disconnect & Field Wiring**

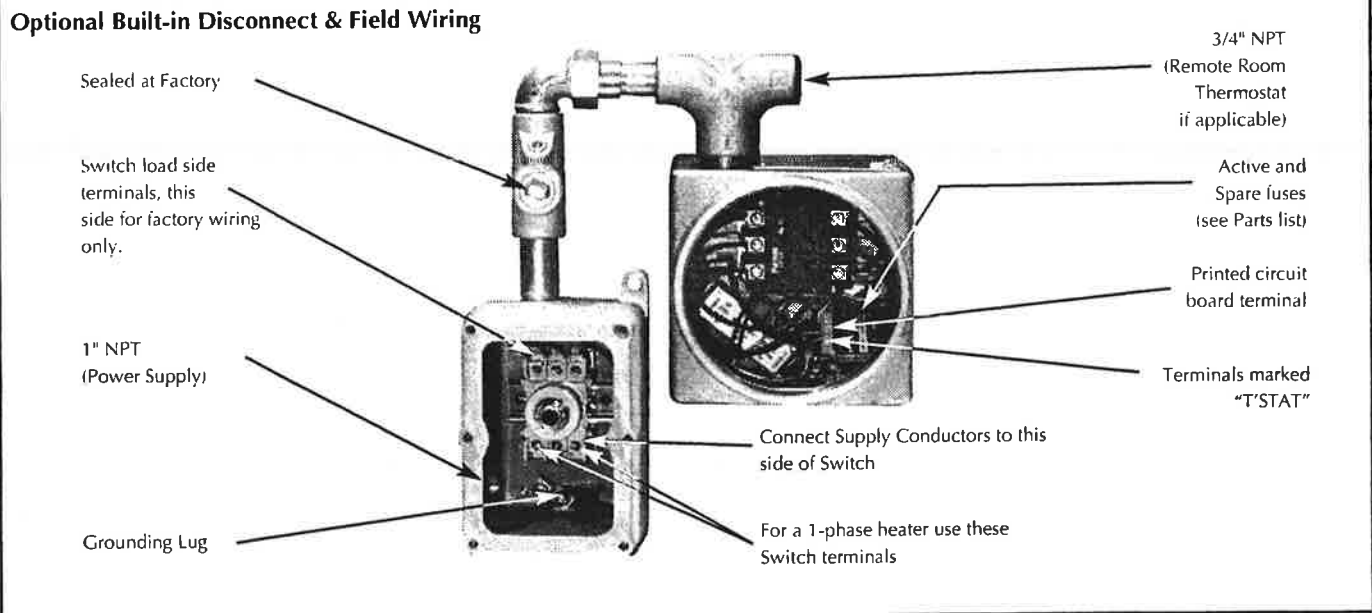


FIGURE 6B

## WIRING DIAGRAMS

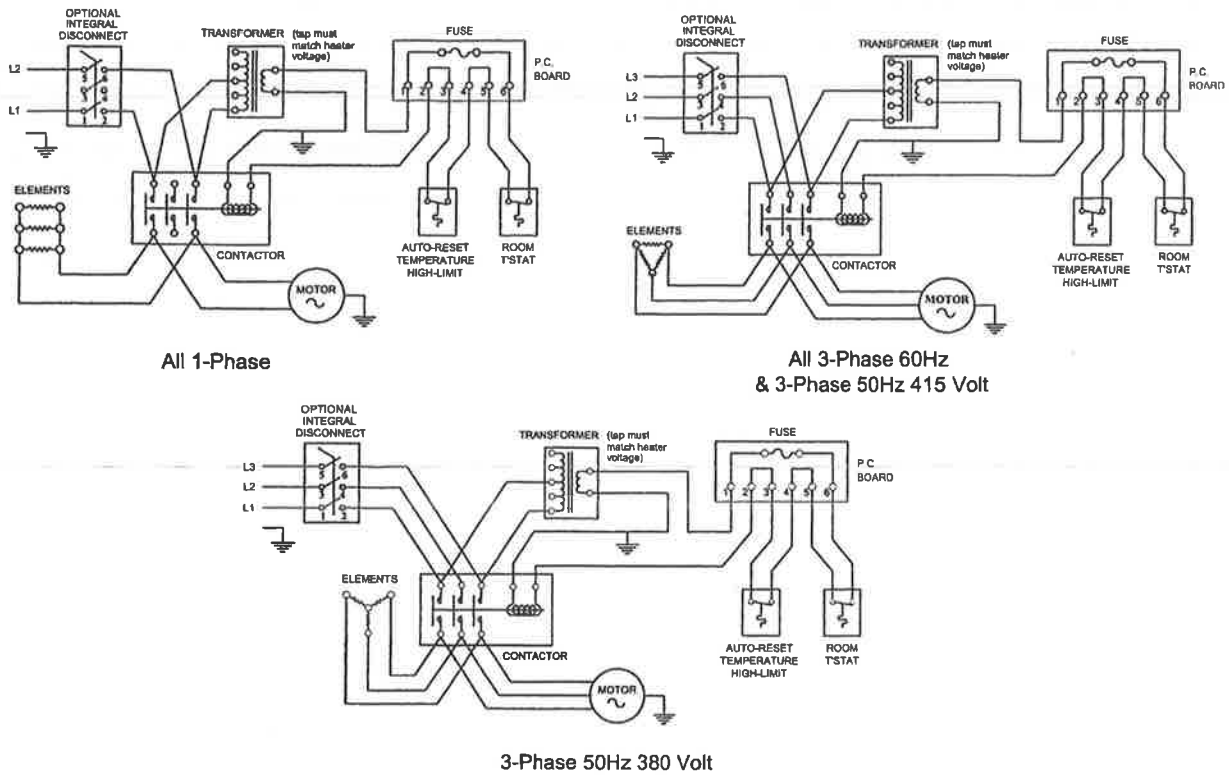


FIGURE 8



## FX4 TECHNICAL DATA FOR 50 HZ ELECTRIC AIR HEATERS

MODEL	NOTE	DS4-16-1 AVAILABLE	VOLTAGE (V)	NOMINAL WATTAGE (kW)	PHASE	MAX. MOTOR NAMEPLATE CURRENT (A)	HEATER WATTAGE (W)	TOTAL CURRENT (A)	MINIMUM CIRCUIT AMPACITY (A)	SUPPLY WIRE SIZE (AWG)	MAXIMUM FUSE SIZE (A)	TEMPERATURE RISE		CORE PART NUMBER	CONTACTOR PART NUMBER
												°F	°C		
FX412-220150-2.5		✓	220	2.5	1	2.0	2,270	11.4	14.3	14	15	19.7	11.0	4045	3618
FX412-220150-4.2		✓	220	4.2	1	2.0	3,950	19.1	23.9	10	25	33.2	18.4	4049	3618
FX412-220150-6.3		✓	220	6.3	1	2.0	6,050	28.6	35.8	8	40	28.4	15.8	4053	3618
FX412-220150-8.4		✓	220	8.4	1	2.0	8,140	38.2	47.8	6	50	37.9	21.1	4057	3619
FX416-220150-12.6			220	12.6	1	2.0	12,100	57.3	71.6	4	80	27.5	15.3	4061	3619
FX412-380350-2.5		✓	380	2.5	3	0.7	2,260	3.8	4.8	14	15	19.7	11.0	4045	3618
FX412-380350-4.2		✓	380	4.2	3	0.7	3,930	6.4	8.0	14	15	33.2	18.4	4049	3618
FX412-380350-6.3		✓	380	6.3	3	0.7	6,020	9.6	12.0	14	15	28.4	15.8	4053	3618
FX412-380350-8.4		✓	380	8.4	3	0.7	8,100	12.8	16.0	12	20	37.9	21.1	4057	3618
FX416-380350-12.5		✓	380	12.5	3	0.7	12,030	19.0	23.8	10	25	27.2	15.1	4061	3618
FX416-380350-16.7		✓	380	16.7	3	0.7	16,220	25.4	31.8	8	35	36.4	20.2	4065	3618
FX420-380350-20.9		✓	380	20.9	3	1.0	20,230	31.8	39.8	8	40	22.0	12.2	4068	3618
FX412-415350-3.7		✓	415	3.7	3	0.7	3,510	5.1	6.4	14	15	29.2	16.2	4050	3618
FX412-415350-7.5		✓	415	7.5	3	0.7	7,240	10.4	13.0	14	15	33.9	18.8	4058	3618
FX416-415350-14.9		✓	415	14.9	3	0.7	14,510	20.7	25.9	10	30	32.5	18.0	4066	3618
FX420-415350-22.4		✓	415	22.4	3	1.0	21,820	31.2	39.0	8	40	23.6	13.1	4071	3618

**NOTES:**

1. Minimum conductor size for 30°C (86°F) ambient. Derate conductor for ambient temperature. Use minimum 90°C (194°F) insulation.
2. Heater is functioning normally if at rated voltage the amp draw is within 10% of the value in this table.
3. Operation at lower voltages will result in reduced heat output and amp draw.





# FX4 TECHNICAL DATA FOR 60 HZ ELECTRIC AIR HEATERS



MODEL	NOTE	DSA-48-L AVAILABLE	VOLTAGE (V)	NOMINAL WATTAGE (kW)	PHASE	MAX. MOTOR NAMEPLATE CURRENT (A)	HEATER WATTAGE (W)	TOTAL CURRENT (A)	MINIMUM CIRCUIT AMPACITY (A)	SUPPLY WIRE SIZE (AWG)	MAXIMUM FUSE SIZE (A)	TEMPERATURE RISE		CORE PART NUMBER	CONTACTOR PART NUMBER
												°F	°C		
FX412-208160-3		✓	208	3	1	2.7	2,700	14.4	18.0	12	20	19.0	10.5	4044	3618
FX412-208360-3		✓	208	3	3	1.4	2,700	8.3	10.4	14	15	19.0	10.5	4044	3618
FX412-240160-3		✓	240	3	1	2.7	2,700	12.5	15.6	12	20	19.0	10.5	4045	3618
FX412-240360-3		✓	240	3	3	1.4	2,700	7.2	9.0	14	15	19.0	10.5	4045	3618
FX412-480160-3	*	✓	480	3	1	1.3	2,700	6.3	7.9	14	15	19.0	10.5	4046	3618
FX412-480360-3		✓	480	3	3	0.7	2,700	3.6	4.5	14	15	19.0	10.5	4046	3618
FX412-600360-3	*	✓	600	3	3	0.6	2,700	2.9	3.6	14	15	19.0	10.5	4047	3618
FX412-208160-5		✓	208	5	1	2.7	4,700	24.0	30.0	10	30	31.6	17.6	4048	3618
FX412-208360-5		✓	208	5	3	1.4	4,700	13.9	17.4	12	20	31.6	17.6	4048	3618
FX412-240160-5		✓	240	5	1	2.7	4,700	20.8	26.0	10	30	31.6	17.6	4049	3618
FX412-240360-5		✓	240	5	3	1.4	4,700	12.0	15.0	14	15	31.6	17.6	4049	3618
FX412-480160-5	*	✓	480	5	1	1.3	4,700	10.4	13.0	14	15	31.6	17.6	4050	3618
FX412-480360-5		✓	480	5	3	0.7	4,700	6.0	7.5	14	15	31.6	17.6	4050	3618
FX412-600360-5	*	✓	600	5	3	0.6	4,700	4.8	6.0	14	15	31.6	17.6	4051	3618
FX412-208160-7.5		✓	208	7.5	1	2.7	7,200	36.1	45.1	6	50	27.9	15.5	4052	3619
FX412-208360-7.5		✓	208	7.5	3	1.4	7,200	20.8	26.0	10	30	27.9	15.5	4052	3618
FX412-240160-7.5		✓	240	7.5	1	2.7	7,200	31.3	39.1	8	40	27.9	15.5	4053	3618
FX412-240360-7.5		✓	240	7.5	3	1.4	7,200	18.0	22.5	10	25	27.9	15.5	4053	3618
FX412-480160-7.5	*	✓	480	7.5	1	1.3	7,200	15.6	19.5	12	20	27.9	15.5	4054	3618
FX412-480360-7.5		✓	480	7.5	3	0.7	7,200	9.0	11.3	14	15	27.9	15.5	4054	3618
FX412-600360-7.5	*	✓	600	7.5	3	0.6	7,200	7.2	9.0	14	15	27.9	15.5	4055	3618
FX412-208160-10	**	✓	208	10	1	2.7	9,690	48.1	60.1	4	70	37.2	20.6	4056	3619
FX412-208360-10		✓	208	10	3	1.4	9,690	27.8	34.8	8	35	37.2	20.6	4056	3618
FX412-240160-10		✓	240	10	1	2.7	9,690	41.7	52.1	6	60	37.2	20.6	4057	3619
FX412-240360-10		✓	240	10	3	1.4	9,690	24.1	30.1	8	35	37.2	20.6	4057	3618
FX412-480160-10	*	✓	480	10	1	1.3	9,690	20.8	26.0	10	30	37.2	20.6	4058	3618
FX412-480360-10		✓	480	10	3	0.7	9,690	12.0	15.0	14	15	37.2	20.6	4058	3618
FX412-600360-10	*	✓	600	10	3	0.6	9,690	9.6	12.0	14	15	37.2	20.6	4059	3618
FX416-208360-15		✓	208	15	3	1.4	14,400	41.6	52.0	6	60	27.1	15.0	4060	3619
FX416-240160-15	**	✓	240	15	1	2.7	14,400	62.5	78.1	4	80	27.1	15.0	4061	3619
FX416-240360-15		✓	240	15	3	1.4	14,400	36.1	45.1	6	50	27.1	15.0	4061	3619
FX416-480160-15	*	✓	480	15	1	1.3	14,400	31.3	39.1	8	40	27.1	15.0	4062	3618
FX416-480360-15		✓	480	15	3	0.7	14,400	18.0	22.5	10	25	27.1	15.0	4062	3618
FX416-600360-15	*	✓	600	15	3	0.6	14,400	14.4	18.0	12	20	27.1	15.0	4063	3618
FX416-208360-20	**	✓	208	20	3	1.4	19,410	55.5	69.4	4	70	36.1	20.1	4064	3619
FX416-240360-20	**	✓	240	20	3	1.4	19,410	48.1	60.1	4	70	36.1	20.1	4065	3619
FX416-480160-20	*	✓	480	20	1	1.3	19,410	41.7	52.1	6	60	36.1	20.1	4066	3619
FX416-480360-20		✓	480	20	3	0.7	19,410	24.1	30.1	8	35	36.1	20.1	4066	3618
FX416-600360-20	*	✓	600	20	3	0.6	19,410	19.2	24.0	10	25	36.1	20.1	4067	3618
FX420-240360-25	**	✓	240	25	3	2.0	24,210	60.1	75.1	4	80	21.9	12.2	4068	3619
FX420-480360-25		✓	480	25	3	1.0	24,210	30.1	37.6	8	40	21.9	12.2	4069	3618
FX420-600360-25	*	✓	600	25	3	0.8	24,210	24.1	30.1	8	35	21.9	12.2	4070	3618
FX420-480360-30		✓	480	30	3	1.0	29,190	36.1	45.1	6	50	26.3	14.6	4071	3619
FX420-600360-30	*	✓	600	30	3	0.8	29,190	28.9	36.1	8	40	26.3	14.6	4072	3618
FX420-480360-35		✓	480	35	3	1.0	34,200	42.1	52.6	6	60	28.0	15.6	4073	3619
FX420-600360-35	*	✓	600	35	3	0.8	34,200	33.7	42.1	8	45	28.0	15.6	4074	3619

- \* - CSA Certified **ONLY**
- - Exceeds the 48 amp circuit limit of NEC 424-22

**NOTES:**

1. Minimum conductor size for 30°C (86°F) ambient. Derate conductor for ambient temperature. Use minimum 90°C (194°F) insulation.
2. Heater is functioning normally if at rated voltage the amp draw is within 10% of the value in this table.
3. Operation at lower voltages will result in reduced heat output and amp draw.

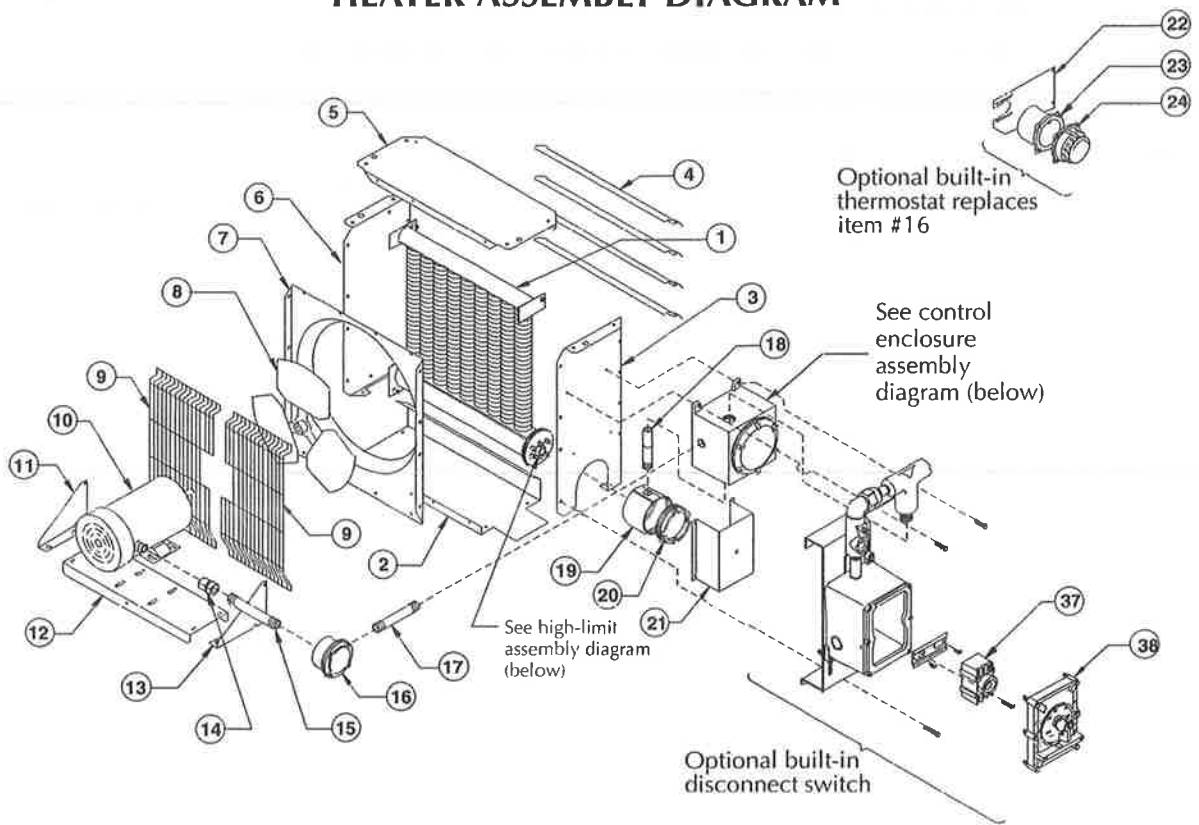
# SPECIFICATIONS FOR ALL 60 HZ MODEL

Nominal kW		3	5	7.5	10	15	20	25	30	35
Max. Altitude	(ft.)	12,000	8,000	10,000	7,000	10,000	7,000	10,000	7,000	6,000
	(m)	3,658	2,438	3,048	2,134	3,048	2,134	3,048	2,134	1,829
Air Flow	@ 70°F (CFM)	500		850		1750		3600		3950
	@ 21°C (m <sup>3</sup> /hr.)	850		1444		2973		6116		6711
Horizontal Air Throw	(ft.)	15		30		40		70		
	(m)	4.6		9.1		12.2		21.3		
Max. Mounting Height (to underside)	(ft.)	7		10		10		20		
	(m)	2.1		3.0		3.0		6.1		
Motor Power	(HP)	1/4				1/4		1/2		
	(kW)	0.187				0.187		0.373		
Fan Diameter	(in.)	12				16		20		
	(mm)	305				406		508		
Net Weight	without (lbs.)	111				133		154		
	DS4-48-L (kg)	50				61		70		
	with (lbs.)	125				147		168		
Shipping Weight	without (lbs.)	151				173		204		
	DS4-48-L (kg)	69				79		93		
	with (lbs.)	165				187		218		
DS4-48-L (kg)	75				85		99			
Enclosures	NEMA Type 7 & 9. For dry, indoor use only. Do not immerse in water. Do not store or use in areas exposed to rain or snow.									
Motor Type	Explosion-proof. Thermally protected. Permanently lubricated ball bearings. 1725 RPM									
Fan	Aluminum blade. Steel spider and hub with 5/8 in. (15.875 mm) bore.									
Fan Guard	Split design with close wire spacing. 1/4 in. (6.3 mm) dia. probe will not enter.									
Mounting Holes	Two 9/16 in. (14.3 mm) diameter holes at top of heater.									
Heating Elements	Three long-life, low watt-density, high grade metal-sheathed elements.									
Temperature High-Limit	Automatic reset type, snap-action bimetal, open on temperature rise. Rated 100,000 cycles at 10 amps, handles 0.128 amps.									
Control Circuit	120 Volts, 0.128 amps, 15VA. (Grounded)									
Optional Built-in Thermostat	Explosion-proof. 36°F to 82°F (2°C to 28°C)									
Control Transformer	Multi-tap primary, 120 V secondary, 25 VA.									
Contactors	40 or 75 amp. Rated for 500,000 mechanical operations. 120 Volts, 15VA coil (separately fuse-protected).									
Heat Transfer Fluid	Long life formulated ethylene glycol and water, freeze protected to -49°F (-45°C).									
Cabinet Material	14 ga. (0.075 in.) (1.90 mm) steel. Epoxy coated with five-stage pretreatment, including iron phosphate.									
Core	Steel with integral aluminum fins, vacuum charged and hermetically sealed.									
Conduit Material	Heavy walled, 0.122 in. (3.1 mm) steel, cadmium plated.									
Overpressure Protection	Preset 100 psig (690 kPa) seep pressure relief valve, aluminum body, no field serviceable parts.									
Temperature Code Rating	T3B 165°C (329°F) Class I & II.									
Temperature Limitations	-49°F to 104°F (-45°C to 40°C).									
Storage Limitations	-49°F to 176°F (-45°C to 80°C), short term to 248°F (120°C). Do not store or use areas exposed to rain or snow. Do not immerse in water.									
Optional Integral Disconnect	DS4-48-L for use only on heaters with total current not exceeding 48-Amps. Lockout bar accepts 1/4" to 7/16" diameter padlock shackle.									

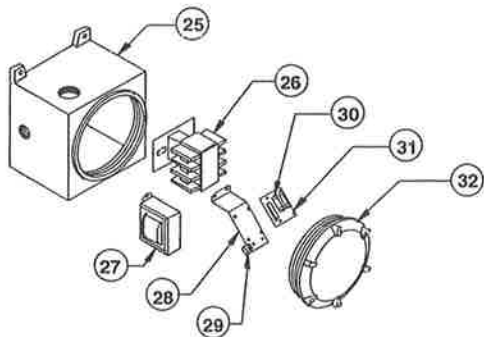
## SPECIFICATIONS FOR ALL 50 HZ MODEL

Nominal kW		2.5	3.7&4.2	6.3&7.5	8.4	12.5&12.6	14.9&16.7	20.9	22.4
Max. Altitude	(ft.)	12,000	8,000	10,000	7,000	10,000	7,000	10,000	7,000
	(m)	3,658	2,438	3,048	2,134	3,048	2,134	3,048	2,134
Air Flow	@ 70°F (CFM)	400		700		1450		3000	
	@ 21°C (m <sup>3</sup> /hr.)	679		1189		2463		5096	
Horizontal Air Throw	(ft.)	13		25		35		60	
	(m)	4.0		7.6		10.7		18.2	
Max. Mounting Height (to underside)	(ft.)	7		10		10		20	
	(m)	2.1		3.0		3.0		6.1	
Motor Power	(HP)	1/4				1/4		1/2	
	(kW)	0.107				0.187		0.373	
Fan Diameter	(in.)	12				16		20	
	(mm)	305				406		508	
Net Weight	without (lbs.)	111				133		154	
	DS4-48-L (kg)	50				61		70	
	with (lbs.)	125				147		168	
Shipping Weight	DS4-48-L (kg)	57				67		76	
	without (lbs.)	151				173		204	
	DS4-48-L (kg)	69				79		93	
Shipping Weight	with (lbs.)	165				187		218	
	DS4-48-L (kg)	75				85		99	
Enclosures	NEMA Type 7 & 9. For dry, indoor use only. Do not immerse in water. Do not store or use in areas exposed to rain or snow.								
Motor Type	Explosion-proof. Thermally protected. Permanently lubricated ball bearings. 1425 RPM								
Fan	Aluminum blade. Steel spider and hub with 5/8 in. (15.875 mm) bore.								
Fan Guard	Split design with close wire spacing. 1/4 in. (6.3 mm) dia. probe will not enter.								
Mounting Holes	Two 9/16 in. (14.3 mm) diameter holes at top of heater.								
Heating Elements	Three long-life, low watt-density, high grade metal-sheathed elements.								
Temperature High-Limit	Automatic reset type, snap-action bimetal, open on temperature rise. Rated 100,000 cycles at 10 amps, handles 0.130 amps.								
Control Circuit	115 Volts, 0.130 amps, 15VA. (Grounded)								
Optional Built-in Thermostat	Explosion-proof. 36°F to 82°F (2°C to 28°C)								
Control Transformer	Multi-tap primary, 115 V secondary, 25 VA.								
Contactors	40 or 75 amp. Rated for 500,000 mechanical operations. 120 Volts, 15VA coil (separately fuse-protected).								
Heat Transfer Fluid	Long life formulated ethylene glycol and water, freeze protected to -49°F (-45°C).								
Cabinet Material	14 ga. (0.075 in.) (1.90 mm) steel. Epoxy coated with five-stage pretreatment, including iron phosphate.								
Core	Steel with integral aluminum fins, vacuum charged and hermetically sealed.								
Conduit Material	Heavy walled, 0.122 in. (3.1 mm) steel, cadmium plated.								
Overpressure Protection	Preset 100 psig (690 kPa) seep pressure relief valve, aluminum body, no field serviceable parts.								
Temperature Code Rating	T3B 165°C (329°F) Class I & II.								
Temperature Limitations	-49°F to 104°F (-45°C to 40°C).								
Storage Limitations	-49°F to 176°F (-45°C to 80°C), short term to 248°F (120°C). Do not store or use areas exposed to rain or snow. Do not immerse in water.								
Optional Integral Disconnect	DS4-48-L for use only on heaters with total current not exceeding 48-Amps. Lockout bar accepts 1/4" to 7/16" diameter padlock shackle.								

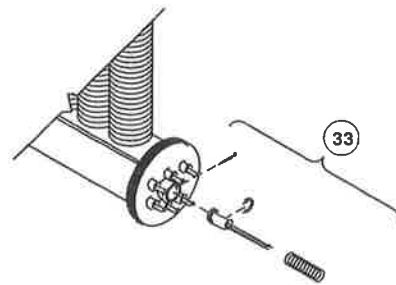
# HEATER ASSEMBLY DIAGRAM



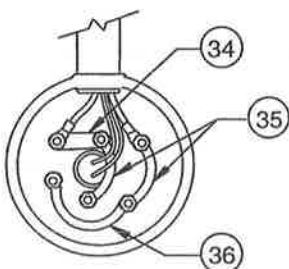
**CONTROL ENCLOSURE ASSEMBLY DIAGRAM**



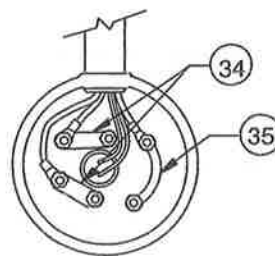
**HIGH LIMIT ASSEMBLY DIAGRAM**



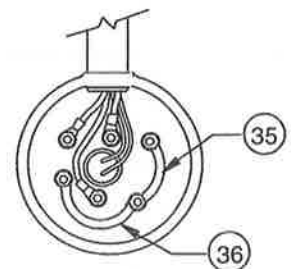
**BUS-BAR CONFIGURATION ALL 1-PHASE MODELS**



**BUS-BAR CONFIGURATION ALL 3-PHASE MODELS (EXCEPT 380 VOLT 50 HERTZ)**



**BUS-BAR CONFIGURATION 3-PHASE 380 VOLT 50 HERTZ MODELS ONLY**



# PARTS LIST

## FORCED AIR ELECTRIC HEATERS

PART NUMBERS				Please have model and serial number available before calling.
ITEM	2.5 - 10 kW	12.5 - 20 kW	20.9 - 35 kW	DESCRIPTION
1	**	**	**	Core
2	3773	3774	3775	Panel, Bottom
3	3776	3777	3778	Panel, Left Side
4	4075	4076	4077	Louver Kit, c/w Screws
5	3770	3771	3772	Panel, Top
6	3779	3780	3781	Panel, Right Side
7	3782	3783	3784	Fan Shroud
8	2.5 - 5 kW: 4022 6.3 - 10 kW: 4023	12.5 - 20 kW: 4024	20.9-30 kW: 4025 35 kW: 4026	Fan
9	4078	4079	4080	Fan Guard Kit
10	208/240V 60 HZ 1 PH: 1377 220V 50 HZ 1 PH: 1377 480V 60 HZ 1 PH: 2396 208/240/480V 60HZ 3PH: 1862 380/415V 50 HZ 3 PH: 1862 600V 60HZ 3 PH: 1861	1377 1377 2396 1862 1862 1861	240/480V 60 HZ 3 PH: 1699 380/415V 50 HZ 3 PH: 1699 600V 60 HZ 3 PH: 2433	Motor, Explosion-Proof
11	3789	3789	3789	Bracket, Motor Mount Right
12	3785	3786	3787	Channel, Motor Mount
13	3788	3788	3788	Bracket, Motor Mount Left
14	3737	3737	3737	Coupling, Motor
15	3811	3812	3813	Conduit, Motor
16	3838	3838	3838	Enclosure, Conduit Junction
17	208/240V 60 HZ 1PH: 3815 220V 50 HZ 1PH: 3815 480V 60 HZ 1PH: 3813 ALL 3PH: 3814	3815 3815 3813 3814	3813	Conduit, Control Enclosure
18	3810	3810	3810	Conduit, Element Enclosure
19	3793	3793	3793	Enclosure, Element
20	3510	3510	3510	Cover, Element Enclosure
21	3790	3790	3790	Panel, Element Enclosure Guard
22	3791	3791	3791	Bracket, Thermostat
23	4983	4983	4983	Enclosure, Thermostat
24	5032	5032	5032	Thermostat, Built-in Kit
25	3524	3525	3526	Enclosure, Control
26	**	**	**	Contactor
27	60 HERTZ: 3612	50 HERTZ: 4416		Transformer
28	3809	3809	3809	Bracket, Printed Circuit Board
29	1876	1876	1876	Terminal, 6-14 ga. Screw Lug
30	3519	3519	3519	Fuse, Buss MDQ-1/4 Amp
31	3514	3514	3514	Printed Circuit Board Assembly
32	3516	3516	3516	Cover, Control Enclosure
33	4082	4082	4082	Temperature High-Limit Kit
34	3816	3816	3816	Bus-Bar, Straight
35	3817	3817	3817	Bus-Bar, Small Curved
36	3818	3818	3818	Bus-Bar, Large Curved
37	6471	6471	6471	Switch, rotary
38	6709	6709	6709	Kit, DS4 cover

\*\* See technical data table for part numbers. NOTE: For items not shown, contact factory



# REPAIR & REPLACEMENT

## WARNING

Disconnect heater from power supply at integral disconnect or fuse box before opening enclosures or servicing heater. Lock the switch in the "OFF" (open) position and/or tag the switch to prevent unexpected power application. IF INTEGRAL DISCONNECT IS BEING SERVICED, verify that power has been disconnected at fuse box or main panel. Lock the switch in the "OFF" (open) position and/or tag the switch to prevent unexpected power application. Heater surfaces may be hot.

- After repairing any component:
  - check that electrical connections are correct and secure (see Figure 8),
  - remove any foreign material from enclosures,
  - install and secure all covers,
  - ensure that all fasteners are tight,
  - remove all foreign objects from heater, and
  - ensure air exits through louvers and fan rotates counterclockwise when viewed from rear of heater (see Figure 13).

## CORE

The heater core is vacuum charged and not field repairable. For core removal:

- Remove cabinet bottom and element enclosure cover.
- Disconnect all wires entering element enclosure (see Figure 9).
- Slightly loosen all cabinet bolts shown in Figure 9, to prevent the core from binding.
- With an assistant supporting the weight of the core, remove the 3 core mounting bolts. Carefully lower the core out of the cabinet (see Figure 10).
- To return core to factory, use crate supplied with exchange core to protect the element terminals and plate threads.
- To reinstall, lift the core up into cabinet while an assistant guides the element wires into the element enclosure conduit.
- Position the core and tighten the 3 core mounting bolts. Tighten the remaining cabinet bolts.

## TEMPERATURE HIGH-LIMIT

- Remove temperature high-limit assembly and clean the inside of the thermowell (see Figure 11). A clean thermowell will ensure good thermal contact.
- Use only a factory supplied temperature high-limit to ensure safe operation.
- Apply a small drop, 3/32" (2mm) diameter, of heat sink compound to the center of the metal cap but do not spread. This is critical for proper thermal contact between the temperature high-limit and the thermowell (see Figure 11).
- Reinstall the temperature high-limit assembly with the snap ring and spring into the thermowell without damaging the insulating tube. Secure in place with the cotter pin (see Figure 12).

## MOTOR, FAN & FAN GUARD

- Remove bolts holding the motor to the motor mount. On units with a built in thermostat, remove the bolts on the back of the thermostat enclosure.
- Remove conduit #1 located between motor junction box and control enclosure by turning it in the direction illustrated (see Figure 13). Note conduits #1 and #2 are not interchangeable and have left hand threads on one end, this end is indicated by a machined groove.
- Remove the 2 piece fan guard assembly (see Figure 14).
- Lift the motor assembly off the motor mount.
- Before removing the fan, measure and record the location of the fan hub on the motor shaft (see Figure 15). If difficult to remove, use a gear puller on the fan hub.
- To reassemble, place motor assembly onto motor mount and fasten the fan guard to cabinet.
- Simultaneously engage and tighten both ends of conduit #1 into enclosures. Leave a 1/16" to 3/16" (1.6 to 4.8 mm) gap between the motor and fan guard (see Figure 16). Adjust conduit #2 to center the fan in the shroud.
- To ensure a minimum 5 thread engagement, threaded ends of conduits must protrude a minimum of 1/16" (1.6mm) into enclosures. The groove on conduit #2 must not be more than 7/8" (22mm) from motor coupling (see Figure 13).
- Bolt motor to motor mount. Manually spin the fan blade to ensure fan rotates freely.
- Air must exit through louvers and fan must rotate counterclockwise when viewed from rear of heater (see Figure 13).

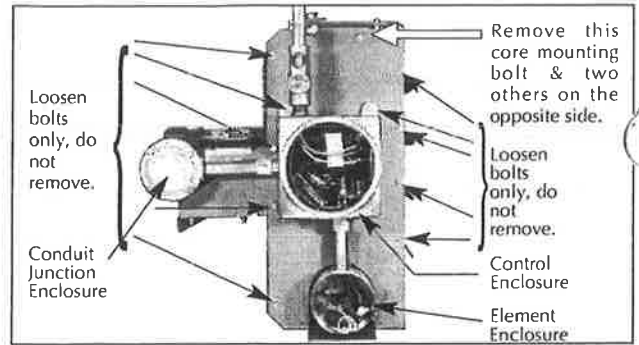


FIGURE 9

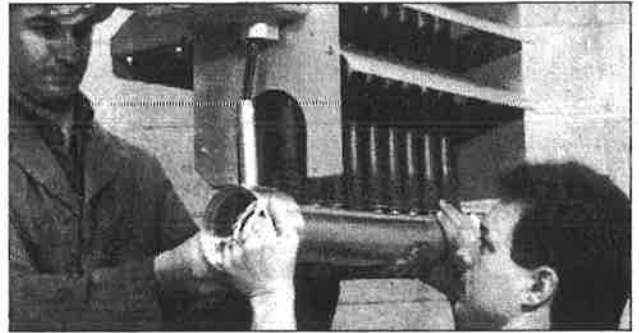


FIGURE 10

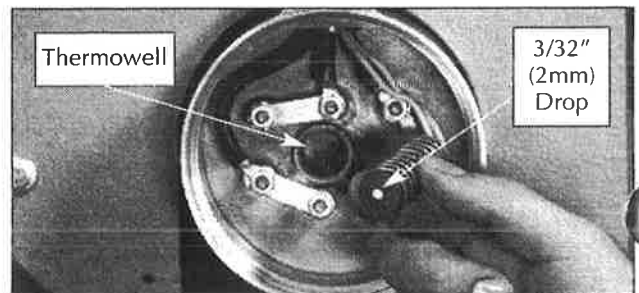


FIGURE 11

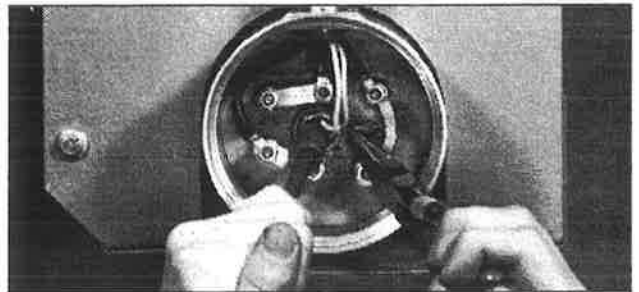


FIGURE 12

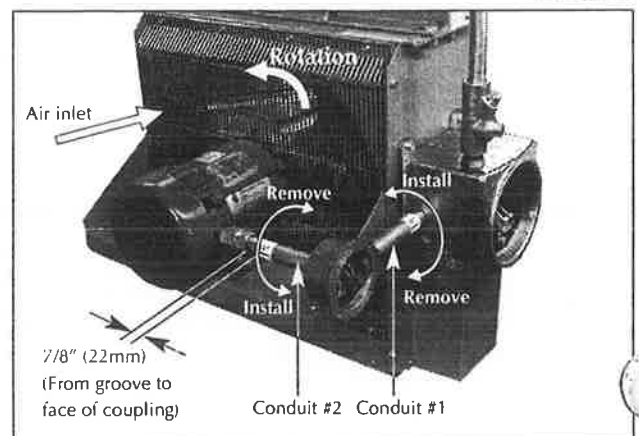


FIGURE 13

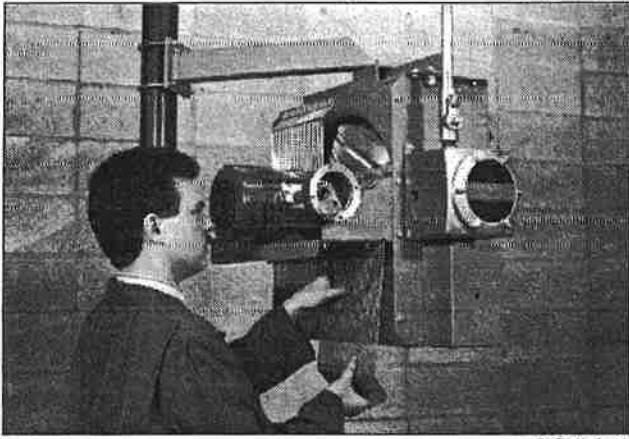


FIGURE 14

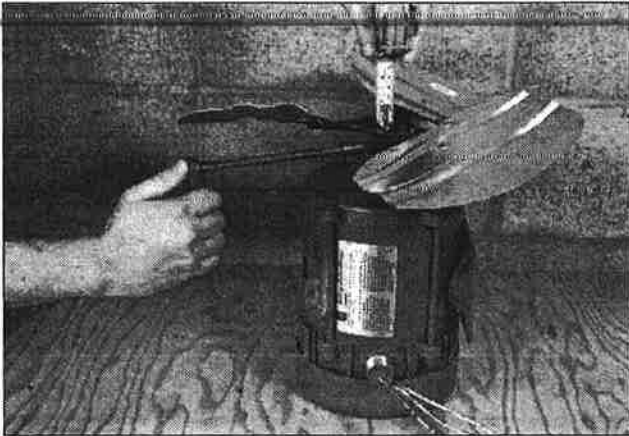


FIGURE 15

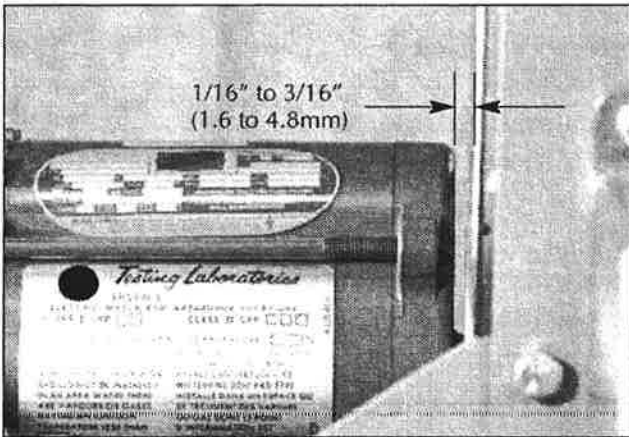


FIGURE 16

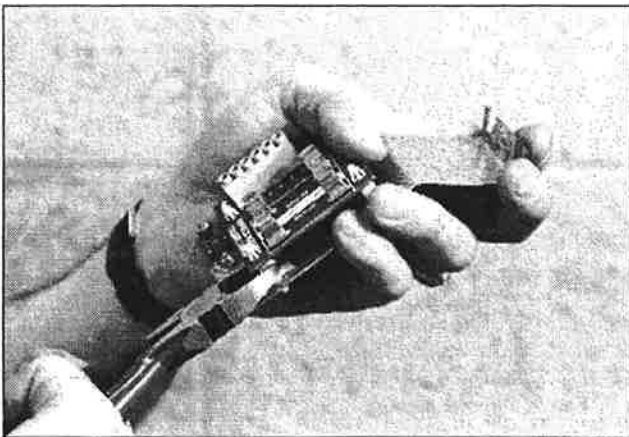


FIGURE 17

## PRINTED CIRCUIT BOARD

1. After removing the printed circuit board (P.C. Board) bracket assembly from the control enclosure, separate the P.C. Board from the bracket by cutting off the plastic spacers (see Figure 17).
2. Reinstall a new factory supplied P.C. Board onto the mounting bracket using new non-conducting spacers of the same length. Spacers are supplied with a new P.C. Board. Reinstall the control circuit ground wire to the printed circuit board bracket (see Figure 8).

## CONTACTOR

1. Loosen, but do not remove contactor mounting screws. Slide contactor off mounting screws.
2. Replace with a factory supplied contactor of the same rating.

## TRANSFORMER

1. Replace with a factory supplied transformer of the same rating.
2. On the new transformer, select primary wires to match heater voltage. **Ensure that the correct transformer secondary lead is grounded (see Figure 8).** Individually terminate all unused wires using closed end connectors.

## FUSE

Replace fuse with one of the same type and rating as indicated on P.C. Board or refer to parts list. An extra fuse should be stored in the clips marked "SPARE".

## HEATING ELEMENTS

Heating elements are an integral part of the vacuum charged core. A factory exchange core can be shipped immediately from stock. Refer to "Core" section for details.

## CABINET PANELS

Bolt-on cabinet panels are individually replaceable.

## INTEGRAL DISCONNECT ROTARY SWITCH

1. Disconnect power supply at main panel before opening enclosure. Lock and tag main panel switch in the "OFF" position to prevent unexpected power application.
2. Center factory supplied replacement switch along DIN rail and secure left edge of switch using pre-existing screw and lock-washer (see Figure 18).
3. Re-establish electrical-power to heater. Confirm airflow enters core through fan-guard and exits through louvers.

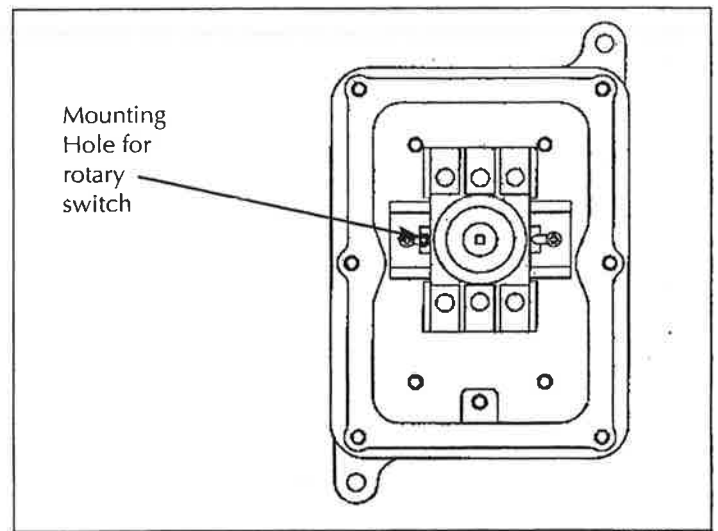


FIGURE 18



2827 Sunridge Blvd. N.E.  
Calgary, Alberta T1Y 6G1  
Canada

Phone: (403) 291-5488  
Fax: (403) 291-7042  
www.ruffneck.com  
service@ruffneck.com



**PLEASE ADHERE TO INSTRUCTIONS PUBLISHED IN THIS MANUAL.**  
Failure to do so may be dangerous and may void certain provisions of your warranty.  
For further assistance, please call:

**24 Hr. Hotline: 1-800-661-8561**  
(U.S.A. and Canada)

Please have model and serial numbers available before calling.



## LIMITED 3 YEAR WARRANTY

All Electric Forced Air Heaters for Hazardous Locations are warranted against defects in materials and workmanship for a period of three (3) years from date of purchase on the following terms:

1. We will provide replacement parts free of charge as necessary to restore any unit to operating condition, provided that the inoperative parts be returned to us freight prepaid and that the replacement parts be accepted freight collect.
2. The complete heater may be returned to our plant for repair or replacement (at our discretion), provided that all related freight costs be borne by the customer.
3. Corrosion and contamination by dirt, dust, etc. will not be considered as defects and, therefore, are not warrantable.
4. The heater must not be modified in any way.
5. The heater must be installed, used and stored only in accordance with the owner's manual and placarded information.

This warranty shall be limited to the actual equipment involved and, under no circumstances, shall include or extend to installation or removal costs, or to consequential losses or damages.





2827 Sunridge Blvd. N.E.  
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Fax: (403) 291-7042  
service@ruffneck.com  
www.ruffneck.com



## S'IL VOUS PLAÎT S'ACCROCHER À LA MODE D'EMPLOI PUBLIER DANS CETTE MANUAL.

Dans le cas contraire, cela peut être dangereux et risque d'annuler certaines clauses de la garantie.  
Pour assistance supplémentaire s'il vous plaît appeler:

ligne sans frais: **1-800-661-8561**  
(É.U. et Canada)

Lorsque vous appelez, veuillez avoir à portée de la main les numéros de modèle et de série.



## GARANTIE LIMITÉE DE 3 ANS

Tout les aérothermes électriques d'air forcer pour endroits dangereux être garantit contre les défauts matériels et de fabrication pour une période de trois (3) ans à compter de la date d'achat, comme suit:

1. Nous fournirons les pièces de remplacement sans frais, si nécessaire, afin de remettre tout appareil en état de fonctionnement normal à condition que les pièces défectueuses nous soient retournées fret payé d'avance et que les pièces de remplacement soient acceptées port dû.
2. L'aérotherme complet peut être retourné à notre usine en vue d'être réparé ou remplacé, à notre choix, à condition que tous les frais d'expédition reliés soient assumés par le client.
3. La corrosion et la contamination dues à la saleté, à la poussière, etc. ne seront pas considérées comme des défauts et, par conséquent, ne sont pas couverts par la présente garantie.
4. L'aérotherme ne doit être modifié d'aucune façon.
5. L'aérotherme doit être installé et utilisé uniquement selon l'information affichée ou indiquée dans le guide d'utilisation.

La présente garantie se limite à l'équipement courant concerné et, en aucun cas, ne s'étend ou n'inclut les coûts d'installation ou de retrait, ou tous dommages ou pertes encourus.

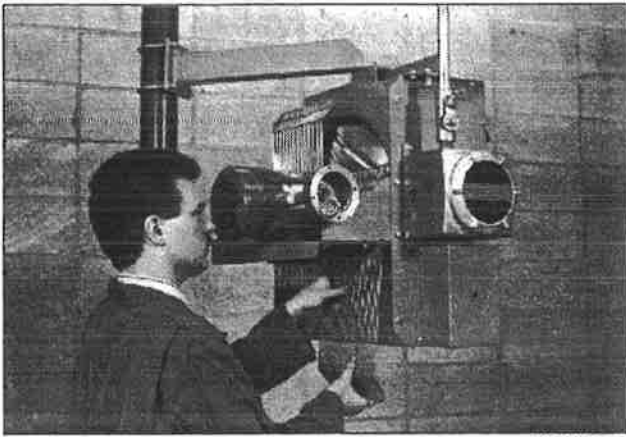


FIGURE 14

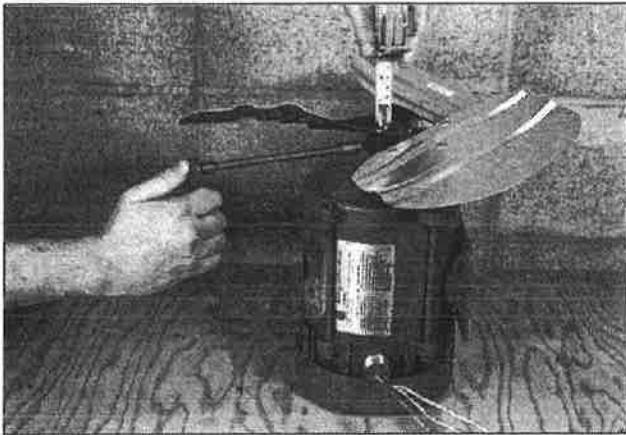


FIGURE 15

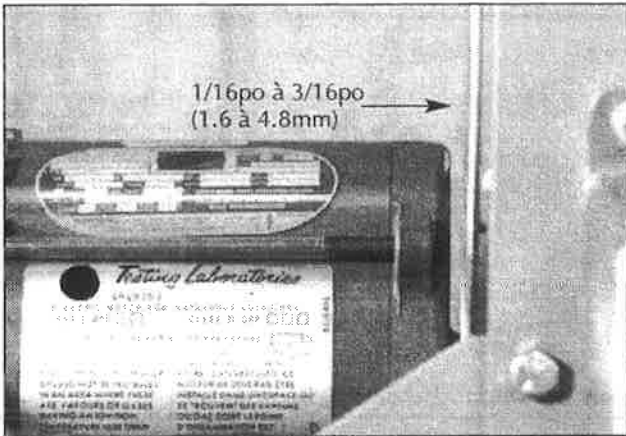


FIGURE 16

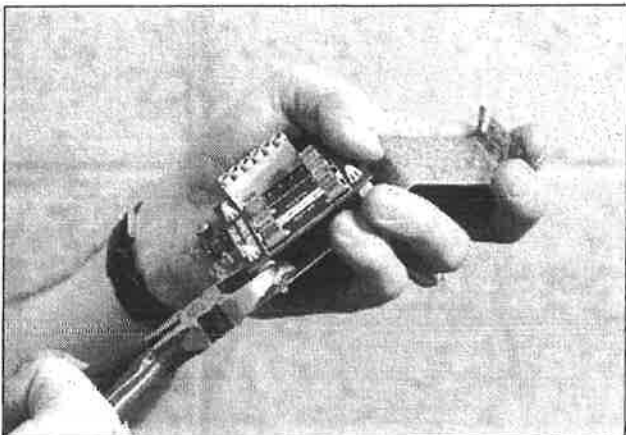


FIGURE 17

8. Afin d'avoir au moins 5 tours de vissés, les extrémités vissées des conduits doivent dépasser d'au moins 1/16 po (1,6 mm) dans les boîtiers. La rainure du conduit no. 2 ne doit pas dépasser de plus de 7/8 po (22 mm) du raccord du moteur (voir figure 13).
9. Boulonner le moteur au support moteur. Faire tourner à la main les pales du ventilateur afin de s'assurer qu'elles tournent librement.
10. L'air doit sortir par les persiennes et les pales du ventilateur doivent tourner dans le sens contraire des aiguilles d'une montre lorsqu'on regarde par l'arrière de l'aérotherme (voir figure 13).

### CARTE À CIRCUITS IMPRIMÉ

1. Après avoir retiré l'ensemble support de la carte à circuits imprimés du boîtier de commande, dégager la carte à circuits imprimés du support en coupant les entretoises de plastique (voir figure 17).
2. Remettre un nouveau du fournisseur usine carte à circuits imprimés en place sur le support de montage à l'aide de nouvelles entretoises non conductrices de la même longueur. Les entretoises sont fournies avec une nouvelle carte à circuit imprimés. Remettre en place le fil de mise à la masse du circuit de commande sur le support de la carte à circuits imprimés (voir figure 8).

### CONTACTEUR

1. Desserrer, mais ne pas enlever, les vis de fixation du contacteur. Glisser le contacteur des vis de fixation.
2. Remplacer par un contacteur fourni en usine ayant la même valeur.

### TRANSFORMATEUR

1. Remplacer par un transformateur de la même valeur fourni en usine.
2. Sur le nouveau transformateur, repérer les fils primaires de manière qu'ils correspondent à la tension de l'aérotherme. S'assurer que le bon conducteur secondaire du transformateur soit mis à la masse (voir figure 8) Faire des terminaisons pour chacun des fils inutilisés à l'aide de connecteurs à bout fermé.

### FUSIBLE

Remplacer le fusible par un autre du même type et de la même valeur, tel qu'indiqué sur la carte à circuits imprimés, ou consulter la liste des pièces. Un fusible de rechange devrait être mis dans le porte-fusible identifié "SPARE".

### ÉLÉMENTS CHAUFFANTS

Les éléments chauffants font partie intégrale du faisceau chargé à vide. Un faisceau de rechange fourni en usine peut être livré immédiatement à partir des stocks. Consulter la section "Faisceau" pour avoir plus de détails.

### PANNEAUX DE L'ARMOIRE

On peut remplacer chacun des panneaux d'armoire à boulonner.

### DÉBRANCHER INTÉGRÉ ROTATIF

1. Débrancher la source d'alimentation à le control principal avant a'ouvrir le boîtier. Fermer le bouton en position "OFF" et mettre une étiquette afin d'éviter que l'appareil ne soit mis en marche par inadvertance.
2. Centre le débrancher d'usine le long de DIN et bien fermer le bond gauche utiliser les vis et se bloquer préexister. (Voir Figure 18)
3. Rengrèner la source d'alimentation. Verifé d'nir entrer dans le faisceau et traverse dans la grille de protection et sorties pars les tuyeres.

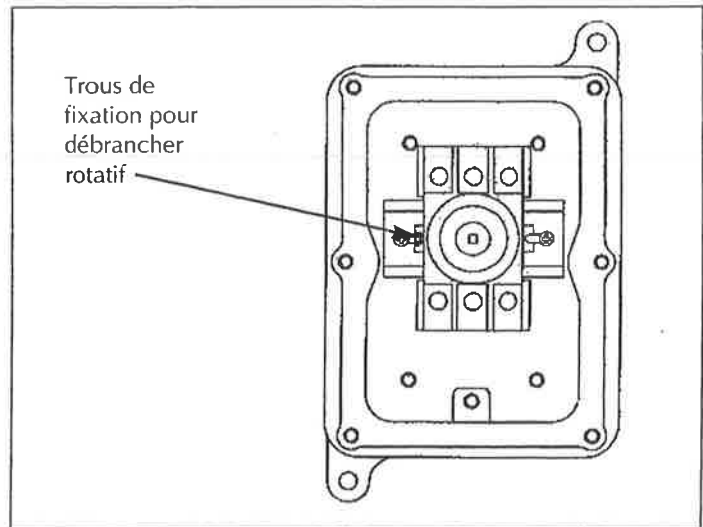


FIGURE 18

# RÉPARATION ET REMPLACEMENT

## AVERTISSEMENT

Débrancher la source d'alimentation de l'aérotherme avant d'ouvrir les boîtiers ou d'en faire la maintenance. Bloquer le commutateur en position "OFF" (circuit ouvert) et/ou y mettre une étiquette afin d'éviter que l'appareil ne soit mis en marche par inadvertance. Si la débranche intégré être entretien, vérifiez le courant être débrancher à la source d'alimentation. Bloquer le commutateur en position "OFF" (circuit ouvert) et/ou y mettre une étiquette afin d'éviter que l'appareil ne soit mis en marche par inadvertance. L'aérotherme peut être chaud.

1. Après avoir réparé un composant:
  - a. Vérifier si les connexions électrique sont bien faites et serrées (voir figure 8);
  - b. retirer tout corps étranger à l'intérieur des boîtiers;
  - c. installer et bien fixer en place tous les couvercles;
  - d. s'assurer que toutes les attaches soient bien serrées;
  - e. retirer tous les corps étrangers à l'intérieur de l'aérotherme; et
  - f. s'assurer que l'air sorte par les persiennes et que les pales du ventilateur tournent dans le sens contraire des aiguilles d'une montre lorsqu'on regarde à l'arrière de l'aérotherme (voir figure 13).

## FAISCEAU

Le faisceau de l'aérotherme est chargé à vide et ne peut être réparé sur place. Pour retirer le faisceau:

1. Enlever le bas de l'unité et le couvercle du boîtier.
2. Débrancher tout les fils qui pénètrent dans le boîtier des éléments (voir figure 9).
3. Desserrer légèrement tous les boulons de l'unité, tel qu'illustré à la figure 9, afin d'éviter que le faisceau plie.
4. Avec l'aide d'une autre personne qui soutient le faisceau, enlever les trois boulons de fixation du faisceau. Retirer délicatement le faisceau de l'enceinte par le bas (voir figure 10).
5. Retourner le faisceau à l'usine en utilisant la boîte fournie avec le faisceau de rechange afin de protéger les bornes des éléments et les fils de la plaque.
6. Pour remettre en place, soulever le faisceau jusque dans l'unité pendant qu'une autre personne fait passer les fils dans les trous du boîtier destinés à cet usage.
7. Place le faisceau et serrer les trois boulons de fixation. Serrer les autres boulons de l'unité.

## LIMITEUR DE TEMPÉRATURE À MAXIMUM

1. Retirer l'ensemble limiteur de température à maximum et nettoyer l'intérieur de la sonde thermométrique (voir figure 11) afin d'assurer un bon contact thermique.
2. N'utiliser qu'un limiteur de température à maximum fourni en usine afin d'assurer un fonctionnement sûr.
3. Mettre une petite goutte de 3/32 po (2 mm) de diamètre de graisse thermoconductrice au centre du capuchon de métal, mais sans l'étendre. Cela est important afin d'assurer un bon contact thermique entre le limiteur de température à maximum et la sonde thermométrique (voir figure 11).
4. Remettre en place l'ensemble limiteur de température à maximum, en mettant le circlip et le ressort dans la sonde thermométrique sans endommager le tube isolant. Fixer en place à l'aide de la goupille fendue (voir figure 12).

## MOTEUR, VENTILATEUR ET GRILLE DE PROTECTION

1. Enlever les boulons qui fixent la moteur au support du moteur. Pour les modèles avec thermostat intégré, enlever les boulons à l'arrière du boîtier du thermostat.
2. Enlever le conduit n° 1 situé entre la boîte de jonction du moteur et le boîtier de commande en tournant dans le sens indiqué indiqué à la figure 13. Prendre note que les conduits no. 1 et no.2 ne sont pas interchangeables et ont un filetage à gauche à une extrémité, cette dernière étant indiquée par une rainure usinée.
3. Enlever les deux parties de l'ensemble grille de protection (voir figure 14).
4. Soulever l'ensemble moteur du support moteur.
5. Avant d'enlever le ventilateur, mesurer et prendre note de l'emplacement du moyeu du ventilateur sur l'arbre moteur (voir figure 15). S'il est difficile à enlever, utiliser un arrache-pignons sur le moyeu du ventilateur.
6. Pour remettre en place, mettre l'ensemble moteur sur le support moteur et fixer la grille de protection au boîtier.
7. En même temps, insérer et serrer chaque extrémité du conduit no. 1 dans les boîtiers. Laisser un espace de 1/16 po à 3/16 po (1,6mm à 4,8 mm) entre le moteur et la grille de protection (voir figure 16). Ajuster le conduit no. 2 de manière à centrer le ventilateur dans la tuyère.

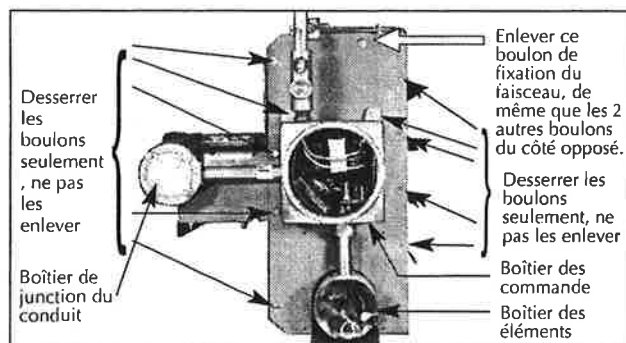


FIGURE 9

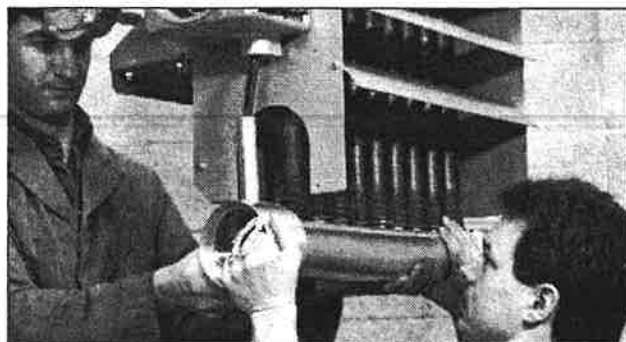


FIGURE 10

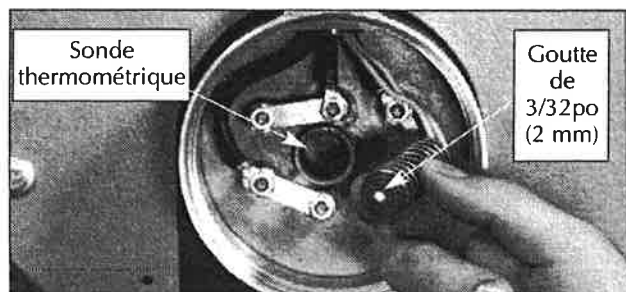


FIGURE 11



FIGURE 12

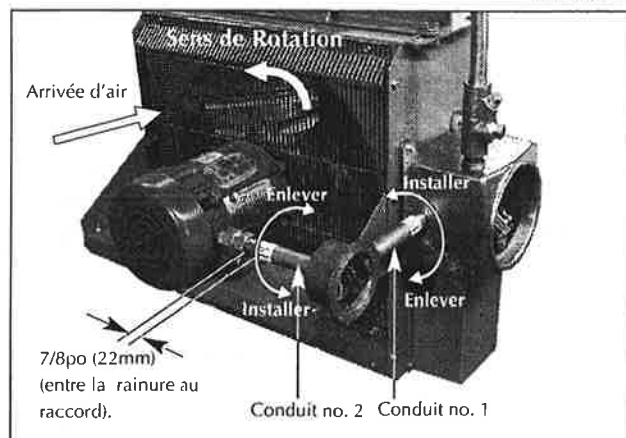


FIGURE 13

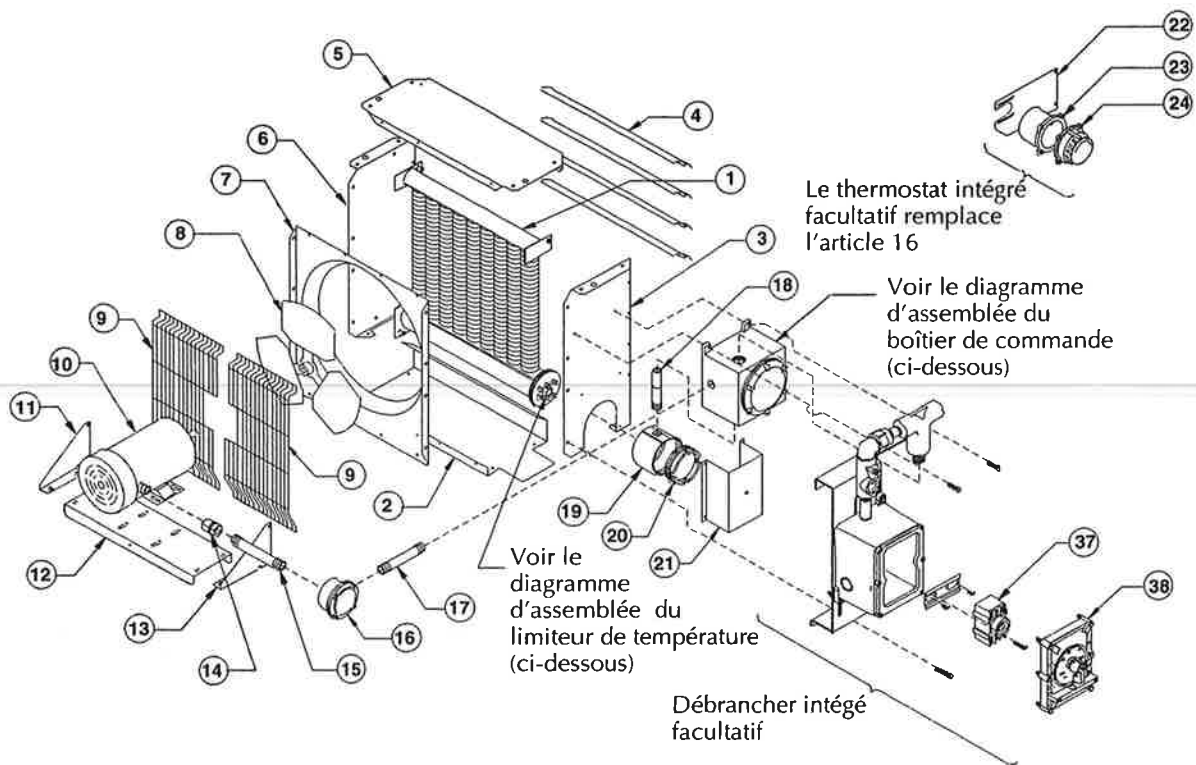
# LISTE DES PIÈCES

## AÉROTHERMES ÉLECTRIQUES D'AIR FORCER

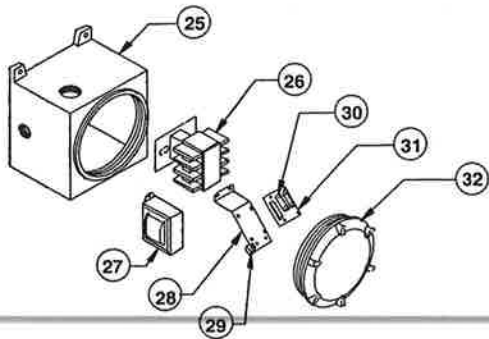
NUMÉRO DE PIÈCE				Veuillez avoir le numéro de modèle et de série avant de téléphoner.
ARTICLE	2.5 - 10 kW	12.5 - 20 kW	20.9 - 35 kW	DESCRIPTION
1	**	**	**	Faisceau
2	3773	3774	3775	Panneau, dessous
3	3776	3777	3778	Panneau, côté gauche
4	4075	4076	4077	Persiennes (vis incluses)
5	3770	3771	3772	Panneau, dessus
6	3779	3780	3781	Panneau, côté droit
7	3782	3783	3784	Tuyère de ventilateur
8	2.5 - 5 kW: 4022 6.3 - 10 kW: 4023	12.5 - 20 kW: 4024	20.9-30 kW: 4025 35 kW: 4026	Ventilateur
9	4078	4079	4080	Grille de protection
10	208/240V 60 HZ 1 PH: 1377 220V 50 HZ 1 PH: 1377 480V 60 HZ 1 PH: 2396 208/240/480V 60HZ 3PH: 1862 380/415V 50 HZ 3 PH: 1862 600V 60HZ 3 PH: 1861	1377 1377 2396 1862 1862 1861	240/480V 60 HZ 3 PH: 1699 380/415V 50 HZ 3 PH: 1699 600V 60 HZ 3 PH: 2433	Moteur (antidéflagrant)
11	3789	3789	3789	Support de fixation du moteur, droit
12	3785	3786	3787	Profilé en U, support du moteur
13	3788	3788	3788	Support de fixation du moteur, gauche
14	3737	3737	3737	Raccord du moteur
15	3811	3812	3813	Conduit du moteur
16	3838	3838	3838	Boîtier, jonction des conduits
17	208/240V 60 HZ 1PH: 3815 220V 50 HZ 1PH: 3815 480V 60 HZ 1PH: 3813 TOUS 3PH: 3814	3815 3815 3813 3814	3813	Conduit du boîtier de commande
18	3810	3810	3810	Conduit du boîtier d'éléments
19	3793	3793	3793	Boîtier, éléments chauffants
20	3510	3510	3510	Couvercle, boîtier des éléments
21	3790	3790	3790	Panneau de protection, boîtier des éléments
22	3791	3791	3791	Support du thermostat
23	4983	4983	4983	Boîtier du thermostat
24	5032	5032	5032	Thermostat intégré
25	3524	3525	3526	Boîtier du commande
26	**	**	**	Contacteur
27	60 HERTZ: 3612		50 HERTZ: 4416	Transformateur
28	3809	3809	3809	Support de carte à circuits imprimés
29	1876	1876	1876	Cosse à vis, calibre 6-14
30	3519	3519	3519	Fusible, Buss MDQ - 1/4 A
31	3514	3514	3514	Carte à circuits imprimés
32	3516	3516	3516	Couvercle du boîtier de commande
33	4082	4082	4082	Limiteur de température à maximum
34	3816	3816	3816	Barre omnibus, droite
35	3817	3817	3817	Barre omnibus, petite, courbée
36	3818	3818	3818	Barre omnibus, grande, courbée
37	6471	6471	6471	Débranche, Rotatif
38	6709	6709	6709	Trousse, Couverture DS4

\*\* Pour connaître les numéros de pièces, consulter le tableau des données techniques. **NOTA:** Pour les articles qui ne sont pas illustrés, communiquer avec le personnel de l'usine.

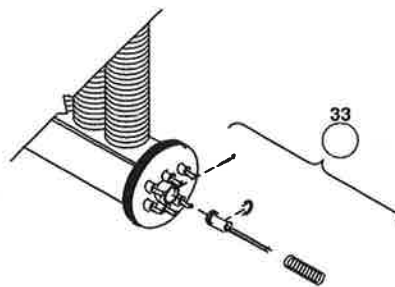
# DIAGRAMME D'ASSEMBLÉE D'ÁEROTHERMES



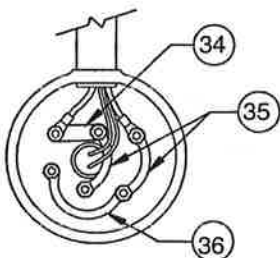
## BOÎTIER DE COMMANDE DIAGRAM D'ASSEMBLÉE



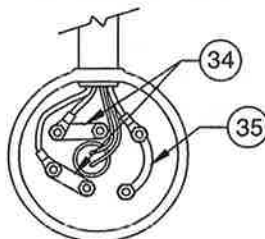
## LIMITEUR DE TEMPÉRATURE DIAGRAM D'ASSEMBLÉE



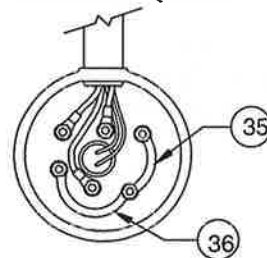
### CONFIGURATION DE LA BARRE OMNIBUS TOUS LES MONOPHASÉS MODÈLES



### CONFIGURATION DE LA BARRE OMNIBUS TOUS LES TRIPHASÉS MODÈLES (SAUF 380 VOLTS, 50 HERTZ)



### CONFIGURATION DE LA BARRE OMNIBUS TRIPHASÉS, 380 VOLTS, 50 HERTZ MODÈLES UNIQUEMENT



# — SPÉCIFICATIONS POUR TOUS LES MODÈLES DE 50 HZ —

Puissance nominale		2.5	3.7&4.2	6.3&7.5	8.4	12.5&12.6	14.9&16.7	20.9	22.4
Altitude max.	(pi.) (m)	12,000 3,658	8,000 2,438	10,000 3,048	7,000 2,134	10,000 3,048	7,000 2,134	10,000 3,048	7,000 2,134
Débit de soufflage	@ 70°F (PCM) @ 21°C (m/hr.)	400 679		700 1189		1450 2463		3600 5096	
Portée d'air horizontale	(pi.) (m)	13 4.0		25 7.6		35 10.7		60 18.2	
Hauteur maximale (Pl)	(pi.) (le dessous) (m)	7 2.1		10 3.0		10 3.0		20 6.1	
Puissance du moteur	(HP) (kW)		1/4 0.187			1/4 0.187		1/2 0.373	
Diamètre du ventilateur	(po) (mm)		12 305			16 406		20 508	
Poids net	(lbs.) (kg)		111 50			133 61		154 70	
Poids net avec DS4-48-L	(lbs.) (kg)		125 57			147 67		168 76	
Poids d'expédition	(lbs.) (kg)		151 69			173 79		204 93	
Poids d'expédition avec DS4-48-L	(lbs.) (kg)		165 75			187 85		218 99	
Boîtiers	NEMA Type 7 & 9. <b>Uniquement</b> pour utilisation à l'intérieur, au sec. Ne pas immerger dans l'eau. Ne pas entreposer ou utiliser dans des endroits exposés à la pluie ou à la neige.								
Type de moteur	Antidéflagrant. À protection thermique. Roulements à billes à lubrification permanente. 1425tr/mn								
Ventilateur	Pales d'aluminium. Grillage en acier et moyeu avec alésage de 5/8 po (15,875 mm).								
Grille de protection	Séparable, à faible écartement entre les broches; impossible d'y faire passer un objet de 1/4 po (6.3 mm) de diamètre.								
Trous de montage	2 trous de 9/16 po (14.3 mm) de diamètre sur le dessus de l'aérotherme.								
Éléments chauffants	3 éléments à gaine de métal de haut calibre, à faible puissance, à durée de vie prolongée.								
Limiteur de température à maximum	Du type à réenclenchement automatique, avec bimétal à rupture, à ouverture de contact lorsqu'il y a hausse de température. Évalué à 100,000 cycles à 10 A, tolère 0, 130 A.								
Circuit de commande	115 Volts, 0.130 A, 15VA. (mis à la masse).								
Thermostat intégré facultatif	Antidéflagrant. 36°F à 82°F (2°C à 28°C)								
Transformateur de commande	À sorties multiples, primaire 115 Volts, secondaire 25 VA.								
Contacteur	40 ou 75 A. Calculé pour 500,000 opérations mécaniques. Bobine de 120 Volts, 15 VA (à protection par fusible séparée).								
Fluide de transfert de chaleur	Mélange d'éthylèneglycol et eau formulé pour une durée de vie prolongée, protection contre le gel jusqu'à -49°F (-45°C) min.								
Boîtier	En acier de calibre 14 (0.075 po) (1.90 mm). À revêtement d'époxyde avec prétraitement en cinq étapes, y compris au phosphate de fer.								
Faisceau	En acier avec ailettes complètement en aluminium, chargé à vide et scellé hermétiquement.								
Matériel du conduit	À paroi épaisse en acier de 0.122 po (3.1 mm) à revêtement de cadmium.								
Protection contre surpressions	Determined à 100 PSI (690kpa) pression soulagement soudade, corps aluminum, aucun pièce de terrain de service								
Code de température	T3B 165°C (329°F) Classes I & II.								
Limites de température	-49°F à 104°F (-45°C à 40°C).								
Limites d'entreposage	-49°F à 176°F (-45°C à 80°C), courte durée jusqu'à 248°F (120°C). Ne pas entreposer ou utiliser dans des endroits exposés à la pluie ou à la neige. Ne pas immerger dans l'eau.								
Débrancher intégré facultatif	Cet DS4-48-L et pour utilisation sur l'aérotherme pas avec plus du 48 AMPS. La barre laisser dehors accepter 1/4" à 7/16" diamètre enclos enchaîner.								



# — SPÉCIFICATIONS POUR TOUS LES MODÈLES DE 60 HZ —

	Puissance nominale	3	5	7.5	10	15	20	25	30	35
Altitude max. (pi.) (m)		12,000 3,658	8,000 2,438	10,000 3,048	7,000 2,134	10,000 3,048	7,000 2,134	10,000 3,048	7,000 2,134	6,000 1,829
Débit de soufflage @ 70°F (PCM) @ 21°C (m³/hr.)		500 850	850 1444	1750 2973	3600 6116	3950 6711				
Portée d'air horizontale (pi.) (m)		15 4.6	30 9.1	40 12.2	70 21.3					
Hauteur maximale (Pl) (pi.) (le dessous) (m)		7 2.1	10 3.0	10 3.0	20 6.1					
Puissance du moteur (HP) (kW)		1/4 0.187	1/4 0.187	1/2 0.373						
Diamètre du ventilateur (po) (mm)		12 305	16 406	20 508						
Poids net (lbs.) (kg)		111 50	125 57	147 67	168 76					
Poids net avec DS4-48-L (lbs.) (kg)		151 69	173 79	204 93						
Poids d'expédition (lbs.) (kg)		165 75	187 85	218 99						
Boîtiers	NEMA Type 7 & 9. Uniquement pour utilisation à l'intérieur, au sec. Ne pas immerger dans l'eau. Ne pas entreposer ou utiliser dans des endroits exposés à la pluie ou à la neige.									
Type de moteur	Antidéflagrant. À protection thermique. Roulements à billes à lubrification permanente. 1725tr/mn									
Ventilateur	Pales d'aluminium. Grillage en acier et moyeu avec alésage de 5/8 po (15,875 mm).									
Grille de protection	Séparable, à faible écartement entre les broches; impossible d'y faire passer un objet de 1/4 po (6.3 mm) de diamètre.									
Trous de montage	2 trous de 9/16 po (14.3 mm) de diamètre sur le dessus de l'aérotherme.									
Éléments chauffants	3 éléments à gaine de métal de haut calibre, à faible puissance, à durée de vie prolongée.									
Limiteur de température à maximum	Du type à réenclenchement automatique, avec bimétal à rupture, à ouverture de contact lorsqu'il y a hausse de température. Évalué à 100,000 cycles à 10 A, tolère 0, 128 A.									
Circuit de commande	120 Volts, 0.128 A, 15VA. (mis à la masse).									
Thermostat intégré facultatif	Antidéflagrant. 36°F à 82°F (2°C à 28°C)									
Transformateur de commande	À sorties multiples, primaire 120 Volts, secondaire 25 VA.									
Contacteur	40 ou 75 A. Calculé pour 500,000 opérations mécaniques. Bobine de 120 Volts, 15 VA (à protection par fusible séparée).									
Fluide de transfert de chaleur	Mélange d'éthylèneglycol et eau formulé pour une durée de vie prolongée, protection contre le gel jusqu'à -49°F (-45°C) min.									
Boîtier	En acier de calibre 14 (0.075 po) (1.90 mm). À revêtement d'époxyde avec prétraitement en cinq étapes, y compris au phosphate de fer.									
Faisceau	En acier avec ailettes complètement en aluminium, chargé à vide et scellé hermétiquement.									
Matériel du conduit	À paroi épaisse en acier de 0.122 po (3.1 mm) à revêtement de cadmium.									
Protection contre surpressions	Déterminé à 100 PSI (690kpa) pression soulagement soudade, corps aluminium, aucun pièce de terrain de service									
Code de température	T3B 165°C (329°F) Classes I & II.									
Limites de température	-49°F à 104°F (-45°C à 40°C).									
Limites d'entreposage	-49°F à 176°F (-45°C à 80°C), courte durée jusqu'à 248°F (120°C). Ne pas entreposer ou utiliser dans des endroits exposés à la pluie ou à la neige. Ne pas immerger dans l'eau.									
Débrancher intégré facultatif	Cet DS4-48-L et pour utilisation sur l'aérotherme pas avec plus du 48 AMPS. La barre laisser dehors accepter 1/4" à 7/16" diamètre enclos enchaîner.									



# DONNÉES TECHNIQUES POUR TOUS LES AÉROTHERMES FX4 ÉLECTRIQUES D'AIR FORCER POUR MODÈLES À 60 HERTZ



MODÈLE	NOTA	DS4-48-L	TENSION	PISANCE NOMINALE (kW)	PHASE	COURANT DU MOTOR (A)	COURANT DES ELEMENTS (W)	COURANT TOTAL (A)	ADMISSABLE MINIMAL DU CIRCUIT (A)	CALIBRE DES FILS D'ALIMENTATION (AWG)	AMPÉRAGE MAXIMAL DU FUSIBLE DU CIRCUIT (A)	HAUSSE DU TEMPÉRATURE		N° DE PIÈCE DU FAISCEAU	N° DE PIÈCE DU CONTACTEUR
			(V)									°F	°C		
FX412-208160-3		✓	208	3	1	2.7	2,700	14.4	18.0	12	20	19.0	10.5	4044	3618
FX412-208360-3		✓	208	3	3	1.4	2,700	8.3	10.4	14	15	19.0	10.5	4044	3618
FX412-240160-3		✓	240	3	1	2.7	2,700	12.5	15.6	12	20	19.0	10.5	4045	3618
FX412-240360-3		✓	240	3	3	1.4	2,700	7.2	9.0	14	15	19.0	10.5	4045	3618
FX412-480160-3	*	✓	480	3	1	1.3	2,700	6.3	7.9	14	15	19.0	10.5	4046	3618
FX412-480360-3		✓	480	3	3	0.7	2,700	3.6	4.5	14	15	19.0	10.5	4046	3618
FX412-600360-3	*	✓	600	3	3	0.6	2,700	2.9	3.6	14	15	19.0	10.5	4047	3618
FX412-208160-5		✓	208	5	1	2.7	4,700	24.0	30.0	10	30	31.6	17.6	4048	3618
FX412-208360-5		✓	208	5	3	1.4	4,700	13.9	17.4	12	20	31.6	17.6	4048	3618
FX412-240160-5		✓	240	5	1	2.7	4,700	20.8	26.0	10	30	31.6	17.6	4049	3618
FX412-240360-5		✓	240	5	3	1.4	4,700	12.0	15.0	14	15	31.6	17.6	4049	3618
FX412-480160-5	*	✓	480	5	1	1.3	4,700	10.4	13.0	14	15	31.6	17.6	4050	3618
FX412-480360-5		✓	480	5	3	0.7	4,700	6.0	7.5	14	15	31.6	17.6	4050	3618
FX412-600360-5	*	✓	600	5	3	0.6	4,700	4.8	6.0	14	15	31.6	17.6	4051	3618
FX412-208160-7.5		✓	208	7.5	1	2.7	7,200	36.1	45.1	6	50	27.9	15.5	4052	3619
FX412-208360-7.5		✓	208	7.5	3	1.4	7,200	20.8	26.0	10	30	27.9	15.5	4052	3618
FX412-240160-7.5		✓	240	7.5	1	2.7	7,200	31.3	39.1	8	40	27.9	15.5	4053	3618
FX412-240360-7.5		✓	240	7.5	3	1.4	7,200	18.0	22.5	10	25	27.9	15.5	4053	3618
FX412-480160-7.5	*	✓	480	7.5	1	1.3	7,200	15.6	19.5	12	20	27.9	15.5	4054	3618
FX412-480360-7.5		✓	480	7.5	3	0.7	7,200	9.0	11.3	14	15	27.9	15.5	4054	3618
FX412-600360-7.5	*	✓	600	7.5	3	0.6	7,200	7.2	9.0	14	15	27.9	15.5	4055	3618
FX412-208160-10	**		208	10	1	2.7	9,690	48.1	60.1	4	70	37.2	20.6	4056	3619
FX412-208360-10		✓	208	10	3	1.4	9,690	27.8	34.8	8	35	37.2	20.6	4056	3618
FX412-240160-10		✓	240	10	1	2.7	9,690	41.7	52.1	6	60	37.2	20.6	4057	3619
FX412-240360-10		✓	240	10	3	1.4	9,690	24.1	30.1	8	35	37.2	20.6	4057	3618
FX412-480160-10	*	✓	480	10	1	1.3	9,690	20.8	26.0	10	30	37.2	20.6	4058	3618
FX412-480360-10		✓	480	10	3	0.7	9,690	12.0	15.0	14	15	37.2	20.6	4058	3618
FX412-600360-10	*	✓	600	10	3	0.6	9,690	9.6	12.0	14	15	37.2	20.6	4059	3618
FX416-208360-15		✓	208	15	3	1.4	14,400	41.6	52.0	6	60	27.1	15.0	4060	3619
FX416-240160-15	**		240	15	1	2.7	14,400	62.5	78.1	4	80	27.1	15.0	4061	3619
FX416-240360-15		✓	240	15	3	1.4	14,400	36.1	45.1	6	50	27.1	15.0	4061	3619
FX416-480160-15	*	✓	480	15	1	1.3	14,400	31.3	39.1	8	40	27.1	15.0	4062	3618
FX416-480360-15		✓	480	15	3	0.7	14,400	18.0	22.5	10	25	27.1	15.0	4062	3618
FX416-600360-15	*	✓	600	15	3	0.6	14,400	14.4	18.0	12	20	27.1	15.0	4063	3618
FX416-208360-20	**		208	20	3	1.4	19,410	55.5	69.4	4	70	36.1	20.1	4064	3619
FX416-240360-20	**		240	20	3	1.4	19,410	48.1	60.1	4	70	36.1	20.1	4065	3619
FX416-480160-20	*	✓	480	20	1	1.3	19,410	41.7	52.1	6	60	36.1	20.1	4066	3619
FX416-480360-20		✓	480	20	3	0.7	19,410	24.1	30.1	8	35	36.1	20.1	4066	3618
FX416-600360-20	*	✓	600	20	3	0.6	19,410	19.2	24.0	10	25	36.1	20.1	4067	3618
FX420-240360-25	**		240	25	3	2.0	24,210	60.1	75.1	4	80	21.9	12.2	4068	3619
FX420-480360-25		✓	480	25	3	1.0	24,210	30.1	37.6	8	40	21.9	12.2	4069	3618
FX420-600360-25	*	✓	600	25	3	0.8	24,210	24.1	30.1	8	35	21.9	12.2	4070	3618
FX420-480360-30		✓	480	30	3	1.0	29,190	36.1	45.1	6	50	26.3	14.6	4071	3619
FX420-600360-30	*	✓	600	30	3	0.8	29,190	28.9	36.1	8	40	26.3	14.6	4072	3618
FX420-480360-35		✓	480	35	3	1.0	34,200	42.1	52.6	6	60	28.0	15.6	4073	3619
FX420-600360-35	*	✓	600	35	3	0.8	34,200	33.7	42.1	8	45	28.0	15.6	4074	3619

- \* - Certifiés pas le CSA seulement.
- \*\* - Excéder le 48 A limites de circuit du NEC 424-22

### NOTAS:

1. Dimensions minimales du conducteur à 30° C (86°F) de température ambiante. Réduire la valeur nominale du contacteur à la température ambiante. Employer une isolation valable pour au moins 90°C (194°F).
2. L'aérotherme fonctionne de façon normale si, à la tension nominale, l'ampérage est +/- 10% la valeur indiquée au tableau ci-dessus.
3. Le fonctionnement à une tension moindre entraînera une moins grande production de chaleur, ainsi qu'un ampérage réduit.



## SCHÉMAS DE CABLAGE

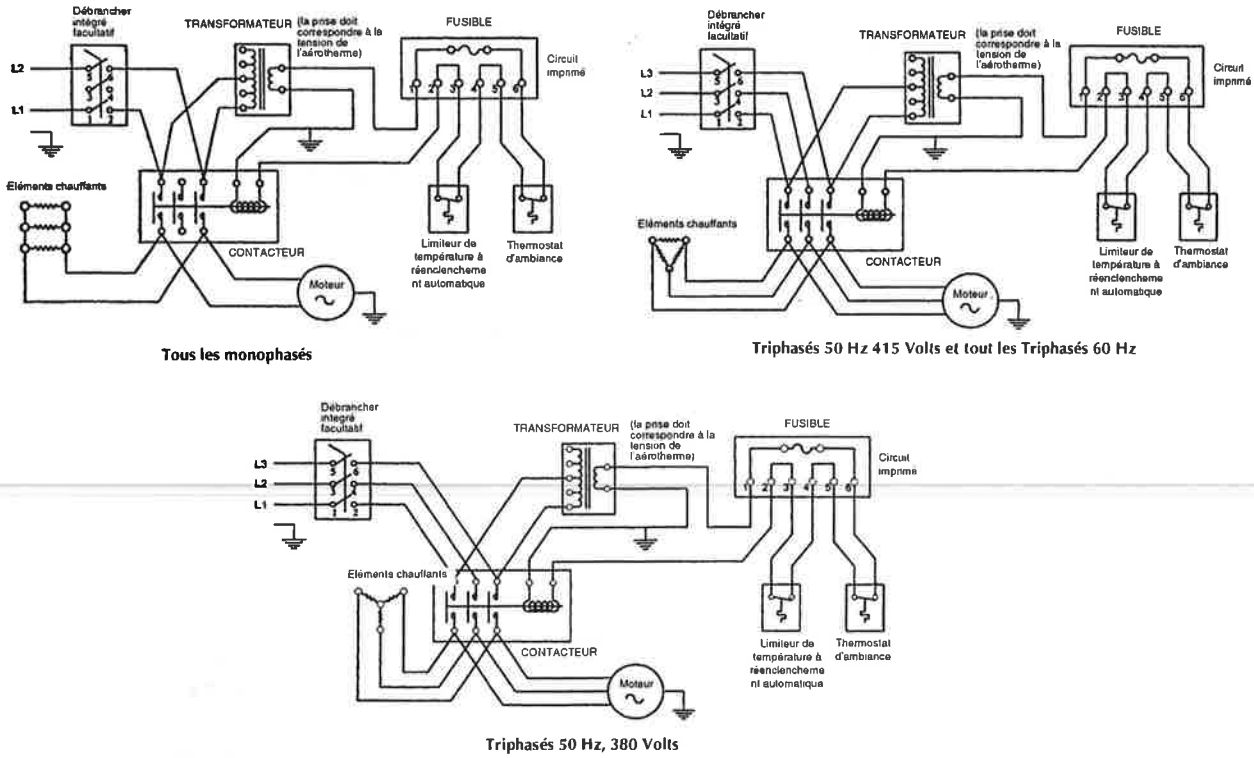


FIGURE 8



## DONNÉES TECHNIQUES POUR TOUS LES AÉROTHERMES FX4 ÉLECTRIQUES D'AIR FORCÉ POUR MODÈLES À 50 HERTZ

MODÈLE	NOTA DS4-48-L	TENSION (V)	PISANCE NOMINALE (kW)	PHASE	COURANT DU MOTOR (A)	COURANT DES ELEMENTS (W)	COURANT TOTAL (A)	ADMISSIBLE MINIMAL DU CIRCUIT (A)	CALIBRE DES FILS D'ALIMENTATION (AWG)	AMPÉRAGE MAXIMAL DU FUSIBLE DU CIRCUIT (A)	HAUSSE DU TEMPÉRATURE		N° DE PIÈCE DU FAISCEAU	N° DE PIÈCE DU CONTACTEUR
											°F	°C		
FX412-220150-2.5	✓	220	2.5	1	2.0	2,270	11.4	14.3	14	15	19.7	11.0	4045	3618
FX412-220150-4.2	✓	220	4.2	1	2.0	3,950	19.1	23.9	10	25	33.2	18.4	4049	3618
FX412-220150-6.3	✓	220	6.3	1	2.0	6,050	28.6	35.8	8	40	28.4	15.8	4053	3618
FX412-220150-8.4	✓	220	8.4	1	2.0	8,140	38.2	47.8	6	50	37.9	21.1	4057	3619
FX416-220150-12.6		220	12.6	1	2.0	12,100	57.3	71.6	4	80	27.5	15.3	4061	3619
FX412-380350-2.5	✓	380	2.5	3	0.7	2,260	3.8	4.8	14	15	19.7	11.0	4045	3618
FX412-380350-4.2	✓	380	4.2	3	0.7	3,930	6.4	8.0	14	15	33.2	18.4	4049	3618
FX412-380350-6.3	✓	380	6.3	3	0.7	6,020	9.6	12.0	14	15	28.4	15.8	4053	3618
FX412-380350-8.4	✓	380	8.4	3	0.7	8,100	12.8	16.0	12	20	37.9	21.1	4057	3618
FX416-380350-12.5	✓	380	12.5	3	0.7	12,030	19.0	23.8	10	25	27.2	15.1	4061	3618
FX416-380350-16.7	✓	380	16.7	3	0.7	16,220	25.4	31.8	8	35	36.4	20.2	4065	3618
FX420-380350-20.9	✓	380	20.9	3	1.0	20,230	31.8	39.8	8	40	22.0	12.2	4068	3618
FX412-415350-3.7	✓	415	3.7	3	0.7	3,510	5.1	6.4	14	15	29.2	16.2	4050	3618
FX412-415350-7.5	✓	415	7.5	3	0.7	7,240	10.4	13.0	14	15	33.9	18.8	4058	3618
FX416-415350-14.9	✓	415	14.9	3	0.7	14,510	20.7	25.9	10	30	32.5	18.0	4066	3618
FX420-415350-22.4	✓	415	22.4	3	1.0	21,820	31.2	39.0	8	40	23.6	13.1	4071	3618

**NOTES:**

1. Dimensions minimales du conducteur à 30°C (86°F) de température ambiante. Réduire la valeur nominale du contacteur à la température ambiante. Employer une isolation valable pour au moins 90°C (194°F).
2. L'aérotherme fonctionne de façon normale si, à la tension nominale, l'ampérage est +/- 10% la valeur indiquée au tableau ci-dessus.
3. Le fonctionnement à une tension moindre entrainera une moins grande production de chaleur, ainsi qu'un ampérage réduit.

3. L'aérotherme peut être fourni avec un débrancher intégral installé en usine. (Voir figure 6B). Câblage sur place pour le débrancher intégral:

- Les conducteurs pour le courant et de terre sont passés dans le 1" NPT de la débrancher enclosure. (Voir Figure 6B) les conducteurs être fils à l'interrupteur sont dedans. Le conducteur de terre à la patte de mise à la masse attacher dedans enclosure débrancher.
- Si applicable, les conducteurs de les thermostats éloigné sont passés dans le 3/4" NPT ouvert de le point et les fils sont attaches à la plaquette marque T STAT.
- Pour réduire risque s'inflammer dans l'atmosphère dangereaux, les conduits sont besoin un adéquat sceau dans les limites de 18 pouce (457mm).

Les conduits installé en usine ne pas besoin plus du sceau. Le débrancher intégral sont sceu à l'usine.

## INSPECTION FINALE

- Avant de mettre sous tension:
  - vérifier si toutes les connexions sont bien faites et correspondent au schéma de câblage applicable (voir figure 8) et aux codes en vigueur;
  - s'assurer que l'alimentation électrique soit compatible avec la puissance de l'aérotherme indiquée sur la plaque signalétique;
  - enlever tout corps étranger à l'intérieur de l'aérotherme,
  - installer tous les couvercles et vérifier si tous les boîtiers sont bien fermés et,
  - s'assurer que le ventilateur tourne librement. Voir la figure 5 pour connaître le sens de rotation des pales du ventilateur.

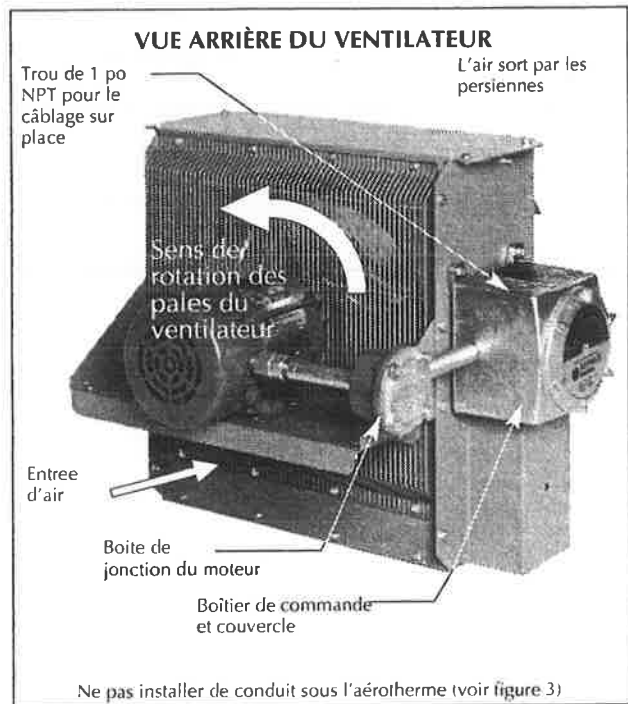


FIGURE 5

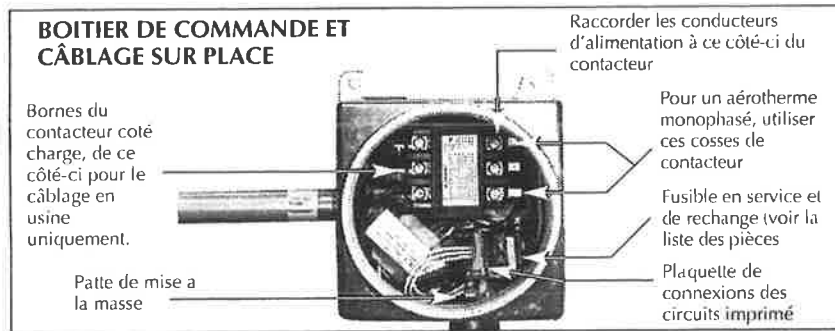


FIGURE 6

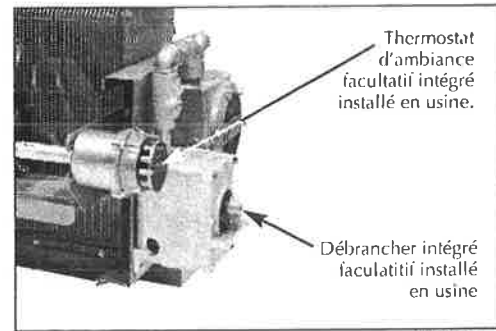


FIGURE 7

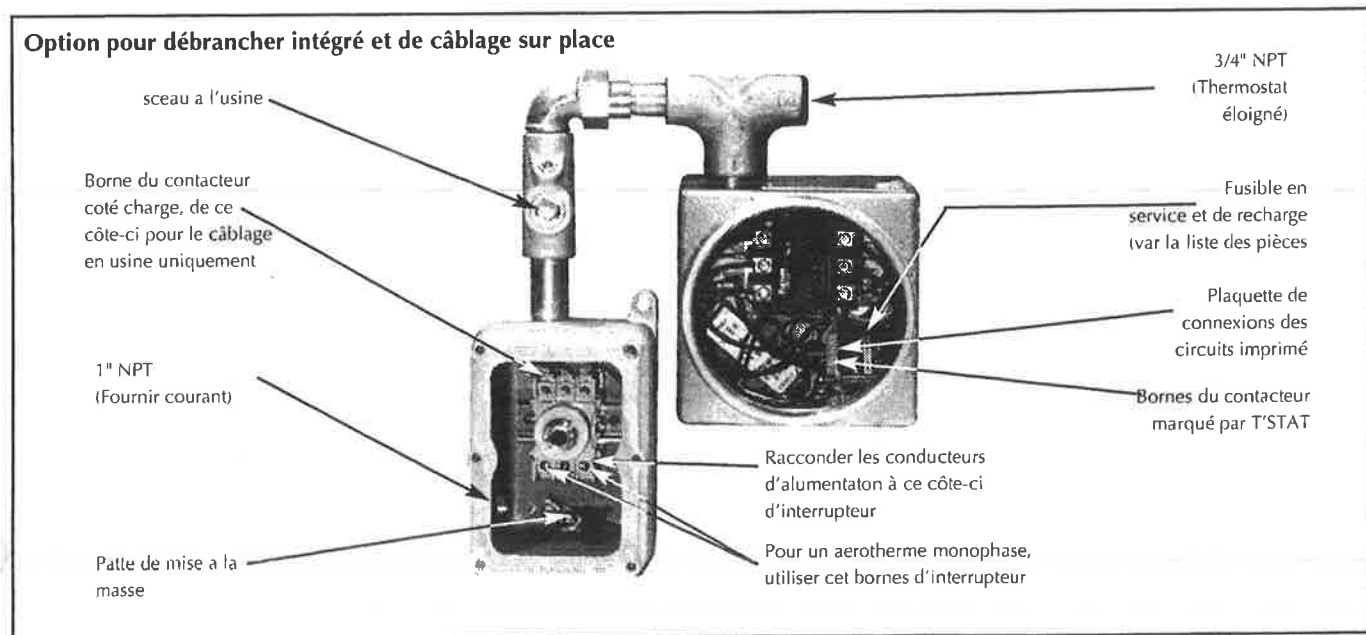


FIGURE 6B

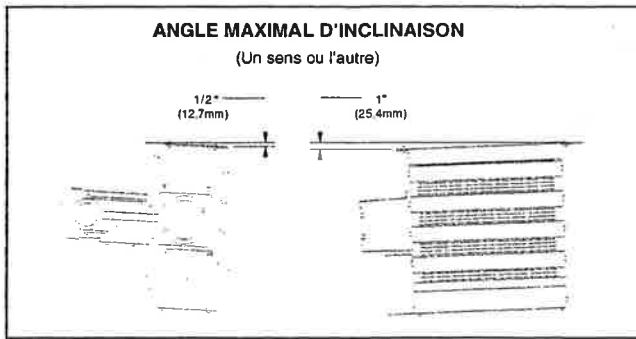


FIGURE 2

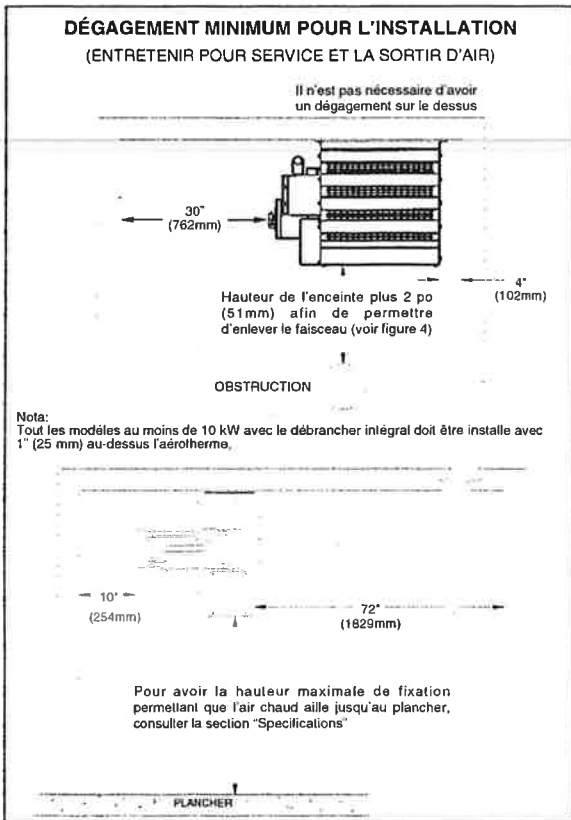


FIGURE 3

## MONTAGE

1. Pour le fonctionnement, l'aérotherme doit être installé de façon permanente en position verticale et de niveau. Voir les figures 2, 3 et 4 pour connaître l'angle d'inclinaison maximal, le dégagement maximal, ainsi que les dimensions.

Afin de faciliter l'installation, on peut se procurer en usine divers types de nécessaires de montage.

2. La structure de montage doit être suffisamment forte pour:
  - a. supporter les poids de l'aérotherme; se reporter à la section "Specifications";
  - b. offrir suffisamment de rigidité pour éviter les vibrations excessives; et
  - c. résister aux situations difficiles comme les installations démontables.

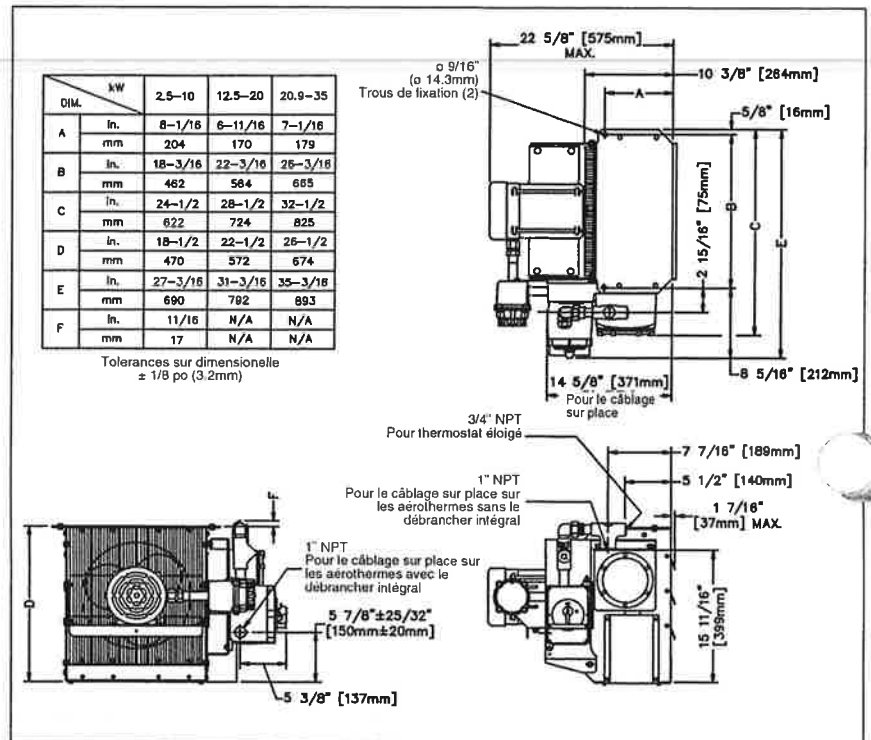


FIGURE 4

DIM.	kW	2.5-10			12.5-20			20.9-35		
		In.	mm	In.	mm	In.	mm	In.	mm	
A		8-1/16	204	6-11/16	170	7-1/16	179			
B		18-3/16	462	22-3/16	564	26-3/16	665			
C		24-1/2	622	28-1/2	724	32-1/2	825			
D		18-1/2	470	22-1/2	572	26-1/2	674			
E		27-3/16	690	31-3/16	792	35-3/16	893			
F		11/16	17	N/A	N/A	N/A	N/A			

Tolerances sur dimensionnelle  
± 1/8 po (3.2mm)

## ÉLECTRIQUE

### AVERTISSEMENT

Débrancher la source d'alimentation ou à la débrancher intégré avant d'ouvrir les boîtiers ou d'en faire la maintenance. Bloquer le commutateur en position "OFF" (circuit ouvert) et/ou y mettre une étiquette afin d'éviter que l'appareil ne soit mis en marche par inadvertance. Si la débranche intégré être entretien, vérifiez le courant être débrancher à la source d'alimentation. Bloquer le commutateur en position "OFF" (circuit ouvert) et/ou y mettre une étiquette afin d'éviter que l'appareil ne soit mis en marche par inadvertance. L'installation et le câblage de l'aérotherme doivent être conformes à tous les codes en vigueur.

### GÉNÉRALITÉS

1. Pour raccorder l'aérotherme, n'utiliser que des conducteurs de cuivre et des méthodes de câblage approuvées antidéflagration. Consulter le tableau "Données techniques" et la plaque signalétique de l'aérotherme pour connaître la valeur du conducteur.
2. Une protection externe de surintensité est requise. Consulter le tableau "Données techniques" et la plaque signalétique de l'aérotherme pour connaître la tension, la fréquence, l'ampérage et la phase. La tension d'alimentation doit être ±10% la tension indiquée sur la plaque signalétique.

### CÂBLAGE SUR PLACE

1. Les conducteurs d'alimentation, les conducteurs de mise à la masse et les conducteurs du thermostat d'ambiance (voir 2, page 5) passent dans le trou de 1 po NPT (voir figure 5) et sont raccordés dans le boîtier de commande (voir figure 6).

2. L'aérotherme peut être fourni avec un thermostat d'ambiance intégré (voir figure 7). Pour les aérothermes qui ne sont pas dotés de cette option, on recommande d'utiliser un thermostat d'ambiance à distance. Raccorder les conducteurs du thermostat d'ambiance à distance à la plaque de connexions du circuit imprimé portant l'inscription "TSTAT". Tout thermostat utilisé avec cet aérotherme doit:
  - a) être du type antidéflagrant;
  - b) avoir une tension nominale d'au moins 125 V;
  - c) avoir une capacité minimale de 2 A; et
  - d) fonctionner avec ouverture de contact lorsqu'il y a hausse de température.

On peut se procurer des thermostats d'ambiance pour les endroits dangereux appropriés en usine.

(suite à la page suivante)

# AVIS IMPORTANT

## AVERTISSEMENT

Bien lire attentive les avis suivants et s'y conformer, sinon il y a risque de blessures graves ou même mortelles.

1. Lire les instructions du guide et les suivre.
2. N'utiliser l'aérotherme que dans des endroits où la température d'allumage est supérieure à la température nominale maximale de l'aérotherme, tel qu'indiqué sur la plaque signalétique. Se reporter aux codes électriques en vigueur pour avoir plus de renseignements.
3. N'utiliser l'aérotherme que dans les endroits dangereux qui sont indiqués sur la plaque signalétique de l'aérothermes.
4. L'aérotherme ne doit être utilisé qu'à l'intérieur, au sec. Ne pas immerger dans l'eau. Ne pas entreposer ou utiliser dans les endroits exposés à la pluie ou à la neige.
5. Seul un électricien qualifié et expérimenté avec l'équipement destiné aux endroits dangereux peut faire le raccordement et l'entretien de l'aérotherme.
6. Pour l'installation et le raccordement de l'aérotherme, il faut respecter tous les codes en vigueur.
7. Avant d'ouvrir un boîtier, débrancher l'aérotherme de sa source d'alimentation à la débrancher intégré. Bloquer le commutateur en position "OFF" (circuit ouvert) et/ou y mettre une étiquette afin d'éviter que l'appareil ne soit mis en marche par inadvertance. Si la débranche intégré être entretien, vérifiez le courant être débrancher à la source d'alimentation. Bloquer le commutateur en position "OFF" (circuit ouvert) et/ou y mettre une étiquette afin d'éviter que l'appareil ne soit mis en marche par inadvertance.
8. Cet aérotherme est muni d'un seul bimétal limiteur de température à maximum. Il est du type à réenclenchement automatique ce qui signifie que l'aérotherme peut se remettre en marche sans avertissement. Il ne faut pas faire fonctionner l'aérotherme lorsque le bimétal à maximum est hors service ou débranché du circuit de commande.
9. La pression de purger de la pression soulagement soupape être poser à l'usine. Ne pas jouer avec l'écrou serrure.
10. Ne faire fonctionner l'aérotherme que lorsqu'il est installé de façon permanente en position verticale. Consulter la section "Installation - mécanique" pour avoir plus de détails.
11. L'aérotherme doit toujours être propre. Lorsqu'il fonctionne dans un environnement où il y a beaucoup de saletés, nettoyer régulièrement les tubes à ailettes, le ventilateur et la grille de protection. Suivre les procédures de maintenance recommandées. Consulter la section "Liste de contrôle pour la maintenance de l'aérotherme" pour avoir plus de détails.
12. Le faisceau de l'aérotherme est chargé à vide et contient de l'éthylène glycol, lequel est toxique. S'il y a une fuite de fluide de l'aérotherme, le débrancher de sa source d'alimentation et remplacer le faisceau par un faisceau fourni en usine. Se reporter à la section "Réparation et remplacement" pour avoir plus de détails.
13. Ne pas faire fonctionner l'aérotherme si des persiennes sont complètement fermées ou dépassent des butées.
14. Ne pas faire fonctionner l'aérotherme dans des milieux où il y a risque de corrosion de l'acier ou de l'aluminium.
15. N'utiliser l'aérotherme dans température plus de 40°C (104°F).
16. N'utiliser que les pièces de remplacement approuvées en usine.
17. Se reporter aux codes électriques en vigueur relativement aux exigences des joints pour les conduits installés sur place. Des joints de conduits ne sont pas requis pour les conduits de l'aérotherme installés en usine.
18. Lors de la mise en marche de l'aérotherme, on peut entendre des bruits de cognement ou de craquement à l'intérieur du faisceau, ce qui est normal.
19. L'air qui sort près du bas de l'aérotherme peut être plus chaud que celui qui sort par le haut, ce qui est normal.
20. Si vous avez des questions en ce qui concerne l'aérotherme, communiquer avec le personnel de l'usine. Veuillez consulter la dernière page de ce guide pour avoir plus de renseignements.

LA GARANTIE SERA ANNULÉE SI LES INSTRUCTIONS NE SONT PAS SUIVIES

## INSTALLATION

Les instructions d'installation servent de directives générales pour l'installation et le câblage de l'aérotherme. Tous les codes en vigueur doivent être respectés.

## MÉCANIQUE

### POSITIONNEMENT

Pour un chauffage optimum, l'aérotherme doit être installé de manière:

1. qu'il n'y ait aucune obstruction empêchant l'arrivée ou la sortie d'air de l'aérotherme.
2. que la sortie d'air soit dirigée dans les espaces vastes et non vers les personnes.
3. que la sortie d'air ne soit pas dirigée sur un thermostat.
4. que la sortie d'air soit dirigée directement vers les endroits où il y a des pertes de chaleur, comme les portes ou les fenêtres (voir figure 1).
5. que la sortie d'air soit dirigée le long des murs extérieurs, avec un angle légèrement vers l'extérieur (voir figure 1).
6. que si on vise d'abord à protéger l'équipement contre le gel, la sortie d'air soit dirigée vers l'équipement.
7. que les courants de sortie d'air soient complémentaires et créent une circulation d'air. Il n'est pas nécessaire que la portée d'air de l'aérotherme se rende jusqu'à l'autre aérotherme (voir figure 1).

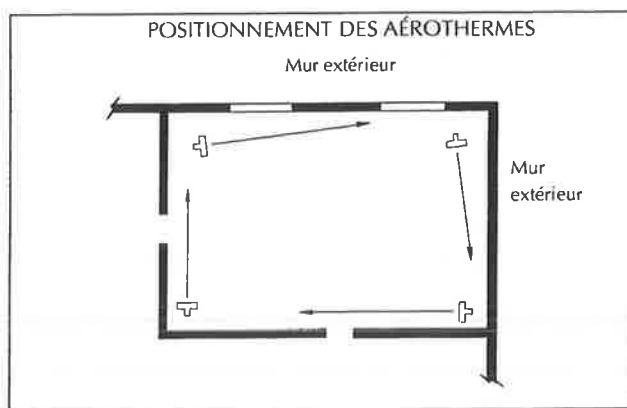


FIGURE 1

# LISTE DE CONTRÔLE POUR LA MAINTENANCE DE L'AÉROTHERME D'Électronique D'Air Forcer

Photocopier  
cette page  
pour la  
réutiliser.

N<sup>o</sup>. Modèle D'Aérotherme: \_\_\_\_\_ NO. De Série: \_\_\_\_\_

Date De Maintenance: \_\_\_\_\_ Entretien Par: \_\_\_\_\_

Commentaires: \_\_\_\_\_

## AVERTISSEMENT

Débrancher la source d'alimentation ou à la débrancher intégré avant d'ouvrir les boîtiers ou d'en faire la maintenance. Bloquer le commutateur en position "OFF" (circuit ouvert) et/ou y mettre une étiquette afin d'éviter que l'appareil ne soit mis en marche par inadvertance. Si la débranche intégré être entretien, vérifiez le courant être débrancher à la source d'alimentation. Bloquer le commutateur en position "OFF" (circuit ouvert) et/ou y mettre une étiquette afin d'éviter que l'appareil ne soit mis en marche par inadvertance. L'installation et le câblage de l'aérotherme doivent être conformes à tous les codes en vigueur. L'entretien de cet aérotherme ne doit être fait que par du personnel expérimenté avec l'équipement de chauffage pour les endroits dangereux.

## PÉRIODIQUE (avant la saison froide et lorsque nécessaire au cours de la saison)

- |                    |   |                    |   |
|--------------------|---|--------------------|---|
| <b>1. NETTOYER</b> | <input type="checkbox"/> Tube à ailettes      | <b>2. VÉRIFIER</b> | <input type="checkbox"/> Si le moteur fonctionne bien   |
|                    | <input type="checkbox"/> Ventilateur          |                    | <input type="checkbox"/> Si l'angle des persiennes est bon et si elles tiennent bien en place |
|                    | <input type="checkbox"/> Grille de protection |                    | <input type="checkbox"/> Si tous les couvercles antidéflagrants sont bien vissés              |
|                    | <input type="checkbox"/> Moteur               |                    |   |
|                    | <input type="checkbox"/> Persiennes           |                    |   |

**Enlever la poussière à l'aide d'air comprimé. Ne pas vaporiser d'eau ou de solvants.  
Ne pas immerger dans l'eau ou les solvants.**

## ANNUELLE (avant la saison froide)

### 1. ÉLECTRIQUE

- Vérifier tous les conducteurs et les bornes de connexion.** Serrer les connexions lâches. Remplacer les conducteurs dont l'isolation est endommagée.
- Inspecter les contacts des contacteurs.** S'ils sont très corrodés, brûlés ou si la soudure est en mauvais état, les remplacer par des contacteurs fournis en usine.
- Vérifier les fusibles.** La capacité et le type du fusible sont indiqués sur la plaque à circuits imprimés. Le bon fusible doit se trouver dans le porte-fusible en service. On recommande de garder un fusible en bon état dans le porte-fusible de rechange.
- Vérifier tous les conduits antidéflagrants.** Remplacer les conduits endommagés. Tout les raccorder des conduit filets sont besoin minimum de cinq tour fiancailles. Les conduit droit filets doivent dépasser d'au moins 1/16"(1.6mm) dans les boîtiers. Les raccordes diminuer doit être serrés à la main.
- Vérifier la résistance électrique de toutes les bornes du côté charge.** La lecture doit être la même ( $\pm 5\%$ ).

### 2. MÉCANIQUE

- Vérifier s'il y a des fuites de fluide.** Le faisceau de l'aérotherme est chargé à vide et contient de l'éthylène glycol, lequel est toxique. S'il y a une fuite de fluide de l'aérotherme, débrancher ce dernier de la source d'alimentation et faire remplacer le faisceau. Un faisceau fourni en usine peut être expédié immédiatement à partir des stocks. Consulter la section "Réparation et remplacement" pour avoir plus de détails.
- Vérifier tous les boîtiers.** L'intérieur des boîtiers doit être propre, sec et exempt de corps étrangers. Les couvercles vissés doivent être bien poser et serrés à la main.  
**Nota:** Les joints des boîtiers sont métal sur métal. Ne pas utiliser de joints d'étanchéité ou de scellants. De la graisse est mise aux joints en usine et rester intact.
- Vérifier les roulements à billes de l'arbre moteur.** Remplacer le moteur s'il y a trop de jeu ou si le moteur ne fonctionne pas bien et silencieusement. Les roulements à billes du moteur sont lubrifiés de façon permanente.
- Vérifier le ventilateur.** Le remplacer aussitôt s'il est fissuré ou endommagé.
- Vérifier les persiennes.** Les vis des persiennes doivent être serrées. Les persiennes ne doivent pas être complètement fermées ou dépasser des butées.
- Vérifier si toutes les pièces sont bien serrées.** Tous les écrous et les boulons, y compris les pièces de support, doivent être bien serrés.
- Faire fonctionner l'aérotherme pendant au moins cinq minutes.** Vérifier si de l'air chaud sort par les persiennes. Il est normal d'entendre des bruits de craquement ou de cognement au démarrage.



Pour assistance, veuillez composer  
le numéro de la lignesans frais:  
1-800-661-8561 (24 hr) Canada et É.-U.

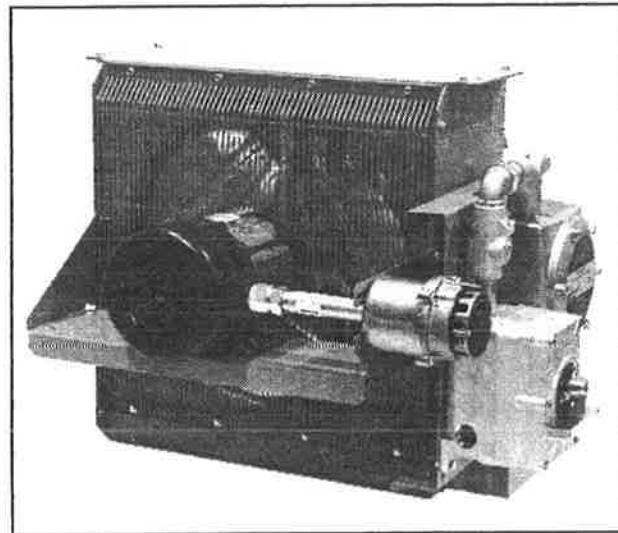
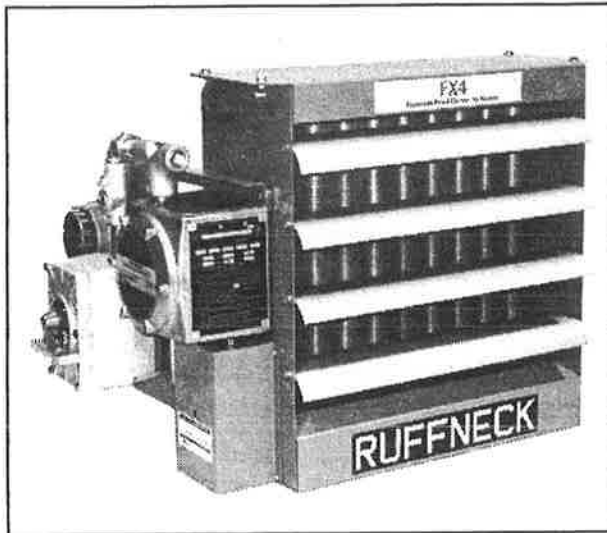
# RUFFNECK® Heaters



Guide d'utilisation

## FX4 Série

Aérothermes électriques d'air forcer pour endroits dangereux



Le présent guide comprend l'information relative à l'installation, à la maintenance, à la réparation et aux pièces de remplacement.

### ENDROITS APPROUVÉS

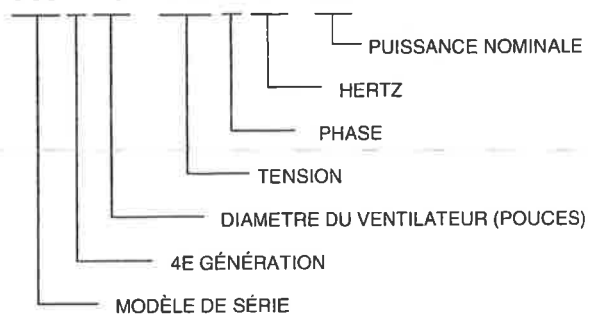
Les aérothermes électriques d'air forcer sont certifiés par le CSA et/ou homologués UL pour les endroits ci-dessous:

Classe I, Divisions 1 & 2, Groupes C & D;  
Classe II, Division 1, Groupes E, F, & G;  
Classe II, Division 2, Groupes F & G;  
Classe I, Zones 1 & 2, Groupes IIA & IIB;  
Code de température T3B 165°C (329°F);  
(modèles de 50 Hz et 60 Hz)

Pour avoir plus de détails sur les endroits dangereux avec risque d'explosion, consulter le Code canadien de l'électricité, première partie, section 18 ou le Code national de l'électricité, articles 500 - 516.

### CODAGE DU MODÈLE

**FX 4 20 - 480 3 60 - 35**



CERTIFIED

## AVERTISSEMENT

LIRE TOUS LES AVIS IMPORTANTS DE LA PAGE 3.



LISTED

Part No 5031-10

Printed in Canada

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# WARRANTY REGISTRATION

To assist us in providing information and service over the life of this product, please complete and return this form in the enclosed envelope. For information about **RUFFNECK Heaters** and its products, please call: **1-800-661-8561**.

## PLEASE PRINT

RUFFNECK Model Number: \_\_\_\_\_ Serial Number: \_\_\_\_\_

Project Name: \_\_\_\_\_

Type of Facility: \_\_\_\_\_ Date Installed: \_\_\_\_\_

Please provide this permanent contact information for future notification purposes.

**Owner / Operator:** \_\_\_\_\_

Address: \_\_\_\_\_

Postal Code: \_\_\_\_\_

Contact Name: \_\_\_\_\_ Position: \_\_\_\_\_

Phone Number: \_\_\_\_\_ Fax Number: \_\_\_\_\_

Type of Business: \_\_\_\_\_

**Installing Company Name:** \_\_\_\_\_

Address: \_\_\_\_\_

Postal Code: \_\_\_\_\_

Contact Name: \_\_\_\_\_ Position: \_\_\_\_\_

Phone Number: \_\_\_\_\_ Fax Number: \_\_\_\_\_

Type of Business: \_\_\_\_\_

## (OPTIONAL)

Is this new construction? Yes  No

Is this a replacement heater? Yes  No  If yes, what is it replacing? \_\_\_\_\_

Did the heater run satisfactorily? Yes  No  Describe: \_\_\_\_\_

Have you worked with RUFFNECK heaters before? Yes  No  Would you buy from RUFFNECK again? Yes  No

What other brands of heaters have impressed you? \_\_\_\_\_

If applicable, which RUFFNECK mounting kit did you use on your Heater?  Basic Mounting Kit (BMK)

Hanging Mounting Kit (HMK)  Pipe Mounting Kit (PMK)  Swivel Hanging Mounting Kit (SHMK)  Wall Mounting Kit (WMK)  Other

Did you use a RUFFNECK thermostat? Yes  No

For hydronic systems, what is the heat transfer fluid? \_\_\_\_\_

Are there any other features you would like to see in a unit heater? \_\_\_\_\_

Comments: \_\_\_\_\_

The warranty on this product is fully described in the sales brochure and installation manual. Please contact the factory to obtain service under the warranty policy.



2827 Sunridge Blvd. N.E.  
Calgary, Alberta  
Canada T1Y 6G1  
www.ruffneck.com  
service@ruffneck.com

Customer Toll-Free: 1-800-661-8561  
Phone: (403) 291-5488  
Fax: (403) 291-7042





KD-200

***Waukesha***<sup>®</sup>

**VHP**<sup>™</sup>

6, 12, & 16 Cylinder  
Operation & Maintenance

First Edition

**DRESSER** *Waukesha*

Form 6277

Serial No.

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Specification No.

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**Waukesha**<sup>®</sup>  
**VHP**<sup>™</sup>  
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**Operation & Maintenance**  
First Edition

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**List Of Illustrations**

**List Of Tables**

**How To Use This Manual**

**CHAPTER 1 - SAFETY AND GENERAL**

**Section 1.00 - Warning Tags And Decal Locations**

Warning Tags And Decal Locations ..... 1.00 - 1  
 VHP 6 Cylinder Engines ..... 1.00 - 2  
 VHP 12 Cylinder Engines ..... 1.00 - 4  
 VHP 16 Cylinder Engines ..... 1.00 - 7

**Section 1.05 - Safety**

Safety Introduction ..... 1.05 - 1  
 Safety Tags And Decals ..... 1.05 - 1  
 Equipment Repair And Service ..... 1.05 - 1  
 Acids ..... 1.05 - 2  
 Batteries ..... 1.05 - 2  
 Body Protection ..... 1.05 - 2  
 Chemicals ..... 1.05 - 2  
     General ..... 1.05 - 2  
     Cleaning Solvents ..... 1.05 - 2  
     Liquid Nitrogen/Dry Ice ..... 1.05 - 2  
 Components ..... 1.05 - 2  
     Heated Or Frozen ..... 1.05 - 2  
     Interference Fit ..... 1.05 - 2  
 Cooling System ..... 1.05 - 3  
 Electrical ..... 1.05 - 3  
     General ..... 1.05 - 3  
     Ignition ..... 1.05 - 3  
 Exhaust ..... 1.05 - 3  
 Fire Protection ..... 1.05 - 3  
 Fuels ..... 1.05 - 3  
     General ..... 1.05 - 3  
     Gaseous ..... 1.05 - 4  
     Liquid ..... 1.05 - 4  
 Intoxicants And Narcotics ..... 1.05 - 4  
 Pressurized Fluids/Gas/Air ..... 1.05 - 4  
 Protective Guards ..... 1.05 - 4  
 Springs ..... 1.05 - 4  
 Tools ..... 1.05 - 4  
     Electrical ..... 1.05 - 4  
     Hydraulic ..... 1.05 - 5  
     Pneumatic ..... 1.05 - 5  
 Weight ..... 1.05 - 5  
 Welding ..... 1.05 - 5  
     General ..... 1.05 - 5  
     On Engine ..... 1.05 - 5

**Section 1.10 - Rigging And Lifting Engines**

Engine Rigging And Lifting ..... 1.10 - 1  
 Location Of The Lifting Eyes ..... 1.10 - 1  
 Correct Method Of Rigging And Lifting Engine ..... 1.10 - 1

**Section 1.15 - General Information**

General Information ..... 1.15 - 1  
 Features And Benefits ..... 1.15 - 1  
 Basic Engine Description ..... 1.15 - 1  
 Component Descriptions ..... 1.15 - 2  
     Crankcase ..... 1.15 - 2  
     Crankshaft ..... 1.15 - 2  
     Intake Manifold(s) ..... 1.15 - 2  
     Exhaust Manifold(s) ..... 1.15 - 2  
     Connecting Rods ..... 1.15 - 2  
     Pistons ..... 1.15 - 2  
     Cylinder Liners ..... 1.15 - 2  
     Camshafts ..... 1.15 - 2  
     Cylinder Head And Valves ..... 1.15 - 2  
     Turbocharger(s) ..... 1.15 - 2  
     Custom Engine Control® (CEC) Ignition Module ..... 1.15 - 2  
     Custom Engine Control® (CEC) Detonation Sensing Module ..... 1.15 - 3  
     Intercooler(s) ..... 1.15 - 3  
     Carburetor(s) ..... 1.15 - 3  
     Serial Numbers And Engine Nameplate ..... 1.15 - 3  
     Instrument Panel ..... 1.15 - 3  
 Engine Identification Views ..... 1.15 - 6  
     Six Cylinder GL Views ..... 1.15 - 6  
     5115GL Views ..... 1.15 - 9  
     Twelve Cylinder GL Views ..... 1.15 - 13  
     Sixteen Cylinder GL Views ..... 1.15 - 16  
 Engine Specifications ..... 1.15 - 19  
 Torque Values ..... 1.15 - 22  
 Engine Timing Data ..... 1.15 - 24  
 Service Tools List ..... 1.15 - 24

**CHAPTER 2 - ENGINE SYSTEMS**

**Section 2.00 - Speed Governing System**

Speed Governing System Description ..... 2.00 - 1  
     Woodward UG-BL Governor ..... 2.00 - 1  
     Woodward UG-Actuator Governor ..... 2.00 - 1  
     Woodward UG-8 Dial Governor ..... 2.00 - 1  
     Woodward EG-3P Electronic Governing System ..... 2.00 - 2  
     Overspeed Governor ..... 2.00 - 2  
     Governor Linkage ..... 2.00 - 3  
     Magnetic Pickup ..... 2.00 - 3  
     Control Panel ..... 2.00 - 4

# CONTENTS

## Section 2.05 – Fuel System

Fuel System Description	2.05 – 1
Main Fuel Gas Pressure Regulators	2.05 – 1
Carburetor(s)	2.05 – 2
Prechamber Regulator	2.05 – 2
Prechamber Gas Valve	2.05 – 2
Prechamber Gas Safety Shutdown Valve	2.05 – 3
Admission Valve Assemblies	2.05 – 3
Prechambers And Spark Plug Carriers	2.05 – 4
Custom Engine Control® Air/Fuel Module System	2.05 – 4
Draw-thru Engines	2.05 – 5

## Section 2.10 – Ignition System

Ignition System Description	2.10 – 1
Spark Plugs, Spark Plug Carriers, And Connectors	2.10 – 1
Ignition Coils	2.10 – 2
Custom Engine Control® Ignition Module	2.10 – 2
Magneto Ignition System	2.10 – 4
CSA Ignition System	2.10 – 4
Custom Engine Control® Detonation Sensing Module	2.10 – 5

## Section 2.15 – Air Intake System

Air Intake System Description	2.15 – 1
Carburetor(s) And Intake Manifold(s)	2.15 – 1
Air Cleaner(s)	2.15 – 1
Turbocharger(s)	2.15 – 2
Intercooler(s)	2.15 – 2

## Section 2.20 – Turbocharger System

Turbocharger System Description	2.20 – 1
Turbocharger(s)	2.20 – 1

## Section 2.25 – Cooling System

Cooling System Description	2.25 – 1
Jacket Water Header/Jacket Water	2.25 – 1
Exhaust Manifold	2.25 – 1
Jacket Water Pump	2.25 – 3
Water Manifold	2.25 – 3
Cluster Thermostat Housing	2.25 – 3
Surge Tank	2.25 – 4
Remote Heat Transfer Device	2.25 – 4
Auxiliary Water Pump	2.25 – 4
Intercooler(s)	2.25 – 4
Oil Cooler	2.25 – 5
Auxiliary Water Remote Heat Transfer Device	2.25 – 5

## Section 2.30 – Lubrication System

Lubrication System Description	2.30 – 1
Prelube System Components	2.30 – 1
Internal Oil Control	2.30 – 1
Oil Pan And Pickup Screen	2.30 – 4
Oil Pump	2.30 – 4
Oil Cooler	2.30 – 5

Oil Strainer	2.30 – 5
MICROSPIN™ Cleanable Lube Oil Filtering System	2.30 – 6
Prelube Pushbutton Valve	2.30 – 7
Prelube Pump/Motor	2.30 – 7
Prelube Valve	2.30 – 7
In-line Lubricator	2.30 – 8

## Section 2.35 – Exhaust System

Exhaust System Description	2.35 – 1
Exhaust Manifold(s)	2.35 – 1
Turbochargers(s)	2.35 – 2
Wastegate(s)	2.35 – 2

## Section 2.40 – Crankcase Breather System

Crankcase Breather System Description	2.40 – 1
Separator Screen Maintenance	2.40 – 1
Oil Separator(s)	2.40 – 2
Choke Valve/Vacuum Valve	2.40 – 4
Breather Regulator	2.40 – 5
Venturi Extractor	2.40 – 5
Crankcase Pressure Relief Valves	2.40 – 5

## Section 2.45 – Prelube And Starting System

Prelube And Starting System Description	2.45 – 1
Prelube Pushbutton Valve	2.45 – 1
Prelube Pump And Motor	2.45 – 1
In-line Lubricator	2.45 – 2
Start Pushbutton Valve	2.45 – 2
Starter Motor – Air/Gas	2.45 – 2
Starter Motor – Electric Start	2.45 – 2

## Section 2.50 – Engine Protection Shutdown System

Engine Protection Shutdown System Description Options	2.50 – 1
K-Type Thermocouples	2.50 – 1
Thermocouple Junction Box	2.50 – 3
Manual Shutdown Lever And Governor Speed Control Lever	2.50 – 3
Ignition Switch/Switches	2.50 – 4
Customer Supplied Control Switches	2.50 – 4
Pressure And Temperature Switch Calibration	2.50 – 4
Optional Instrument Panel	2.50 – 4
Detonation Sensing Module And Sensors	2.50 – 5

**CHAPTER 3 - ENGINE STARTUP AND SHUTDOWN**

**Section 3.00 - Engine Startup And Shutdown**

Prestart Inspection ..... 3.00 - 1  
 Engine Startup Procedures ..... 3.00 - 3  
 Engine During Operation Checks ..... 3.00 - 6  
 Engine Shutdown Procedures ..... 3.00 - 8  
     Routine Shutdown ..... 3.00 - 8  
     Emergency Shutdown ..... 3.00 - 8  
 Maintenance Of Standby Units ..... 3.00 - 11  
 Engine Performance Record ..... 3.00 - 11

**CHAPTER 4 - ENGINE MAINTENANCE AND STORAGE**

**Section 4.00 - Speed Governing System Maintenance**

Speed Governing System Maintenance ..... 4.00 - 1  
     Governor Maintenance ..... 4.00 - 1  
     Governor Rod Maintenance ..... 4.00 - 2

**Section 4.05 - Fuel System Maintenance**

Fuel System Maintenance ..... 4.05 - 1  
     Admission Valve Maintenance ..... 4.05 - 1

**Section 4.10 - Ignition System Maintenance**

Ignition Maintenance ..... 4.10 - 1  
     Spark Plug Maintenance - Non-CSA ... 4.10 - 1  
     Spark Plug Maintenance - CSA ..... 4.10 - 5  
     Timing Adjustment - Dynamic (Magneto System) ..... 4.10 - 8  
     CEC Ignition Module Timing Adjustment - Dynamic ..... 4.10 - 10  
     Ignition System General Maintenance And Inspection ..... 4.10 - 11

**Section 4.15 - Air Intake System Maintenance**

Air Intake System Maintenance ..... 4.15 - 1  
     Air Filter Maintenance ..... 4.15 - 1

**Section 4.20 - Turbocharger System Maintenance**

Turbocharger System Maintenance ..... 4.20 - 1  
     Turbocharger Inspection ..... 4.20 - 1  
     Turbocharger Lubrication Check ..... 4.20 - 2

**Section 4.25 - Cooling System Maintenance**

Cooling System Maintenance ..... 4.25 - 1  
     Cooling System Additives ..... 4.25 - 1  
     Cooling System Specifications And Recommendations ..... 4.25 - 2  
     Jacket Cooling Water Circuit - Initial Fill ..... 4.25 - 3  
     Auxiliary Cooling Water Circuit - Initial Fill ..... 4.25 - 4  
     Cooling Water System - Air Bleed ..... 4.25 - 4  
     Cooling Water Circuits - Drain And Flush ..... 4.25 - 5  
     Idle Pulley Bearing Lubrication ..... 4.25 - 8  
     Auxiliary Water Pump Bearings Lubrication ..... 4.25 - 8  
     Grease Recommendations ..... 4.25 - 9  
     Jacket Water Pump Drive Belts Replacement ..... 4.25 - 9  
     Jacket Water Pump Drive Belt Tension Adjustment ..... 4.25 - 11  
     Auxiliary Water Pump Drive Belt Replacement ..... 4.25 - 13  
     Auxiliary Water Pump Drive Belt Tension Adjustment ..... 4.25 - 14  
     Jacket/Auxiliary Water Pump Inspection ..... 4.25 - 16

**Section 4.30 - Lubrication System Maintenance**

Lubrication System Maintenance ..... 4.30 - 1  
     Oil Fill - Initial Procedure ..... 4.30 - 1  
     Oil Cooler and Lube Oil Filter Installation Requirements ..... 4.30 - 2  
     Purging The Lube Oil System Piping ..... 4.30 - 2  
     Crankcase Oil Level Checking ..... 4.30 - 3  
     Oil Change ..... 4.30 - 3  
     Oil Pan Maintenance ..... 4.30 - 4  
     Oil Pickup Screen Maintenance ..... 4.30 - 5  
     Oil Cooler Maintenance ..... 4.30 - 10  
     Lube Oil System Air Bleed ..... 4.30 - 10  
     Lube Oil Filter Maintenance ..... 4.30 - 11  
     Lube Oil Filter Relief Valve Inspection .. 4.30 - 13  
     Lube Oil Strainer Maintenance ..... 4.30 - 14  
     Magnetic Plug Maintenance ..... 4.30 - 15  
     In-line Lubricator ..... 4.30 - 15  
     Lube Oil Pressure Adjustment ..... 4.30 - 15  
     Prelube Y-Strainer maintenance ..... 4.30 - 16  
     MICROSPINE Maintenance ..... 4.30 - 17  
     Oil Recommendations ..... 4.30 - 19  
     Lubricating Oil Performance ..... 4.30 - 19  
     Oil Designations ..... 4.30 - 19  
     Oil Additives ..... 4.30 - 19  
     Catalyst Contaminants ..... 4.30 - 19  
     Oil Filtration Requirement ..... 4.30 - 19  
     Waukesha Cogeneration Installations - Oil Recommendations ..... 4.30 - 20  
     Sour Gas, Alternate Fuel Gas, And Landfill Gas Recommendations ..... 4.30 - 21  
     Recommended Lube Oils For Landfill Gas Applications ..... 4.30 - 21

## CONTENTS

Recommendations For Fuel Gas Filtration Of Solids And Liquids . . . . .	4.30 - 22
Lube Oil Condemning Limits . . . . .	4.30 - 23
Oil Viscosity Selection . . . . .	4.30 - 24
Multi-viscosity Oils . . . . .	4.30 - 24
Synthetic Oils . . . . .	4.30 - 24
Low Ambient Temperature Operation . . . . .	4.30 - 24
Lube Oil Consumption Rates . . . . .	4.30 - 24
Formulas For Determining Oil Consumption Rates . . . . .	4.30 - 24
Recommended Oil Change Intervals . . . . .	4.30 - 25
<b>Section 4.35 - Exhaust System Maintenance</b>	
Exhaust System Maintenance . . . . .	4.35 - 1
Exhaust System Backpressure Measurement . . . . .	4.35 - 1
Exhaust System Temperature Monitoring . . . . .	4.35 - 1
Exhaust System Inspection . . . . .	4.35 - 1
<b>Section 4.40 - Crankcase Breather System Maintenance</b>	
Crankcase Breather System Maintenance . . . . .	4.40 - 1
Separator Screen Maintenance . . . . .	4.40 - 1
Oil Separator(s) Maintenance . . . . .	4.40 - 3
Crankcase Pressure Check . . . . .	4.40 - 5
Crankcase Pressure Adjustment Controls . . . . .	4.40 - 6
Crankcase Pressure Adjustment . . . . .	4.40 - 7
Crankcase Breather Regulator Maintenance . . . . .	4.40 - 7
Crankcase Breather Regulator - Cleaning And Inspection . . . . .	4.40 - 8
Crankcase Pressure Relief Valves Maintenance . . . . .	4.40 - 8
<b>Section 4.45 - Prelube And Starting System Maintenance</b>	
Prelube And Starting System Maintenance . . . . .	4.45 - 1
Electric Starter System Maintenance . . . . .	4.45 - 1
Air/Gas Starter Lubrication Reservoir Maintenance . . . . .	4.45 - 1
In-line Lubricator . . . . .	4.45 - 2
<b>Section 4.50 - Engine Protection Shutdown System Maintenance</b>	
Engine Protection Shutdown System Maintenance . . . . .	4.50 - 1
K-Type Thermocouples Inspection . . . . .	4.50 - 1
Manual Shutdown Lever Maintenance . . . . .	4.50 - 1
Pressure And Temperature Switches Calibration . . . . .	4.50 - 1
Optional Instrument Panel . . . . .	4.50 - 1
Detonation Sensing Module And Sensors . . . . .	4.50 - 2
<b>Section 4.55 - Valve Adjustment</b>	
Valve Adjustment . . . . .	4.55 - 1
Intake And Exhaust Valves - Adjustment - 5115GL Engines Only . . . . .	4.55 - 1
Intake And Exhaust Valves - Adjustment - 6, 12 And 16 Cylinder VHP Gas Engines - Excluding 5115GL . . . . .	4.55 - 5
<b>Section 4.60 - Maintenance Shedule</b>	
Maintenance Schedule . . . . .	4.60 - 1
<b>Section 4.65 - Engine Storage</b>	
Engine Storage . . . . .	4.65 - 1
Preservation Equipment And Material . . . . .	4.65 - 1
Waukesha Engine Preservative Oil . . . . .	4.65 - 2
Waukesha Engine Preservative Oil Usage . . . . .	4.65 - 2
Use Of Other Preservative Oils And Materials . . . . .	4.65 - 2
Engine Storage - New . . . . .	4.65 - 3
Operational . . . . .	4.65 - 3
Non-Operational . . . . .	4.65 - 3
Engine Storage - Used . . . . .	4.65 - 4
Operational . . . . .	4.65 - 4
Non-Operational . . . . .	4.65 - 4
Engines Returned To Service After Storage . . . . .	4.65 - 4
<b>CHAPTER 5 - TROUBLESHOOTING</b>	
<b>Section 5.00 - Troubleshooting</b>	
Troubleshooting . . . . .	5.00 - 1
Alphabetical Index . . . . .	A - 1
<b>WARRANTY</b>	
Waukesha Engine Division - Dresser Industries, Inc.	

LIST OF ILLUSTRATIONS

**Section 1.00 - Warning Tags And Decal Locations**

Figure 1.00-1. VHP 6 Cylinder Safety Label Locations ..... 1.00 - 3

Figure 1.00-2. VHP 12 Cylinder Safety Label Locations ..... 1.00 - 5

Figure 1.00-3. VHP 12 Cylinder Safety Label Locations ..... 1.00 - 6

Figure 1.00-4. VHP 16 Cylinder Safety Label Locations ..... 1.00 - 7

Figure 1.00-5. VHP 16 Cylinder Safety Label Locations ..... 1.00 - 8

Figure 1.00-6. Warning Label - P/N 211910A - Safety Guard ..... 1.00 - 9

Figure 1.00-7. Warning Label - P/N 211910J - Safety Guard ..... 1.00 - 9

Figure 1.00-8. Warning Label - P/N 211910K - Safety Guard ..... 1.00 - 9

Figure 1.00-9. Warning Label - P/N 211910L - Safety Guard ..... 1.00 - 9

Figure 1.00-10. Warning Label - P/N 211910M - Safety Guard ..... 1.00 - 10

Figure 1.00-11. Warning Label - P/N 211910N - Maximum Gas Regulator Pressure ..... 1.00 - 10

Figure 1.00-12. Warning Label - P/N 211910S - Vent Flammable Gas ... 1.00 - 10

Figure 1.00-13. Warning Label - P/N 211911 - Maximum Air Prelube Motor Pressure ..... 1.00 - 10

Figure 1.00-14. Warning Label - P/N 211910W - Gas Venting ..... 1.00 - 10

Figure 1.00-15. Warning Label - P/N 211911B - Built Without Engine Protection ..... 1.00 - 11

Figure 1.00-16. Warning Label - P/N 211911C - Barring Device ..... 1.00 - 11

Figure 1.00-17. Warning Label - P/N 211911D - Built Without An Ignition System ..... 1.00 - 12

Figure 1.00-18. Warning Label - P/N 211911E - 150 psi Gas Inlet Pressure 1.00 - 12

Figure 1.00-19. Caution Label - P/N 211920D - Hot Surface ..... 1.00 - 12

Figure 1.00-20. Caution Label - P/N 211920E - Hot Components ..... 1.00 - 13

Figure 1.00-21. Caution Label - P/N 211920F - Eye/Ear Protection ..... 1.00 - 13

Figure 1.00-22. Safety Instructions - P/N 211930A - Lifting Instructions ..... 1.00 - 13

**Section 1.10 - Rigging And Lifting Engines**

Figure 1.10-1. Correct Method Of Lifting Engine - 6 Cylinder - Side Views ..... 1.10 - 2

Figure 1.10-2. Correct Method Of Lifting Engine - 6 Cylinder - Rear View ..... 1.10 - 2

Figure 1.10-3. Correct Method Of Lifting 12 And 16 Cylinder Engines - 12 Cylinder Side Views Shown ..... 1.10 - 3

Figure 1.10-4. Correct Method Of Lifting 12 And 16 Cylinder Engines - 12 Cylinder Rear View Shown ..... 1.10 - 3

**Section 1.15 - General Information**

Figure 1.15-1. Optional Remote Instrument Panel ..... 1.15 - 3

Figure 1.15-2. Nameplate - Current Production ..... 1.15 - 4

Figure 1.15-3. Nameplate - Previous Production ..... 1.15 - 5

Figure 1.15-4. Right Side View - 6 Cylinder VHP GL ..... 1.15 - 6

Figure 1.15-5. Left Side View - 6 Cylinder VHP GL ..... 1.15 - 7

Figure 1.15-6. Rear View - 6 Cylinder VHP GL ..... 1.15 - 8

Figure 1.15-7. Left Side View - 5115GL ..... 1.15 - 9

Figure 1.15-8. Right Side View - 5115GL ... 1.15 - 10

Figure 1.15-9. Rear View - 5115GL ..... 1.15 - 11

Figure 1.15-10. Front View - 5115GL ..... 1.15 - 12

Figure 1.15-11. Right Side View - 12 Cylinder VHP GL ..... 1.15 - 13

Figure 1.15-12. Left Side View - 12 Cylinder VHP GL ..... 1.15 - 14

Figure 1.15-13. Rear View - 12 Cylinder VHP GL ..... 1.15 - 15

Figure 1.15-14. Right Side View - 16 Cylinder VHP GL ..... 1.15 - 16

Figure 1.15-15. Front View - 16 Cylinder VHP GL ..... 1.15 - 17

Figure 1.15-16. Rear View - 16 Cylinder VHP GL ..... 1.15 - 18

**Section 2.00 - Speed Governing System Description**

Figure 2.00-1. Woodward UG-8L Governor .. 2.00 - 1

Figure 2.00-2. Woodward UG-8 Dial Governor ..... 2.00 - 2

Figure 2.00-3. EG-3P Governor - 6 Cylinder Shown ..... 2.00 - 2

Figure 2.00-4. Overspeed Pressure Switch ... 2.00 - 2

Figure 2.00-5. Governor Speed Control Lever - 5115GL ..... 2.00 - 3

Figure 2.00-6. Manual Shutdown Lever - 5115GL ..... 2.00 - 3

## ILLUSTRATIONS

Figure 2.00-7. 2301A Load Sharing And Speed Control .....	2.00 - 4
Figure 2.00-8. 2301A Speed Control .....	2.00 - 4

### Section 2.05 - Fuel System Description

Figure 2.05-1. 5115GL Right Side Engine View .....	2.05 - 1
Figure 2.05-2. Fisher 99 Main Fuel Gas Pressure Regulator - 12 Cylinder GSI ...	2.05 - 1
Figure 2.05-3. Carburetor - 5115GL Right Side View .....	2.05 - 2
Figure 2.05-4. Prechamber Regulator 5115GL .....	2.05 - 2
Figure 2.05-5. Prechamber Gas Valve - 6 Cylinder GL Engine Shown .....	2.05 - 2
Figure 2.05-6. Prechamber Gas Safety Shutdown Valve - 6 Cylinder Engine GL Shown .....	2.05 - 3
Figure 2.05-7. Admission Valves - 6 Cylinder GL Shown .....	2.05 - 3
Figure 2.05-8. Prechamber/Spark Plug Carrier Assembly GL Engines .....	2.05 - 4
Figure 2.05-9. Air/Fuel Module Front Panel ..	2.05 - 4
Figure 2.05-10. AFM Actuator - 6 Cylinder Engine Shown .....	2.05 - 5
Figure 2.05-11. Draw-thru Engine - 6 Cylinder Engine Shown .....	2.05 - 5
Figure 2.05-12. Draw-thru Engine - 6 Cylinder Engine Shown .....	2.05 - 5

### Section 2.10 - Ignition System Description

Figure 2.10-1. Spark Plug Carriers .....	2.10 - 1
Figure 2.10-2. Spark Plug Carrier And Prechamber Design - GL Engine Cylinder Head Cutaway View .....	2.10 - 2
Figure 2.10-3. Spark Plug, Connector, And Ignition Coil - Standard Ignition .....	2.10 - 2
Figure 2.10-4. IM Diagnostic LEDs .....	2.10 - 2
Figure 2.10-5. Hall-effect And Timing Disc - Internal View 5115GL .....	2.10 - 3
Figure 2.10-6. Hall-effect Sensor And Timing Disc - P9390 .....	2.10 - 3
Figure 2.10-7. Hall-effect Pickup Location - 6 and 12 Cylinder Engines - 12 Cylinder Shown .....	2.10 - 3
Figure 2.10-8. Magneto .....	2.10 - 4
Figure 2.10-9. CSA Spark Plug Adapter And Coil - G, GSI .....	2.10 - 4
Figure 2.10-10. CSA Ignition - GL Engines - 6 Cylinder Shown .....	2.10 - 4
Figure 2.10-11. Detonation Sensing Module Front Panel .....	2.10 - 5

### Section 2.15 - Air Intake System Description

Figure 2.15-1. 6 Cylinder GSI .....	2.15 - 1
Figure 2.15-2. 12 Cylinder GL .....	2.15 - 1
Figure 2.15-3. 16 Cylinder GSI .....	2.15 - 1
Figure 2.15-4. 6 Cylinder GSI - Rear View ...	2.15 - 2
Figure 2.15-5. 12 Cylinder GL - Rear View ...	2.15 - 2
Figure 2.15-6. 16 Cylinder GSI .....	2.15 - 2

### Section 2.20 - Turbocharger System Description

Figure 2.20-1. Turbocharger - 6 Cylinder Rear View .....	2.20 - 1
Figure 2.20-2. Turbochargers - 12 Cylinder GL Rear View .....	2.20 - 1
Figure 2.20-3. Turbochargers - 16 Cylinder GSI Side View .....	2.20 - 1

### Section 2.25 - Cooling System Description

Figure 2.25-1. Water Outlet Elbows .....	2.25 - 1
Figure 2.25-2. 6 Cylinder Engine Cooling Components .....	2.25 - 2
Figure 2.25-3. 12 Cylinder Engine Cooling Components .....	2.25 - 2
Figure 2.25-4. 5115GL Engine Cooling Components .....	2.25 - 3
Figure 2.25-5. 16 Cylinder Engine Cooling Components .....	2.25 - 3
Figure 2.25-6. Surge Tank (Optional) .....	2.25 - 4
Figure 2.25-7. Intercoolers - 12 Cylinder Engine .....	2.25 - 4
Figure 2.25-8. Intercoolers - 16 Cylinder Engine .....	2.25 - 4
Figure 2.25-9. Oil Cooler - 6 Cylinder Engine Shown .....	2.25 - 5

### Section 2.30 - Lubrication System Description

Figure 2.30-1. Internal Oil Flow System .....	2.30 - 2
Figure 2.30-2. External Oil System Schematic .....	2.30 - 3
Figure 2.30-3. 6 Cylinder Engine Oil Pan And Pickup Screen Assembly .....	2.30 - 4
Figure 2.30-4. 6 And 12 Cylinder Engine Oil Pump - 6 Cylinder Shown .....	2.30 - 4
Figure 2.30-5. 5115GL Oil Pump .....	2.30 - 4
Figure 2.30-6. 16 Cylinder Engine Oil Pump ..	2.30 - 4
Figure 2.30-7. Oil Cooler - 6 Cylinder Engine Shown .....	2.30 - 5
Figure 2.30-8. Lube Oil Strainer - 5115GL Engine Shown .....	2.30 - 5
Figure 2.30-9. MICROSPIN® Centrifuge Assembly .....	2.30 - 6
Figure 2.30-10. Cleanable Oil Filter Elements - All VHP, AT, F817G, F1197G, And VGF (Vee) Engines .....	2.30 - 6



Figure 2.30-11. Prelube Pushbutton Valve ... 2.30 - 7  
 Figure 2.30-12. Prelube Motor/Pump Assembly - Similar All Engines ..... 2.30 - 7  
 Figure 2.30-13. Prelube Valve - 6 Cylinder Engine Shown ..... 2.30 - 7  
 Figure 2.30-14. In-line Lubricator ..... 2.30 - 8

**Section 2.35 - Exhaust System Description**

Figure 2.35-1. Exhaust System Components . 2.35 - 1  
 Figure 2.35-2. Water Outlet Elbows ..... 2.35 - 1  
 Figure 2.35-3. Turbocharger and Wastegate - 6 Cylinder Engine Shown ..... 2.35 - 2

**Section 2.40 - Crankcase Breather System Description**

Figure 2.40-1. Crankcase Separator Screen - 6 Cylinder Engine Shown ..... 2.40 - 1  
 Figure 2.40-2. Crankcase Separator Screen - 12 Cylinder Engine Shown ..... 2.40 - 1  
 Figure 2.40-3. Oil Separator Assembly - 6 Cylinder Engine Shown ..... 2.40 - 2  
 Figure 2.40-4. Oil Separator Assembly - 5115GL Engine Rear Right ..... 2.40 - 2  
 Figure 2.40-5. Oil Separator Assembly - 5115GL Engine Front Left ..... 2.40 - 2  
 Figure 2.40-6. Oil Separator Assembly - 16 Cylinder Engine Shown ..... 2.40 - 3  
 Figure 2.40-7. Oil Separator - 6 And 12 Cylinder Engine ..... 2.40 - 3  
 Figure 2.40-8. Venturi/Adjusting Screw Assembly - 6 Cylinder GSI Shown ..... 2.40 - 4  
 Figure 2.40-9. Ejector Breather/Adjusting Valve Assembly - 6 Cylinder Shown .... 2.40 - 4  
 Figure 2.40-10. Vacuum Valve Assembly .... 2.40 - 4  
 Figure 2.40-11. Vacuum Valve Assembly ..... 2.40 - 4  
 Figure 2.40-12. Venturi Extractor/Choke Valve Assembly - 12 Cylinder GL Shown ..... 2.40 - 4  
 Figure 2.40-13. Breather Regulator ..... 2.40 - 5  
 Figure 2.40-14. Crankcase Pressure Relief Valve ..... 2.40 - 5

**Section 2.45 - Prelube And Starting System Description**

Figure 2.45-1. Start And Prelube Pushbutton Valves ..... 2.45 - 1  
 Figure 2.45-2. Prelube Pump and Motor ..... 2.45 - 1  
 Figure 2.45-3. In-line Lubricator ..... 2.45 - 2  
 Figure 2.45-4. Air /Gas Starter ..... 2.45 - 2  
 Figure 2.45-5. Electric Starter ..... 2.45 - 2

**Section 2.50 - Engine Protection Shutdown System Description**

Figure 2.50-1. Lube Oil Inlet Temperature Sensor - 5115GL Engine Shown ..... 2.50 - 1  
 Figure 2.50-2. Jacket Water Temperature Sensor - 5115GL Engine Shown ..... 2.50 - 1  
 Figure 2.50-3. Exhaust Thermocouples Arrangement - 12 Cylinder Engine ..... 2.50 - 2  
 Figure 2.50-4. Intake Manifold Temperature Sensor - 5115GL Engine Shown ..... 2.50 - 2  
 Figure 2.50-5. Exhaust Thermocouple - 12 Cylinder Engine Rear Left ..... 2.50 - 2  
 Figure 2.50-6. Main Bearing Temperature Thermocouples -12 Cylinder Engine .... 2.50 - 3  
 Figure 2.50-7. Thermocouple Junction Box And Governor Speed Control Lever - 5115GL Engine ..... 2.50 - 3  
 Figure 2.50-8. Manual Shutdown Lever - 12 Cylinder ..... 2.50 - 3  
 Figure 2.50-9. Control Panel - Left Side ..... 2.50 - 4  
 Figure 2.50-10. 16 Cylinder Control Panel ... 2.50 - 4  
 Figure 2.50-11. Optional Remote Instrument Panel ..... 2.50 - 4  
 Figure 2.50-12. Detonation Sensing Module Front Panel ..... 2.50 - 5  
 Figure 2.50-13. Detonation Sensing Module LCD Display ..... 2.50 - 5  
 Figure 2.50-14. Detonation Sensor (VHP Series) ..... 2.50 - 5

**Section 3.00 - Engine Startup And Shutdown**

Figure 3.00-1. Engine Guards - 5115GL Engine Shown ..... 3.00 - 1  
 Figure 3.00-2. Air Restriction Indicator/Filter - 6 Cylinder Engine Shown ..... 3.00 - 2  
 Figure 3.00-3. Engine Barring Device - 12 Cylinder Engine ..... 3.00 - 2  
 Figure 3.00-4. Dipstick ..... 3.00 - 2  
 Figure 3.00-5. Woodward UG-8L Governor .. 3.00 - 3  
 Figure 3.00-6. Control Panel - 12 Cylinder Engine ..... 3.00 - 3  
 Figure 3.00-7. Control Panel - 16 Cylinder Engine ..... 3.00 - 3  
 Figure 3.00-8. Manual Shutdown Lever - 12 Cylinder GL Engine ..... 3.00 - 4  
 Figure 3.00-9. Manual Shutdown Lever - 16 Cylinder GSI Engine ..... 3.00 - 4  
 Figure 3.00-10. Manual Shutdown Lever - 6 Cylinder GSI Engine ..... 3.00 - 4  
 Figure 3.00-11. Governor Speed Control Lever - 12 Cylinder Engine ..... 3.00 - 4  
 Figure 3.00-12. Governor Speed Control Lever - 16 Cylinder Engine ..... 3.00 - 5  
 Figure 3.00-13. Fuel Shutoff Valve - Customer Supplied ..... 3.00 - 5

## ILLUSTRATIONS

Figure 3.00-14. Thermocouple Selection Switch - 16 Cylinder .....	3.00 - 6
Figure 3.00-15. Optional Remote Instrument Panel .....	3.00 - 6
Figure 3.00-16. Air Restriction Indicator - 5115GL Engine .....	3.00 - 6
Figure 3.00-17. Air Restriction Indicator - 16 Cylinder Engine .....	3.00 - 7
Figure 3.00-18. Detonation Sensing Module - Front Panel .....	3.00 - 7
Figure 3.00-19. IM Diagnostic LEDs .....	3.00 - 7
Figure 3.00-20. Control Panel - 12 Cylinder Engine Right Side .....	3.00 - 9
Figure 3.00-21. Control Panel - 12 Cylinder Engine Left Side .....	3.00 - 9
Figure 3.00-22. CSA Control Panel - 6 Cylinder Engine Right Side .....	3.00 - 9
Figure 3.00-23. Control Panel - 16 Cylinder Engine Right Side .....	3.00 - 9
Figure 3.00-24. Manual Shutdown Lever - 6 Cylinder GSI Engine .....	3.00 - 10
Figure 3.00-25. Manual Shutdown Lever - 12 Cylinder .....	3.00 - 10
Figure 3.00-26. Manual Shutdown Lever - 16 Cylinder GSI Engine .....	3.00 - 10
Figure 3.00-27. Governor Speed Control Lever - 12 Cylinder Engine .....	3.00 - 11

### Section 4.00 - Speed Governing System Maintenance

Figure 4.00-1. Governor Oil Level Sight Glass .....	4.00 - 1
Figure 4.00-2. Woodward UG-8L Governor .....	4.00 - 1
Figure 4.00-3. Governor Rod Assembly .....	4.00 - 2

### Section 4.05 - Fuel System Maintenance

Figure 4.05-1. Admission Valve Assembly .....	4.05 - 1
Figure 4.05-2. Admission Valve .....	4.05 - 1
Figure 4.05-3. Spring Seats In Cold Poppets .....	4.05 - 2
Figure 4.05-4. Install Stainless Steel Washer In Cylinder Head .....	4.05 - 3

### Section 4.10 - Ignition System Maintenance

Figure 4.10-1. Install Spark Plug/Connections .....	4.10 - 2
Figure 4.10-2. Install Spark Plug/Connections P/N 211357H Extension .....	4.10 - 2
Figure 4.10-3. Spark Plug Carriers .....	4.10 - 3
Figure 4.10-4. Apply KRYTOX® GPL-206 Grease .....	4.10 - 3
Figure 4.10-5. VHP Spark Plug Recess Cover .....	4.10 - 4
Figure 4.10-6. VHP Spark Plug Recess Cover Vent Cap .....	4.10 - 4

Figure 4.10-7. CSA Spark Adapter And Coil - G, GSI .....	4.10 - 5
Figure 4.10-8. CSA Spark Adapter And Coil - G, GSI .....	4.10 - 5
Figure 4.10-9. CSA Spark Plug - G, GSI .....	4.10 - 5
Figure 4.10-10. CSA GL Spark Plug Extension And Coil Assembly - Current Production .....	4.10 - 6
Figure 4.10-11. Apply KRYTOX® GPL-206 Grease .....	4.10 - 7
Figure 4.10-12. Spark Plug Extension .....	4.10 - 7
Figure 4.10-13. Timing Pointer - Rear Right .....	4.10 - 8
Figure 4.10-14. Magneto/Magneto Adapter Flange .....	4.10 - 8
Figure 4.10-15. Timing Tapes .....	4.10 - 9
Figure 4.10-16. Timing Switches "A" And "B" .....	4.10 - 10
Figure 4.10-17. Flywheel Timing Opening .....	4.10 - 10

### Section 4.15 - Air Intake System Maintenance

Figure 4.15-1. Air Cleaner Assembly - 6 And 12 Cylinder Engines .....	4.15 - 1
Figure 4.15-2. Air Cleaner Assembly - 6 And 12 Cylinder Engines .....	4.15 - 2
Figure 4.15-3. Air Cleaner Assembly - 6 Cylinder .....	4.15 - 3
Figure 4.15-4. Air Cleaner Assembly - 16 Cylinder Engines .....	4.15 - 4
Figure 4.15-5. Air Cleaner Assembly - 16 Cylinder .....	4.15 - 5
Figure 4.15-6. Prefilter Pad - 16 Cylinder .....	4.15 - 5

### Section 4.20 - Turbocharger System Maintenance

Figure 4.20-1. 5115GL - Rear View .....	4.20 - 1
Figure 4.20-2. Turbochargers - 16 Cylinder GSI Side View .....	4.20 - 1
Figure 4.20-3. Turbocharger Oil Drain Tubes - 12 Cylinder .....	4.20 - 2

### Section 4.25 - Cooling System Maintenance

Figure 4.25-1. Customer Supplied Ball Valve - 12 Cylinder .....	4.25 - 3
Figure 4.25-2. Idler Pulley Bearing Lube - 12 Cylinder Shown .....	4.25 - 8
Figure 4.25-3. Idler Pulley Bearing Lube - 16 Cylinder .....	4.25 - 8
Figure 4.25-4. Auxiliary Water Pump Lube - 6 Cylinder .....	4.25 - 8
Figure 4.25-5. Auxiliary Water Pump Lube - 12 Cylinder .....	4.25 - 9
Figure 4.25-6. Auxiliary Water Pump Lube - 16 Cylinder .....	4.25 - 9
Figure 4.25-7. Adjusting/Idler Lever Assembly - 12 Cylinder Shown .....	4.25 - 10

Figure 4.25-8. Adjusting/Idler Lever Assembly - 6 Cylinder Shown . . . . . 4.25 - 10

Figure 4.25-9. Tighten Idler Pulley Bracket Bolts - 12 Cylinder Shown . . . . . 4.25 - 10

Figure 4.25-10. Drive Belt Tension Tester . . . . . 4.25 - 11

Figure 4.25-11. Jacket Water Pump Drive Belt Tensioning - 12 Cylinder Shown . . . . . 4.25 - 12

Figure 4.25-12. Jacket Water Pump Drive Belt Tension - 12 Cylinder Shown . . . . . 4.25 - 12

Figure 4.25-13. Adjusting/Idler Lever Assembly - 6 Cylinder Shown . . . . . 4.25 - 13

Figure 4.25-14. Adjusting/Idler Lever Assembly - 12 Cylinder . . . . . 4.25 - 13

Figure 4.25-15. Auxiliary Water Pump Belts - 12 Cylinder . . . . . 4.25 - 13

Figure 4.25-16. Jacket And Auxiliary Water Pump Belts - 12 Cylinder . . . . . 4.25 - 14

Figure 4.25-17. Drive Belt Tension Tester . . . . . 4.25 - 15

Figure 4.25-18. Jacket Water Pump "Weep" Hole - Water Pump Shown Removed . . . . . 4.25 - 16

Figure 4.25-19. Auxiliary Water Pump - 5115GL . . . . . 4.25 - 16

**Section 4.30 - Lubrication System Maintenance**

Figure 4.30-1. Dipstick . . . . . 4.30 - 1

Figure 4.30-2. Oil Filler Pipe . . . . . 4.30 - 2

Figure 4.30-3. Lube Oil Strainer Assembly . . . . . 4.30 - 2

Figure 4.30-4. Oil Pan Door - Previous Production . . . . . 4.30 - 4

Figure 4.30-5. Oil Pan Door Assembly - Current Production . . . . . 4.30 - 5

Figure 4.30-6. Oil Pickup Screen Assembly - 6 Cylinder . . . . . 4.30 - 5

Figure 4.30-7. Oil Pickup Screen Assembly - 12 Cylinder . . . . . 4.30 - 6

Figure 4.30-8. Oil Pickup Screen Assembly - 5115 . . . . . 4.30 - 8

Figure 4.30-9. Oil Pickup Screen Assembly - 16 Cylinder . . . . . 4.30 - 9

Figure 4.30-10. Ferry Head Capscrew - 16 Cylinder . . . . . 4.30 - 10

Figure 4.30-11. Lube Oil Filter . . . . . 4.30 - 11

Figure 4.30-12. Full-Flow Lube Oil Filter . . . . . 4.30 - 12

Figure 4.30-13. Filter Element/Relief Valve Configuration - 6 Cylinder . . . . . 4.30 - 12

Figure 4.30-14. Filter Element/Relief Valve Configuration - 12 Cylinder . . . . . 4.30 - 12

Figure 4.30-15. Filter Element/Relief Valve Configuration - 16 Cylinder . . . . . 4.30 - 12

Figure 4.30-16. Lube Oil Filter Relief Valve Assembly . . . . . 4.30 - 13

Figure 4.30-17. Lube Oil Strainer Assembly . . . . . 4.30 - 14

Figure 4.30-18. Magnetic Plugs . . . . . 4.30 - 15

Figure 4.30-19. Lube Oil Temperature Control Valve . . . . . 4.30 - 15

Figure 4.30-20. Y-Strainer - 12 Cylinder . . . . . 4.30 - 16

Figure 4.30-21. Prelube Y-Strainer . . . . . 4.30 - 16

Figure 4.30-22. Cleanable Oil Filter Elements - All VHP, AT, F817G, F1197G, And VGF (Vee) Engines . . . . . 4.30 - 17

Figure 4.30-23. Service And Cleaning Of MICROSPIN™ P/N 489189 Centrifuge . . . . . 4.30 - 18

Figure 4.30-24. Can Nut - Side View . . . . . 4.30 - 18

**Section 4.40 - Crankcase Breather System Maintenance**

Figure 4.40-1. Crankcase Separator Screen - 6 Cylinder . . . . . 4.40 - 1

Figure 4.40-2. Crankcase Separator Screen - 6 Cylinder . . . . . 4.40 - 1

Figure 4.40-3. Crankcase - Rear Right . . . . . 4.40 - 2

Figure 4.40-4. Crankcase Separator Screen Assembly - 12 Cylinder GL Shown . . . . . 4.40 - 2

Figure 4.40-5. Oil Separator 6 And 12 Cylinder Engine . . . . . 4.40 - 3

Figure 4.40-6. Oil Separator Assembly - 5115GL Engine Rear Right . . . . . 4.40 - 3

Figure 4.40-7. Pry Screen From Cover . . . . . 4.40 - 3

Figure 4.40-8. Wring Foam Dry . . . . . 4.40 - 4

Figure 4.40-9. Install Foam In Screen . . . . . 4.40 - 4

Figure 4.40-10. Press Screen Into Cover . . . . . 4.40 - 4

Figure 4.40-11. Wash Separator With Solvent . . . . . 4.40 - 4

Figure 4.40-12. Oil Separator - 16 Cylinder Engine . . . . . 4.40 - 5

Figure 4.40-13. Oil Separator - 16 Cylinder Engine . . . . . 4.40 - 5

Figure 4.40-14. Install Water Manometer Tube Connector . . . . . 4.40 - 5

Figure 4.40-15. Water Manometer . . . . . 4.40 - 6

Figure 4.40-16. Venturi/Adjusting Screw Assembly - 6 Cylinder GSI Shown . . . . . 4.40 - 6

Figure 4.40-17. Ejector Breather/Adjusting Valve Assembly - 6 Cylinder Shown . . . . . 4.40 - 6

Figure 4.40-18. Vacuum Valve Assembly . . . . . 4.40 - 6

Figure 4.40-19. Vacuum Valve Assembly . . . . . 4.40 - 6

Figure 4.40-20. Venturi Extractor/Choke Valve Assembly - 12 Cylinder GL Shown . . . . . 4.40 - 7

Figure 4.40-21. Breather Regulator . . . . . 4.40 - 7

Figure 4.40-22. Breather Regulator Assembly . . . . . 4.40 - 8

Figure 4.40-23. Crankcase Pressure Relief Valve . . . . . 4.40 - 8

**Section 4.45 - Prelube And Starting System Maintenance**

Figure 4.45-1. Electric Starter . . . . . 4.45 - 1

Figure 4.45-2. Air/Gas Starter . . . . . 4.45 - 1

Figure 4.45-3. Air/Gas Starter Reservoir . . . . . 4.45 - 2

## ILLUSTRATIONS

---

- Figure 4.45-4. In-line Lubricator And  
Prelube Motor/Pump Assembly ..... 4.45 - 2
- Figure 4.45-5. In-line Lubricator ..... 4.45 - 3

### **Section 4.50 - Engine Protection Shutdown System Maintenance**

- Figure 4.50-1. Jacket Water Temperature  
Sensor - 5115GL Engine Shown ..... 4.50 - 1
- Figure 4.50-2. Manual Shutdown Lever -  
12 Cylinder VHP GL Shown ..... 4.50 - 1
- Figure 4.50-3. Detonation Sensor -  
VHP Series ..... 4.50 - 2

### **Section 4.55 - Valve Adjustment**

- Figure 4.55-1. Engine Firing Order And  
Direction Of Rotation - 5115GL Engine .. 4.55 - 2
- Figure 4.55-2. Engine Barring Device ..... 4.55 - 2
- Figure 4.55-3. Nameplate -  
Current Production ..... 4.55 - 3
- Figure 4.55-4. Rocker Arm Assembly -  
All Engines Similar ..... 4.55 - 3
- Figure 4.55-5. Rocker Arms ..... 4.55 - 4
- Figure 4.55-6. Rocker Arms ..... 4.55 - 4
- Figure 4.55-7. Engine Firing Order And  
Direction Of Rotation - 6, 12, And  
16 Cylinder Engine, Excluding 5115GL .. 4.55 - 6
- Figure 4.55-8. Nameplate -  
Current Production ..... 4.55 - 7
- Figure 4.55-9. Engine Barring Device ..... 4.55 - 7
- Figure 4.55-10. Rocker Arms ..... 4.55 - 8
- Figure 4.55-11. Previous Rocker Arm  
Adjusting Screws ..... 4.55 - 8
- Figure 4.55-12. Current Rocker Arm  
Adjusting Screws ..... 4.55 - 8
- Figure 4.55-13. Hydraulic Lifter ..... 4.55 - 8
- Figure 4.55-14. Valve Adjusting Wrench ..... 4.55 - 9

**LIST OF TABLES**

**Section 1.00 - Warning Tags And Decal Locations**

Table 1.00-1. VHP 6 Cylinder Engine Safety Labels ..... 1.00 - 2  
 Table 1.00-2. VHP 12 Cylinder Engine Safety Labels ..... 1.00 - 4  
 Table 1.00-3. VHP 16 Cylinder Engine Safety Labels ..... 1.00 - 7

**Section 1.10 - Rigging And Lifting Engines**

Table 1.10-1. Engine Dry Weights ..... 1.10 - 1

**Section 1.15 - General Information**

Table 1.15-1. Engine Models ..... 1.15 - 1  
 Table 1.15-2. VHP Specifications ..... 1.15 - 19  
 Table 1.15-3. Torque Values ..... 1.15 - 22  
 Table 1.15-4. 1/2 Inch Reach Spark Plugs (Used On G and GSI, and 1/2 Inch Reach Spark Plug Carriers on GL Only) ..... 1.15 - 22  
 Table 1.15-5. VHP GL 13/16 Inch Reach Spark Plugs (Used With 13/16 Inch Reach Spark Plug Carriers Only) ..... 1.15 - 23  
 Table 1.15-6. Service Tools ..... 1.15 - 24

**Section 3.00 - Engine Startup And Shutdown**

Table 3.00-1. Engine Performance Record Example ..... 3.00 - 12

**Section 4.10 - Ignition System Maintenance**

Table 4.10-1. Spark Plug Troubleshooting .... 4.10 - 1  
 Table 4.10-2. Spark Plug Tools ..... 4.10 - 2

**Section 4.25 - Cooling System Maintenance**

Table 4.25-1. Water Versus Glycol Concentration ..... 4.25 - 1  
 Table 4.25-2. Other Cooling System Treatments ..... 4.25 - 2  
 Table 4.25-3. Air Bleed Petcocks ..... 4.25 - 5  
 Table 4.25-4. Water Drain Petcocks ..... 4.25 - 6

**Section 4.30 - Lubrication System Maintenance**

Table 4.30-1. Lubrication System ..... 4.30 - 1  
 Table 4.30-2. Oil Recommendations By Model And Fuel ..... 4.30 - 4  
 Table 4.30-3. Oil Filter Capscrew Pattern ... 4.30 - 11  
 Table 4.30-4. Engine Filter Elements ..... 4.30 - 12  
 Table 4.30-5. Magnetic Plug Locations ..... 4.30 - 15

Table 4.30-6. Recommended Lube Oils For Cogeneration Applications - Using Pipeline Quality Gas ..... 4.30 - 20  
 Table 4.30-7. Recommended Lube Oils For Landfill Gas Applications ..... 4.30 - 21  
 Table 4.30-8. Used Oil Testing And Condemnation ..... 4.30 - 23  
 Table 4.30-9. Sump And Header Temperatures And SAE Number ..... 4.30 - 24  
 Table 4.30-10. Oil Consumption ..... 4.30 - 24  
 Table 4.30-11. Recommended Oil Change Intervals For Engines Receiving Normal Maintenance ..... 4.30 - 25  
 Table 4.30-12. Recommended Oil Change Intervals For Engines Receiving Normal Maintenance And Using Gaseous Fuel Containing H<sub>2</sub>S In Excess Of Published Limits. .... 4.30 - 25  
 Table 4.30-13. Duty Cycle Definitions ..... 4.30 - 25

**Section 4.35 - Exhaust System Maintenance**

Table 4.35-1. Maximum Allowable Exhaust Backpressure And Reductions For Speed And Load ..... 4.35 - 2

**Section 4.55 - Valve Adjustment**

Table 4.55-1. Valve Settings - 5115GL Engines Only ..... 4.55 - 1  
 Table 4.55-2. Valve Settings 6, 12, And 16 Cylinder VHP Gas Engines - Excluding 5115GL ..... 4.55 - 5

**Section 4.60 - Maintenance Shedule**

Table 4.60-1. Routine Maintenance Chart .... 4.60 - 1

**Section 4.65 - Engine Storage**

Table 4.65-1. Waukesha Engine Preservative Oil Application ..... 4.65 - 1  
 Table 4.65-2. Preservative Oils ..... 4.65 - 3  
 Table 4.65-3. Protective Materials ..... 4.65 - 3

**Section 5.00 - Troubleshooting**

Table 5.00-1. Troubleshooting Table ..... 5.00 - 1

# TABLES

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## HOW TO USE THIS MANUAL

Your purchase of a Waukesha VHP Series engine was a wise investment. In the industrial engine field the name, Waukesha Engine, stands for quality and durability. With normal care and maintenance this engine will provide many years of reliable service.

Before placing the engine in service read Chapters 1 and 2 very carefully. These chapters cover Safety, General Information and Engine Operation.

Section 1.00 - *Warning Tags And Decal Location* - gives the location of all warning tags and decals and will show you a duplicate of each tag is illustrated in case the decals or tags have been lost or damaged.

Section 1.05 - *Safety Section* - Provides a list of warnings and cautions to make you aware of the dangers present during operation and maintenance of the engine. - **READ THEM CAREFULLY AND FOLLOW THEM COMPLETELY** -

Section 1.10 - *Rigging and Lifting Engines* - Provides information on engine weights and proper lifting procedures.

Section 1.15 - *General Information* - Provides basic data on the engines such as; engine plate data, specifications and description.

Section 1.20 - *Engine Systems* - Provides basic information on each engine system.

Section 2.00 - *Engine Startup and Shutdown* - provides prestart inspection, troubleshooting, routine startup and shutdown.

This manual contains both operation and maintenance instructions for the VHP engines. There are four chapters within the manual and each chapter contains one or more sections. The title of each chapter or section appears at the top of each page. To locate information on a specific topic, refer to the Table of Contents at the front of the manual or the Index at the back of the manual.

**ALWAYS BE ALERT FOR THE SPECIAL WARNINGS WITHIN THE MANUAL TEXT. THESE WARNINGS PRECEDE INFORMATION THAT IS CRUCIAL TO YOUR SAFETY AS WELL AS OTHER PERSONNEL WORKING ON OR NEAR THE ENGINE. CAUTIONS OR NOTES IN THE MANUAL CONTAIN INFORMATION THAT RELATES TO POSSIBLE DAMAGE TO THE ENGINE OR ITS COMPONENTS DURING ENGINE OPERATION OR MAINTENANCE PROCEDURES.**

Recommendations and data contained in the manual is the latest information available at the time of this printing and is subject to change without notice. Since engine accessories may vary due to customer specifications consult your local distributor or Waukesha Engine Division Service Operations Department for any information on subjects beyond the scope of this manual.

## HOW TO USE THIS MANUAL

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**CONTENTS**

**SECTION 1.00 - WARNING TAGS AND DECAL LOCATIONS**

**SECTION 1.05 - SAFETY**

**SECTION 1.10 - RIGGING AND LIFTING ENGINES**

**SECTION 1.15 - GENERAL INFORMATION**

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## SECTION 1.00

### WARNING TAGS AND DECAL LOCATIONS

#### WARNING TAGS AND DECAL LOCATIONS

Warning tags and decals are placed so that they are visible and readable by the operator when the engine is running. This section provides detailed diagrams and location of the safety labels on VHP engines.

 <b>WARNING</b>
--

**All warning tags and decals must be visible and readable to the operator when the engine is running. Make sure all warning tags and decals remain legible and attached. Likewise, all warning tags and decals removed during any repair work must be replaced in their original position before the engine is placed back into service. Old or badly worn decals and tags should also be replaced. Failure to properly replace these important tags and decals can result in severe personal injury or death.**

***NOTE:** The labels shown in this manual are for current production engines. Your engine may have the previous labels, which do not have visuals. The previous labels, although they look different, will contain similar wordage and will be located very close to the position of the new labels.*

***NOTE:** Not all labels are installed on all engines. Application will depend on model of engine and optional equipment ordered. Example: air/gas starter instead of an electrical starter.*

Clean surfaces of engine of all dirt, oil, etc. before applying labels.

## WARNING TAGS AND DECAL LOCATIONS

### VHP 6 CYLINDER ENGINES

The warning labels on the VHP 6 cylinder engine have specific placement, and must be replaced if they are defaced or removed for any reason. Table 1.00-1 describes where each label is located. Figure 1.00-1 shows the exact location of each label.

**Table 1.00-1. VHP 6 Cylinder Engine Safety Labels**

P/N	LABEL TYPE	TAG/PLATE TYPE	SUBJECT	LOCATION:
211910A	Warning	-	Safety Guard	<ul style="list-style-type: none"><li>• On the front of governor drive housing</li></ul>
211910J	Warning	-	Safety Guard	<ul style="list-style-type: none"><li>• On the front gear housing</li></ul>
211910K	Warning	-	Safety Guard	<ul style="list-style-type: none"><li>• On the flywheel housing (G) or the intercooler housing (GSI, GL)</li></ul>
211910N	Warning	-	Maximum Gas Inlet Pressure	<ul style="list-style-type: none"><li>• On carburetor body, right side of engine</li></ul>
211911B	-	Warning	Built Without Engine Protection	<ul style="list-style-type: none"><li>• Nytyed on governor control rod on right side of engine.</li></ul>
211911C	Warning	-	Barring Device	<ul style="list-style-type: none"><li>• On side of crankcase, near barring device</li></ul>
211920D	Caution	-	Hot Components	<ul style="list-style-type: none"><li>• Located next to turbocharger or exhaust outlet</li></ul>
211920F	Caution	-	Eye/Ear Protection	<ul style="list-style-type: none"><li>• On control panel on right side of engine</li></ul>
211930A	Safety	-	Lifting Instructions	<ul style="list-style-type: none"><li>• On front and rear lifting eyes</li></ul>

# WARNING TAGS AND DECAL LOCATIONS

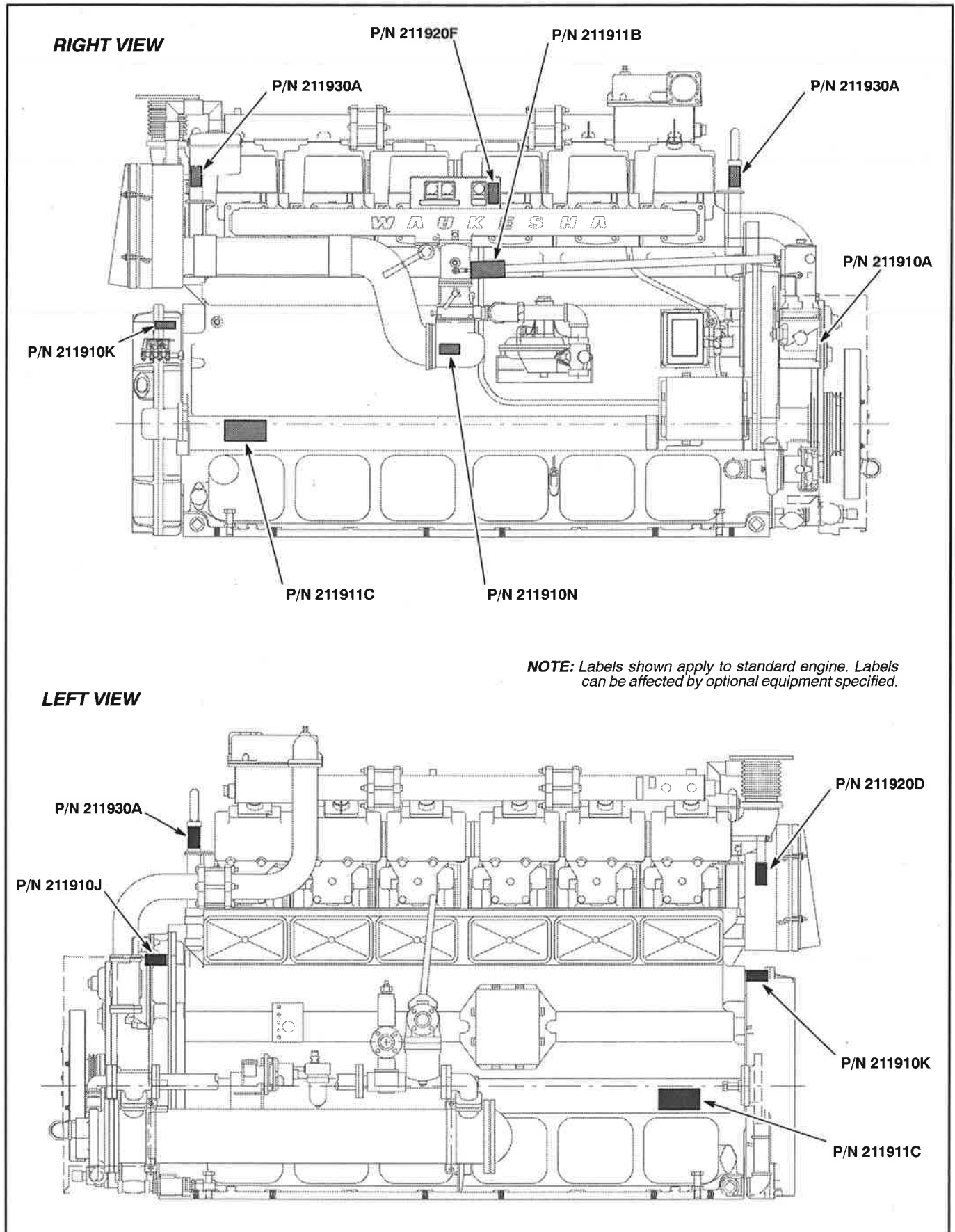


Figure 1.00-1. VHP 6 Cylinder Safety Label Locations

## WARNING TAGS AND DECAL LOCATIONS

### VHP 12 CYLINDER ENGINES

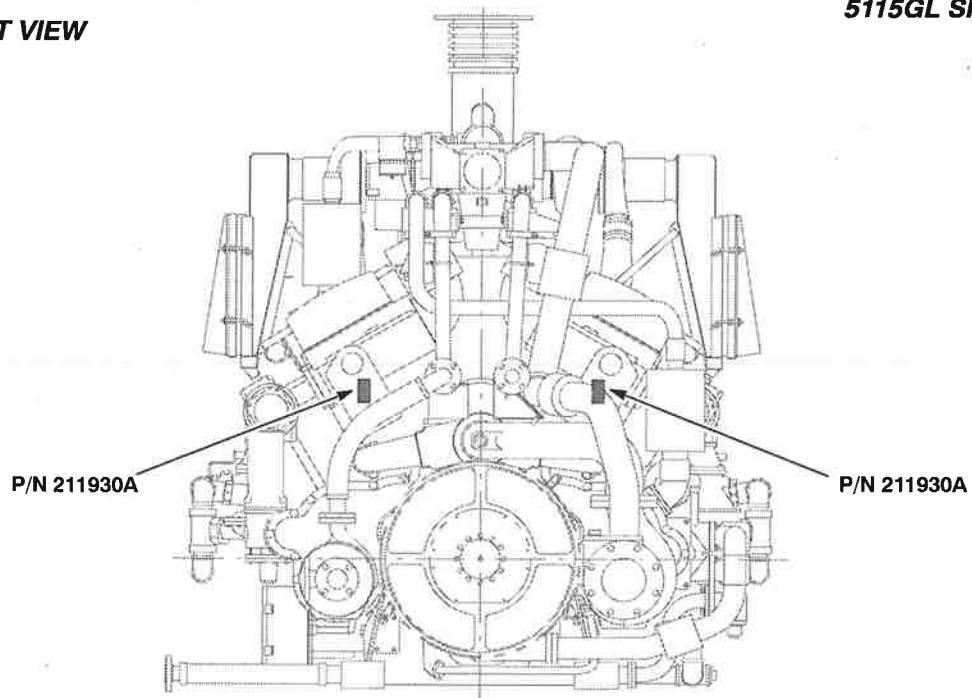
The warning labels on the VHP 12 cylinder engine have specific placement, and must be replaced if they are defaced or removed for any reason. Table 1.00-2 describes where each label is located. Figure 1.00-2 and Figure 1.00-3 show exact location of each label.

**Table 1.00-2. VHP 12 Cylinder Engine Safety Labels**

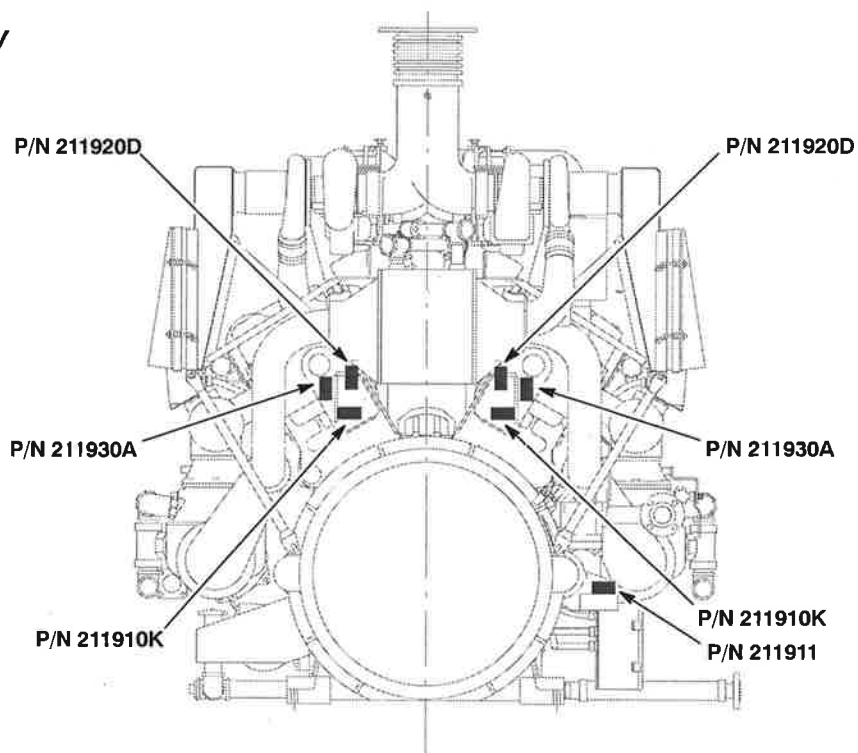
P/N	LABEL TYPE	TAG/PLATE TYPE	SUBJECT	LOCATION:
211910A	Warning	-	Safety Guard	<ul style="list-style-type: none"> <li>On the governor drive (G engines only)</li> </ul>
211910J	Warning	-	Safety Guard	<ul style="list-style-type: none"> <li>On the front gear housing</li> </ul>
211910K	Warning	-	Safety Guard	<ul style="list-style-type: none"> <li>On the intercooler support brackets</li> <li>On the rear lifting eyes (G engines only)</li> </ul>
211910N	Warning	-	Maximum Gas Inlet Pressure	<ul style="list-style-type: none"> <li>On carburetor bodies, both sides of engine</li> <li>On air cleaner/carburetor housing both sides of engine (Draw - thru engines only)</li> </ul>
211911B	-	Warning	Built Without Engine Protection	<ul style="list-style-type: none"> <li>Nyted on governor control rod on right side of engine.</li> </ul>
211911C	Warning	-	Barring Device	<ul style="list-style-type: none"> <li>On both sides of crankcase, near barring device</li> </ul>
211911D	-	Warning	Built Without Ignition System	<ul style="list-style-type: none"> <li>On the empty magneto drive housing</li> </ul>
211920D	Caution	-	Hot Components	<ul style="list-style-type: none"> <li>On the rear lifting eyes (G engines only)</li> <li>On both sides of the water manifold, directly behind the exhaust outlet (G engines only)</li> </ul>
211920E	Caution	-	Hot Components	<ul style="list-style-type: none"> <li>On heat shield near turbochargers or exhaust outlet</li> </ul>
211920F	Caution	-	Eye/Ear Protection	<ul style="list-style-type: none"> <li>On control panel on each side of engine</li> </ul>
211930A	Safety	-	Lifting Instructions	<ul style="list-style-type: none"> <li>On front and rear lifting eyes, both sides of engine</li> </ul>
211910L	Warning	-	Safety Guard	<ul style="list-style-type: none"> <li>On water pipe on front on engine</li> <li>On right and left water inlet tubes</li> </ul>
211910S	Warning	-	Vent Flammable Gas	<ul style="list-style-type: none"> <li>On right flywheel housing</li> </ul>
211910W	Warning	-	Vent Flammable Gas	<ul style="list-style-type: none"> <li>On prelube mounting bracket</li> </ul>
211911	Warning	-	Gas Inlet Pressure	<ul style="list-style-type: none"> <li>On right rear by the air/gas starter</li> </ul>
211911E	Warning	-	Gas Inlet Pressure	<ul style="list-style-type: none"> <li>On right flywheel housing</li> </ul>

**FRONT VIEW**

**5115GL SHOWN**



**REAR VIEW**



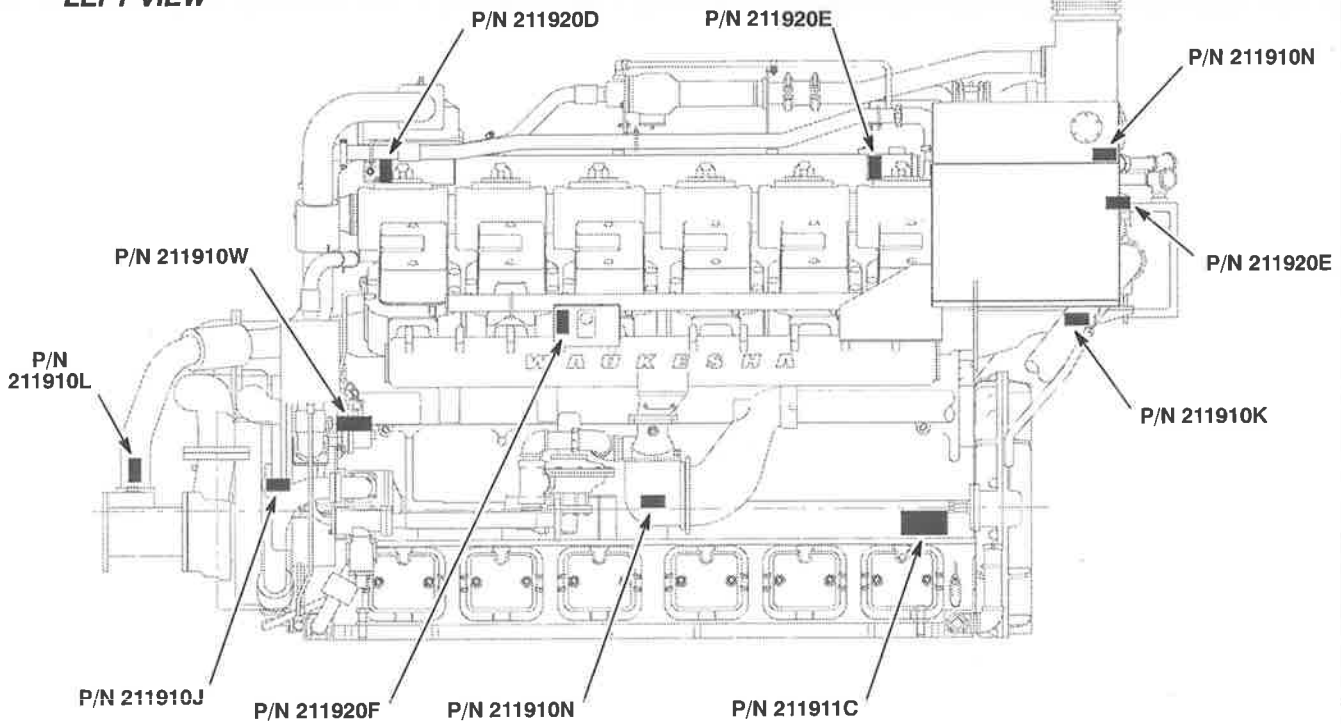
**NOTE:** Labels shown apply to standard engine. Labels can be affected by optional equipment specified.

**Figure 1.00-2. VHP 12 Cylinder Safety Label Locations**

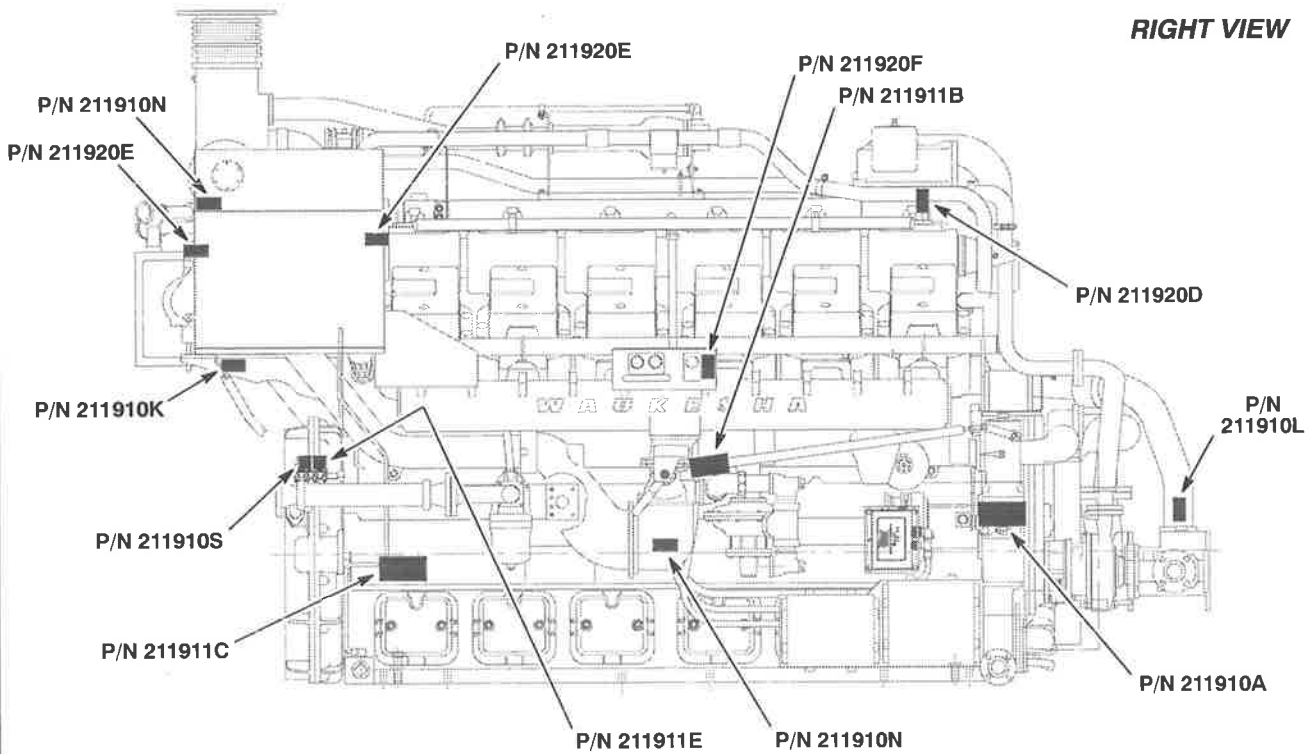
# WARNING TAGS AND DECAL LOCATIONS

5115GL SHOWN

LEFT VIEW



RIGHT VIEW



NOTE: Labels shown apply to standard engine. Labels can be affected by optional equipment specified.

Figure 1.00-3. VHP 12 Cylinder Safety Label Locations



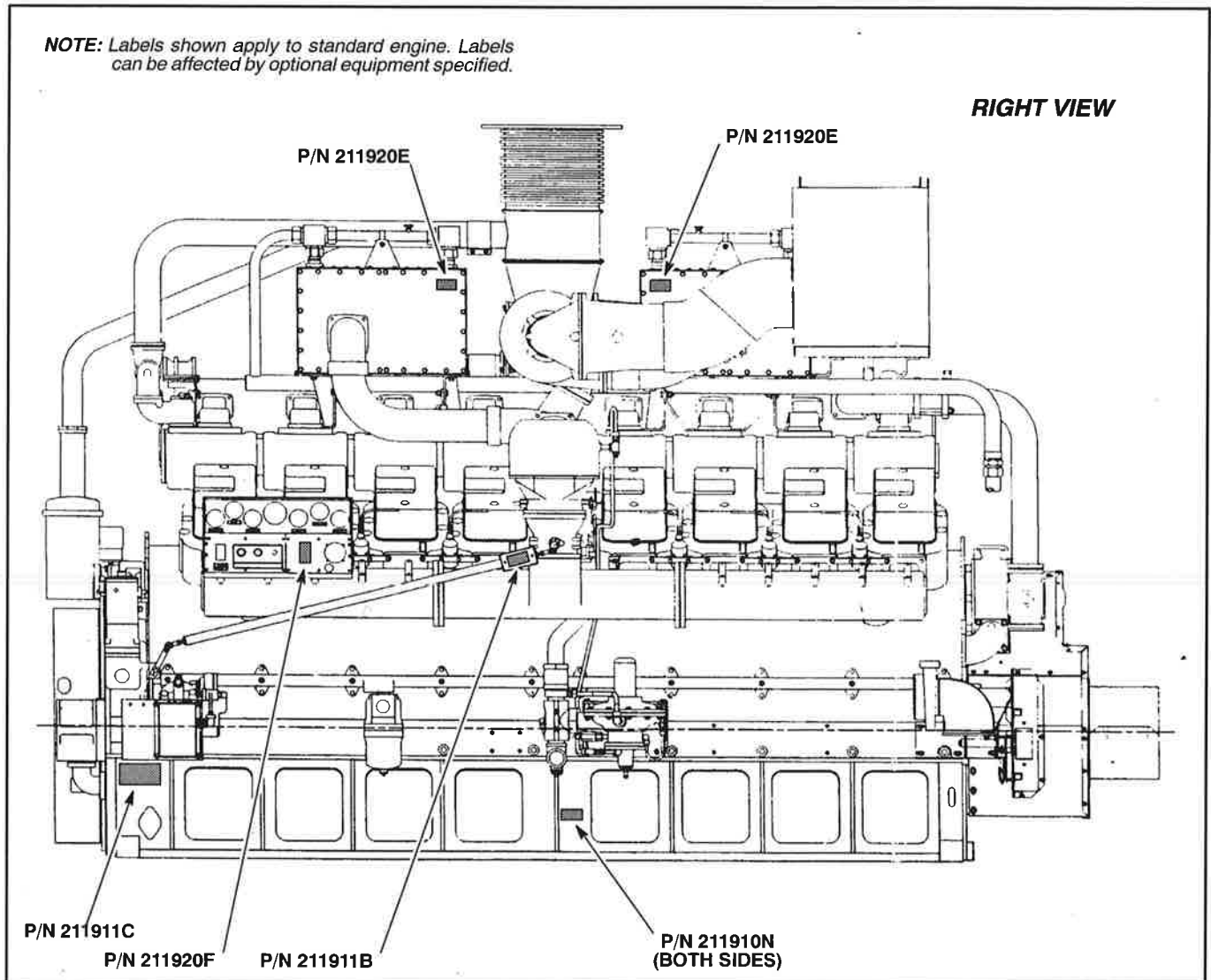
**VHP 16 CYLINDER ENGINES**

The warning labels on the VHP 16 cylinder engine have specific placement, and must be replaced if they are defaced or removed for any reason. Table 1.00-3 describes where each label is located. Figure 1.00-4 and Figure 1.00-5 show exact location of each label.

**Table 1.00-3. VHP 16 Cylinder Engine Safety Labels**

P/N	LABEL TYPE	TAG/PLATE TYPE	SUBJECT	LOCATION:
211910J	Warning	-	Safety Guard	• On the front gear housing
211910N	Warning	-	Maximum Gas Inlet Pressure	• On oil pan, below the regulators, both sides of engine
211911B	-	Warning	Built Without Engine Protection	• Nytyed on governor control rod on right side of engine.
211911C	Warning	-	Barring Device	• On side of crankcase, near barring device
211920E	Caution	-	Hot Components	• On sides of intercoolers, near turbochargers or exhaust outlet, both sides of engine
211920F	Caution	-	Eye/Ear Protection	• On engine control panel
211930A	Safety	-	Lifting Instructions	• On front and rear lifting eyes, both sides of engine
211910M	Warning	-	Safety Guard	• On back plate of engine, both sides of the flywheel

*NOTE: Labels shown apply to standard engine. Labels can be affected by optional equipment specified.*



**Figure 1.00-4. VHP 16 Cylinder Safety Label Locations**

# WARNING TAGS AND DECAL LOCATIONS

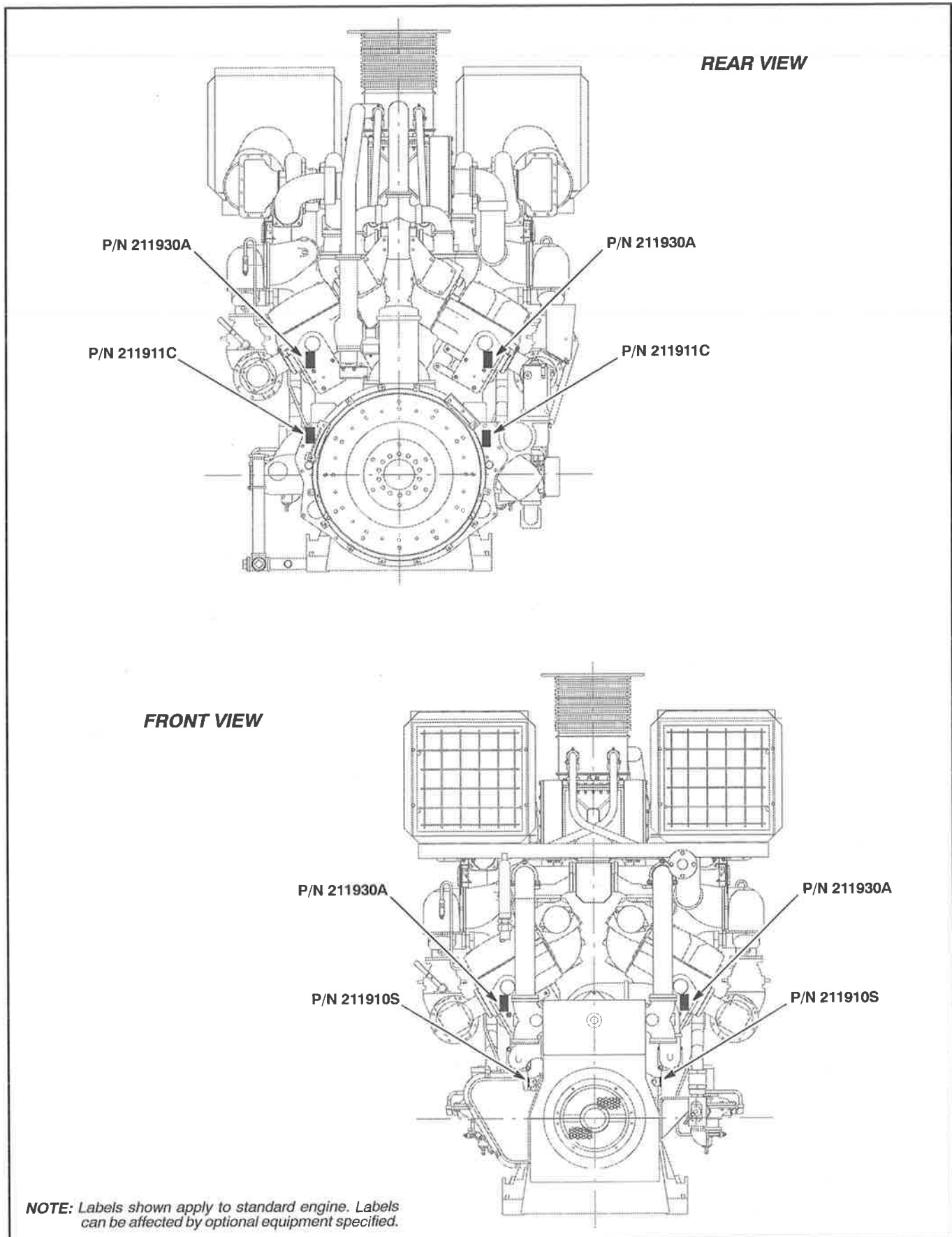


Figure 1.00-5. VHP 16 Cylinder Safety Label Locations



Figure 1.00-6. Warning Label - P/N 211910A - Safety Guard



Figure 1.00-7. Warning Label - P/N 211910J - Safety Guard



Figure 1.00-8. Warning Label - P/N 211910K - Safety Guard



Figure 1.00-9. Warning Label - P/N 211910L - Safety Guard

# WARNING TAGS AND DECAL LOCATIONS



**Figure 1.00-10. Warning Label - P/N 211910M - Safety Guard**



**Figure 1.00-12. Warning Label - P/N 211910S - Vent Flammable Gas**



**Figure 1.00-11. Warning Label - P/N 211910N - Maximum Gas Regulator Pressure**



**Figure 1.00-13. Warning Label - P/N 211911 - Maximum Air Prelube Motor Pressure**



**Figure 1.00-14. Warning Label - P/N 211910W - Gas Venting**



Figure 1.00-15. Warning Label - P/N 211911B - Built Without Engine Protection



Figure 1.00-16. Warning Label - P/N 211911C - Barring Device

## WARNING TAGS AND DECAL LOCATIONS

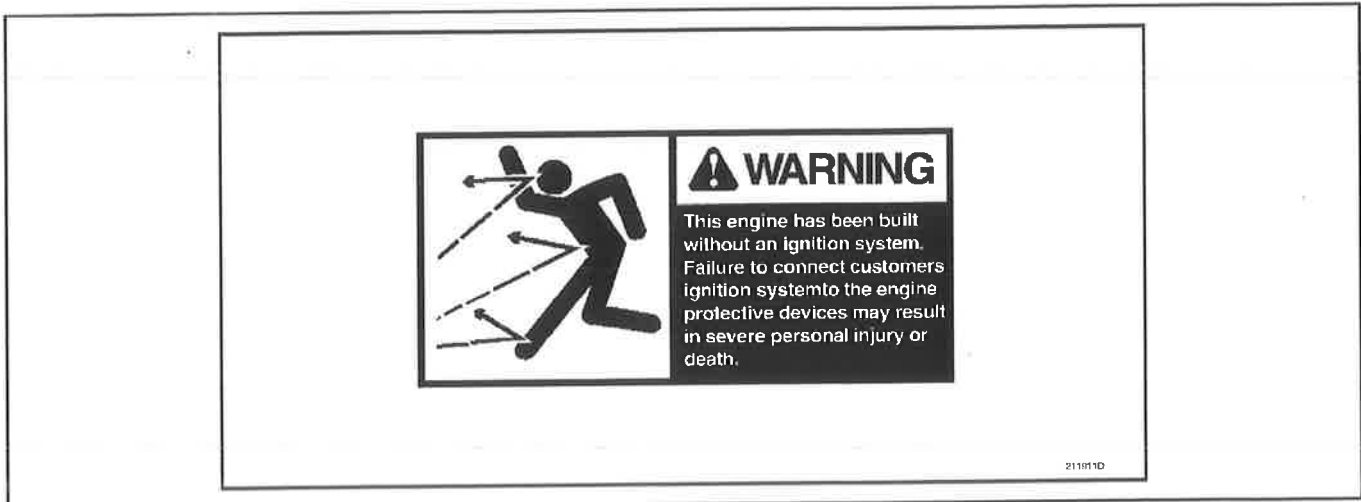


Figure 1.00-17. Warning Label - P/N 211911D - Built Without An Ignition System

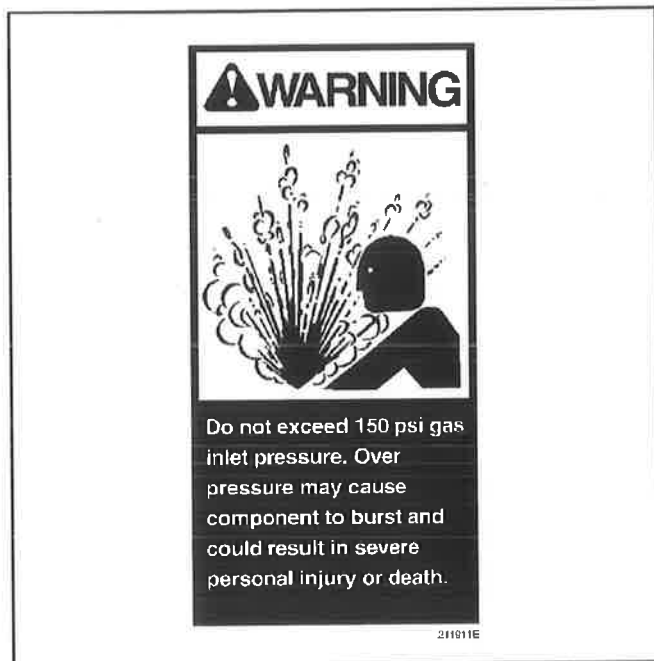


Figure 1.00-18. Warning Label - P/N 211911E - 150 psi Gas Inlet Pressure



Figure 1.00-19. Caution Label - P/N 211920D - Hot Surface



Figure 1.00-20. Caution Label - P/N 211920E - Hot Components



Figure 1.00-22. Safety Instructions - P/N 211930A - Lifting Instructions



Figure 1.00-21. Caution Label - P/N 211920F - Eye/Ear Protection

# WARNING TAGS AND DECAL LOCATIONS

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## SECTION 1.05

### SAFETY

#### SAFETY INTRODUCTION

The following safety precautions are published for your information. Waukesha Engine Division, Dresser Industries, Inc., does not, by the publication of these precautions, imply or in any way represent that they are the sum of all dangers present near industrial engines or fuel rating test units. If you are installing, operating or servicing a Waukesha product, it is your responsibility to ensure full compliance with all applicable safety codes and requirements. All requirements of the Federal Occupational Safety and Health Act must be met when Waukesha products are operated in areas that are under the jurisdiction of the United States of America. Waukesha products operated in other countries must be installed, operated and serviced in compliance with any and all applicable safety requirements of that country.

For details on safety rules and regulations in the United States, contact your local office of the Occupational Safety and Health Administration (OSHA).

The words "danger", "warning", "caution" and "note" are used throughout this manual to highlight important information. Be certain that the meanings of these alerts are known to all who work on or near the equipment.

**NOTE:** *This symbol identifies information which is NECESSARY TO THE PROPER OPERATION, MAINTENANCE OR REPAIR OF THE EQUIPMENT.*

 **CAUTION** This symbol identifies information about hazards or unsafe practices. Disregarding this information could result in PRODUCT DAMAGE AND/OR PERSONAL INJURY.

 **WARNING** This symbol identifies information about hazards or unsafe practices. Disregarding this information could result in SEVERE PERSONAL INJURY OR DEATH.

 **DANGER**

This symbol identifies information about immediate hazards. Disregarding this information will result in SEVERE PERSONAL INJURY OR DEATH.

#### SAFETY TAGS AND DECALS

 **WARNING**

To avoid severe personal injury or death, all warning tags and decals must be visible and legible to the operator while the equipment is operating.

#### EQUIPMENT REPAIR AND SERVICE

Proper maintenance, service and repair are important to the safe, reliable operation of the unit and related equipment. Do not use any procedure not recommended in the Waukesha Engine manuals for this equipment.

 **WARNING**

To prevent severe personal injury or death, always stop the unit before cleaning, servicing or repairing the unit or any driven equipment.

Place all controls in the OFF position and disconnect or lock out starters to prevent accidental restarting. If possible, lock all controls in the OFF position and take the key. Put a sign on the control panel warning that the unit is being serviced.

Close all manual control valves, disconnect and lock out all energy sources to the unit, including all fuel, electric, hydraulic, and pneumatic connections.

Disconnect or lock out driven equipment to prevent the possibility of the driven equipment rotating the disabled engine.

## SAFETY

### WARNING

To avoid severe personal injury or death, ensure that all tools and other objects are removed from the unit and any driven equipment before restarting the unit.

### WARNING

Allow the engine to cool to room temperature before cleaning, servicing or repairing the unit. Hot components or fluids can cause severe personal injury or death.

Some engine components and fluids are extremely hot even after the engine has been shut down. Allow sufficient time for all engine components and fluids to cool to room temperature before attempting any service procedure.

## ACIDS

### WARNING

Comply with the acid manufacturer's recommendations for proper use and handling of acids. Improper handling or misuse could result in severe personal injury or death.

## BATTERIES

### WARNING

Comply with the battery manufacturer's recommendations for procedures concerning proper battery use and maintenance. Improper maintenance or misuse could result in severe personal injury or death.

## BODY PROTECTION

### WARNING

Always wear OSHA approved body, sight, hearing and respiratory system protection. Never wear loose clothing, jewelry or long hair around an engine. The use of improper attire or failure to use protective equipment may result in severe personal injury or death.

## CHEMICALS

### GENERAL

### WARNING

Always read and comply with safety labels on all containers. Do not remove or deface the container labels. Improper handling or misuse could result in severe personal injury or death.

### CLEANING SOLVENTS

### WARNING

Comply with the solvent manufacturer's recommendations for proper use and handling of solvents. Improper handling or misuse could result in severe personal injury or death. Do not use gasoline, paint thinners or other highly volatile fluids for cleaning.

### LIQUID NITROGEN/DRY ICE

### WARNING

Comply with the liquid nitrogen/dry ice manufacturer's recommendations for proper use and handling of liquid nitrogen/dry ice. Improper handling or use could result in severe personal injury or death.

## COMPONENTS

### HEATED OR FROZEN

### WARNING

Always wear protective equipment when installing or removing heated or frozen components. Some components are heated or cooled to extreme temperatures for proper installation or removal. Direct contact with these parts could cause severe personal injury or death.

### INTERFERENCE FIT

### WARNING

Always wear protective equipment when installing or removing components with an interference fit. Installation or removal of interference components may cause flying debris. Failure to use protective equipment may result in severe personal injury or death.

**COOLING SYSTEM****⚠ WARNING**

Always wear protective clothing when venting, flushing or blowing down the cooling system. Operational coolant temperatures can range from 180° - 250° F (82° - 121° C). Contact with hot coolant or coolant vapor can cause severe personal injury or death.

**⚠ WARNING**

Do not service the cooling system while the engine is operating or when the coolant is hot. Operational coolant temperatures can range from 180° - 250° F (82° - 121° C). Contact with hot coolant or vapor can cause severe personal injury or death.

**ELECTRICAL****GENERAL****⚠ WARNING**

Do not install, set up, maintain or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

**⚠ WARNING**

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

**IGNITION****⚠ WARNING**

Avoid contact with ignition units and wiring. Ignition system components can store electrical energy and if contacted can cause electrical shocks. Electrical shock can cause severe personal injury or death.

**⚠ WARNING**

Properly discharge any electrical component that has the capability to store electrical energy before connecting or servicing that component. Electrical shock can cause severe personal injury or death.

**EXHAUST****⚠ WARNING**

Do not inhale engine exhaust gases. Exhaust gases are highly toxic and could cause severe personal injury or death.

Ensure exhaust systems are leak free and that all exhaust gases are properly vented.

**⚠ WARNING**

Do not touch or service any heated exhaust components. Allow sufficient time for exhaust components to cool to room temperature before attempting any service procedure. Contact with hot exhaust system components can cause severe personal injury or death.

**FIRE PROTECTION****⚠ WARNING**

Refer to local and federal fire regulations for guidelines for proper site fire protection. Fires can cause severe personal injury or death.

**FUELS****GENERAL****⚠ WARNING**

Ensure that there are no leaks in the fuel supply. Engine fuels are highly combustible and can ignite or explode causing severe personal injury or death.

## SAFETY

### GASEOUS

#### WARNING

Do not inhale gaseous fuels. Some components of fuel gas are odorless, tasteless, and highly toxic. Inhalation of gaseous fuels can cause severe personal injury or death.

#### WARNING

Shut off the fuel supply if a gaseous engine has been cranked excessively without starting. Crank the engine to purge the cylinders and exhaust system of accumulated unburned fuel. Failure to purge accumulated unburned fuel in the engine and exhaust system can result in an explosion resulting in severe personal injury or death.

### LIQUID

#### WARNING

Do not ingest liquid fuels or breathe in their vapors. Liquid fuels may be highly toxic and can result in severe personal injury or death.

#### WARNING

Use protective equipment when working with liquid fuels and related components. Liquid fuel can be absorbed into the body resulting in severe personal injury or death.

### INTOXICANTS AND NARCOTICS

#### WARNING

Do not allow anyone under the influence of intoxicants and/or narcotics to work on or around industrial engines. Workers under the influence of intoxicants and/or narcotics are a hazard both to themselves and other employees and can cause severe personal injury or death to themselves or others.

### PRESSURIZED FLUIDS/GAS/AIR

#### WARNING

Never use pressurized fluids/gas/air to clean clothing or body parts. Never use body parts to check for leaks or flow rates. Pressurized fluids/gas/air injected into the body can cause severe personal injury or death.

Observe all applicable local and federal regulations relating to pressurized fluid/gas/air.

### PROTECTIVE GUARDS

#### WARNING

Provide guarding to protect persons or structures from rotating or heated parts. Contact with rotating or heated parts can result in severe personal injury or death.

It is the responsibility of the engine owner to specify and provide guarding.

### SPRINGS

#### WARNING

Use appropriate equipment and protective gear when servicing or using products that contains springs. Springs, under tension or compression, can eject if improper equipment or procedures are used. Failure to take adequate precautions can result in serious personal injury or death.

### TOOLS

#### ELECTRICAL

#### WARNING

Do not install, set up, maintain or operate any electrical tools unless you are a technically qualified individual who is familiar with them. Electrical tools use electricity and if used improperly could cause severe personal injury or death.

## HYDRAULIC

 **WARNING**

Do not install, set up, maintain or operate any hydraulic tools unless you are a technically qualified individual who is familiar with them. Hydraulic tools use extremely high hydraulic pressure and if used improperly could cause severe personal injury or death.

 **CAUTION** Always follow recommended procedures when using hydraulic tensioning devices. Improper use of hydraulic tensioning tools can cause severe engine damage.

## PNEUMATIC

 **WARNING**

Do not install, set up, maintain or operate any pneumatic tools unless you are a technically qualified individual who is familiar with them. Pneumatic tools use pressurized air and if used improperly could cause severe personal injury or death.

## WEIGHT

 **WARNING**

Always consider the weight of the item being lifted and use only properly rated lifting equipment and approved lifting methods. Failure to take adequate precautions can result in serious personal injury or death.

 **WARNING**

Never walk or stand under an engine or component while it is suspended. Failure to adhere to this could result in severe personal injury or death.

## WELDING


## GENERAL

 **WARNING**

Comply with the welder manufacturer's recommendations for procedures concerning proper use of the welder. Improper welder use can result in severe personal injury or death.

## ON ENGINE

 **CAUTION** Ensure that the welder is properly grounded before attempting to weld on or near an engine. Failure to properly ground the welder could result in severe engine damage.

 **CAUTION** Disconnect the ignition harness before welding on or near an engine to eliminate charging of an ignition system capacitor. Failure to disconnect the ignition harness could result in severe engine damage.

**SAFETY**

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## SECTION 1.10

### RIGGING AND LIFTING ENGINES

#### ENGINE RIGGING AND LIFTING

#### WARNING

Exercise extreme care when moving the engine or its components. Never walk or stand directly under an engine or component while it is suspended. Always consider the weight of the engine or the components involved when selecting hoisting chains and lifting equipment. Be positive about the rated capacity of lifting equipment. Use only properly maintained lifting equipment with a lifting capacity which exceeds the known weight of the object to be lifted. Disregarding this information could result in severe personal injury or death.

Table 1.10-1 shows the approximate dry weight of the VHP gas engines.

Table 1.10-1. Engine Dry Weights

ENGINE	WEIGHT	
	lb.	kg
F2895G	14,500	6,580
F2895GSI	15,000	6,800
2895GL	15,000	6,800
F3521G	14,500	6,580
F3521GSI	15,000	6,800
3521GL	15,000	6,800
L5108G	20,500	9,300
L5108GSI	21,000	9,525
5108GL	21,000	9,525
L5790G	20,500	9,300
L5790GSI	21,000	9,525
5790GL	21,000	9,525
L7042G	20,500	9,300
L7042GSI	21,000	9,525
7042GL	21,000	9,525
5115GL	23,050	10,477
P9390G	25,000	11,340
P9390GSI	28,750	13,040
9390GL	28,750	13,040

#### LOCATION OF THE LIFTING EYES

#### WARNING

Always lift the engine using the approved lifting eyes. The VHP 6 cylinder gas engines are equipped with two lifting eyes on top of the engine; 12 and 16 cylinder gas engines are equipped with two pairs of lifting eyes, one pair on each cylinder bank. Lifting eyes are only meant for lifting the engine. Do not use to lift driven or auxiliary equipment that may be attached to the engine. Disregarding this information could result in severe personal injury or death.

The VHP 6 cylinder engine is equipped with two lifting eyes on top of the engine, 12 and 16 cylinder engines are equipped with two pairs of lifting eyes, one pair on each cylinder bank. The lifting eyes are only meant for lifting the engine. Do not use the lifting eyes to lift driven equipment that may be attached to the engine.

#### CORRECT METHOD OF RIGGING AND LIFTING ENGINE

Lifting chains should be positioned so that they do not rub or bind against parts of the engine. A properly rigged engine will be able to be lifted in such a manner that the chains will not damage the engine. See Figure 1.10-1 and Figure 1.10-2 for examples of engine lifting.

#### WARNING

To avoid severe personal injury or death, follow approved rigging procedures to ensure that no undue strain is placed on the lifting eyes and hoisting chains/cable sling when the engine is raised. Use the proper spreader beam to avoid damage to the engine.

# RIGGING AND LIFTING ENGINES

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## SECTION 1.15

### GENERAL INFORMATION

#### GENERAL INFORMATION

VHP G, GSI and GL engines (see Table 1.15-1) are 4-cycle; 6 cylinder engines are in-line configuration, while 12 and 16 cylinder engines are V-configuration. All engines rotate in the standard counter-clockwise direction, as viewed from the rear (flywheel) end.

**Table 1.15-1. Engine Models**

<b>6 Cylinder Engines</b>	F2895G F2895GSI 2895GL F3521G F3521GSI 3521GL
<b>12 Cylinder Engines</b>	L5108G L5108GSI 5108GL L5790G L5790GSI 5790GL L7042G L7042GSI 7042GL 5115GL
<b>16 Cylinder Engines</b>	P9390G P9390GSI 9390GL

The basic "G" engines are naturally aspirated.

The "GSI" engines are turbocharged and intercooled.

The "GL" engine is turbocharged, intercooled and lean burn. These engines are designed for low fuel consumption and reduced exhaust emissions. The prechamber design utilizes combustion of a stratified charge. A rich fuel mixture is provided to one part of the cylinder, and a lean fuel mixture to the rest of the cylinder, with the burning taking place in stages. To accomplish this, a small auxiliary combustion chamber, referred to as a prechamber, is located in the cylinder head. The rich fuel mixture is supplied to this chamber while the lean mixture fills the main combustion chamber. When the spark plug ignites the prechamber fuel, a flame torch projects from orifices in the prechamber to ignite the lean mixture in the main chamber. The consistent ignition of the rich mixture in the prechamber ensures complete combustion within the main chamber.

Refer to Figure 1.15-4 thru Figure 1.15-16 for engine identification views.

#### FEATURES AND BENEFITS

The design features of the VHP engine family include:

- High horsepower
- Sturdy construction, rugged and compact
- Low exhaust emissions
- Easy access and serviceability to all major components
- Fuel efficient and minimal fuel system complexity

#### BASIC ENGINE DESCRIPTION

The crankcase is a rigid gray iron casting (16 cylinder engines are two piece). The main bearings are replaceable. The counterweighted crankshaft is made of forged steel and has seven main bearing journals (16 cylinder engines have ten journals). Each engine is equipped with a viscous vibration damper.

There are interchangeable cylinder heads, each with two intake and two exhaust valves. Both exhaust and intake valve seat inserts are replaceable. Roller type valve lifters and hydraulic push rods are standard with the exception of the 5115GL which uses non-hydraulic push rods. The camshaft is heavy duty for long life. The connecting rods are made from drop forged steel and are rifle drilled. The cylinders have replaceable wet cylinder sleeves. The pistons use a full floating piston pin. The flywheel is machined and has a ring gear attached.

The exhaust driven turbocharger (on GSI and GL models) compresses intake air. This charged air is cooled in the intercooler and then enters the carburetor and mixes with pressurized fuel gas. The turbocharged air/fuel mixture enhances the engine's power and performance. On draw-thru equipped GSI and GL models, the turbocharger draws fuel and intake air from the air intake and carburetor(s) (mounted on the air filter housing(s) and compresses the mixture. The mixture is cooled through the intercooler and then enters the intake manifold(s).

## GENERAL INFORMATION

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The pressurized lubricating system consists of an oil sump, pump, piping network, filters, strainers and cooler. The full flow oil filter is externally mounted, separate from the engine. The system also consists of an externally mounted oil cooler.

The cooling system has two water pumps. The main water pump circulates the jacket water of the engine. The auxiliary water pump, circulates water for the oil cooler and the intercooler. The engine jacket, cylinder heads, exhaust manifold, oil and charged intake air are all water cooled.

## COMPONENT DESCRIPTIONS

### CRANKCASE

The crankcase is a gray iron casting (16 cylinder engines are two piece). For assembled rigidity, the main bearing caps are attached to the crankcase with both vertical studs and lateral tie bolts. This feature makes the crankcase assembly more rigid and lengthens the life of the main bearings.

### CRANKSHAFT

The underslung crankshaft is made of a low alloy, high tensile strength forged steel. The crankshaft is counter-weighted to achieve a near perfect balance of rotating forces. 16 cylinder engine crankshafts are two piece.

A viscous vibration damper is installed on the forward end of the crankshaft along with a gear that drives the front end gear train and accessories. The flywheel, with ring gear, is installed on the rear end of the crankshaft and is machined to accept several options.

### INTAKE MANIFOLD(S)

The air/fuel mixture passes through the intake manifold(s) where it is distributed to the individual cylinders.

### EXHAUST MANIFOLD(S)

The exhaust port of each cylinder head is connected to one water-cooled segment of the exhaust manifold. The water-cooled exhaust manifold(s) assembly is comprised of individual segments (one for each cylinder head). Each exhaust manifold segment is joined to the next by a manifold pilot.

### CONNECTING RODS

The connecting rods are machined to ensure maximum strength, precise balance and consistent weight between cylinders. They are made of a low alloy, high tensile strength forged steel, and are rifle-drilled to supply pressurized lube oil from the crankshaft to the piston pin bushings.

The split line of the rod and cap allows for removal of the connecting rod assembly up through the cylinder liner bore.

The serrated split line ensures precise alignment and transfer of loads. The caps and blades are also match numbered to ensure that each cap is mated with the correct blade during re-assembly.

The connecting rod cap fasteners, like all critical fasteners used on the engine, are torqued to specific values.

### PISTONS

The pistons are machined from one-piece castings. Each piston is cam-ground. This means the dimension of the piston skirt at room temperature is slightly larger at a point 90 degrees to the piston pin bore. This feature allows the piston to expand from a shape that is somewhat oval to one that is almost perfectly round when operating at stabilized engine temperatures.

### CYLINDER LINERS

Each wet type cylinder liner has a flange at its upper end to locate it in the crankcase upper deck. The liners have three external ring grooves to hold the lower crankcase bore seals.

### CAMSHAFTS

The design of the camshaft lobe and cam minimizes valve overlap and reduces the flow of gases between the intake and exhaust ports. This improves fuel efficiency and lowers exhaust emissions.

### CYLINDER HEAD AND VALVES

Each cylinder head has four valves, two intake and two exhaust, with overhead rocker and actuator arms. GL model cylinder heads have a prechamber bore in the center, and an additional bore to accommodate the fuel admission valve. The cylinder heads are water cooled, to reduce heat deformation during the combustion process.

### TURBOCHARGER(S)

On GSI and GL models, high efficiency, radial flow turbochargers are mounted on the rear of the engine and generate the required boost levels for the engine.

### CUSTOM ENGINE CONTROL® (CEC) IGNITION MODULE

Waukesha Engine's Custom Engine Control® Ignition Module (IM), is standard equipment on VHP engines. The CEC ignition system uses a Hall-effect pickup and a special timing disc to determine the exact position of the crankshaft. The CEC ignition module interprets the sensor's impulses to set the optimum ignition timing. The CEC module then directs a precisely timed voltage to the appropriate ignition coil.

**CUSTOM ENGINE CONTROL® (CEC)  
DETONATION SENSING MODULE**

Waukesha Engine's Custom engine Control® Detonation Sensing Module (DSM), which functions with the CEC Ignition Module, is standard equipment on VHP engines. The DSM protects the engines from damage due to detonation on an individual cylinder basis. Engine mounted detonation sensors monitor engine output from each cylinder. When the signal exceeds a predetermined limit, the DSM retards the ignition timing for the cylinder associated with that sensor. As soon as conditions permit, the DSM will advance spark timing to the original timing set point.

**INTERCOOLER(S)**

The intercooler(s) (the box-type tube and fin assemblies mounted at the rear of the engine) are standard on GSI and GL models. The flow of air between the aluminum cooling fins, runs perpendicular to the vertical flow of cooling water in the copper tubes. The configuration of the upper and lower bonnets create a U-shaped path, that enables the cooling water to pass through the core assembly four times, before exiting the unit at the top. Header plates separate the air passing through the casing from the cooling water in the upper and lower bonnets.

A supply tube connected to the intercooler cooling water inlet, provides a continuous supply of cooling water to the wastegate(s) (one per turbocharger). The cooling water enters the lower housing of the wastegate(s) and passes through a cavity that encircles the valve guide. Exiting the outlet port on the opposite side of the lower housing, the water passes to the intercooler cooling water outlet through a water return tube.

**CARBURETOR(S)**

The carburetor(s) consists of a main body, with a conventional throttle valve and diaphragm operated gas metering valves. The flow of air through the carburetor(s) is controlled by the throttle valve in the carburetor throat, as in any other carburetor. The amount of air going to the engine is measured by air-flow measuring valves, which rise in direct proportion to the air volume passing through. The gas metering valves are mechanically fixed to the air measuring valves, and rise with them, thus opening the gas passages an amount proportionate to the air entering the engine. This establishes and holds a definite air/fuel ratio throughout the operating range. The actual movement of the parts results from the negative air pressure at the air measuring valves, which is communicated to the back side of each diaphragm through two small holes.

**SERIAL NUMBERS AND ENGINE  
NAMEPLATE**

For ease in identification, the engine model, serial and specification numbers are stamped on a nameplate (see Figure 1.15-2 and Figure 1.15-3).

The VHP engine nameplate provides the following information: model number, serial number, date inspected, special application approval number (power approval), valve clearance, compression ratio, firing order, governed speed, altitude limit at which an engine derate takes place, primary and secondary fuel ratings which show the fuel, minimum WKI™, ignition timing, rated output in horsepower and kilowatts, and overload rating in horsepower and kilowatts. This nameplate is located on the lower left side of the crankcase, adjacent to the front of the engine.

When requesting information, you will need to reference both the engine model and serial numbers. If the nameplate is defaced or detached, the serial number may be obtained directly off the crankcase. To locate it, look directly above the nameplate location, on the cylinder head deck of the crankcase.

**INSTRUMENT PANEL**

Waukesha Engine's optional instrument panel is shipped loose and intended to be remote mounted on site (see Figure 1.15-1). The panel is operated on 24VDC. The instruments are:



Figure 1.15-1. Optional Remote Instrument Panel

- **Intake Manifold Pressure Gauge;** indicates the intake manifold pressure in inches/centimeters of mercury.


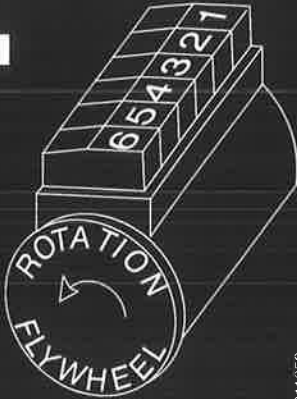
## GENERAL INFORMATION

- **Digital Tachometer/Hour Meter;** indicates the engine speed in revolutions per minute (rpm) and the hours the engine has been in operation.
- **Intake Manifold Temperature Gauge;** indicates the temperature of the air/gas mixture within the intake manifold.
- **Lube Oil Pressure Gauge;** indicates the lube oil pressure at the oil header.
- **Lube Oil/Jacket Water Temperature Gauge;** indicates the lube oil temperature at the oil header and the outlet temperature of the engine coolant.
- **Exhaust Temperature Pyrometer;** indicates the temperature of the exhaust gases.

### WARNING

Switches for alarms and automatic engine shut-down must be supplied by the customer. The sensors provided are for measuring and monitoring temperatures and WILL NOT shut the engine down if potentially harmful temperatures are reached. Disregarding this information could result in severe personal injury or death.

Engine instrument and safety shutdowns are not supplied as standard equipment, due to the wide variety of customer needs. Instruments and safety shut downs are the customer's responsibility. Oil pressure, intake manifold pressure, water temperature, exhaust temperature, main bearing, overspeed and oil temperature, are the minimum required for engine protection. Switches should be wired to an alarm to warn of high temperatures and low pressure as well as provide for automatic engine shutdown if potentially harmful temperatures, pressure or overspeed conditions exist.

MODEL	<input type="text"/>	<b>Waukesha</b> WAUKESHA ENGINE DIVISION DRESSER INDUSTRIES INC. WAUKESHA, WISCONSIN U.S.A. 	SAA #	<input type="text"/>	SERVICE TYPE	<input type="text"/>
SERIAL NUMBER	<input type="text"/>		DATE	<input type="text"/>		
COMP. RATIO	<input type="text"/>					
THIS ENGINE IS FACTORY EQUIPPED AS LISTED. HP(KW) ARE PER ISO 3046/1. CONSULT A W.E.D. AUTHORIZED DISTRIBUTOR OR W.E.D. APPLICATION ENGINEERING FOR ADDITIONAL INFORMATION.						
	PRIMARY	SECONDARY		ALTITUDE LIMIT FT/m		
FUEL	<input type="text"/>	<input type="text"/>		<input type="text"/>		
MIN. WKT <sup>1</sup>	<input type="text"/>	<input type="text"/>		<input type="text"/>		
IGN. TIMING °BTDC	<input type="text"/>	<input type="text"/>		GOVERNED SPEED RPM	<input type="text"/>	
CARB. ADJ.	<input type="text"/>	<input type="text"/>		VALVE CLEARANCE IN. /mm	<input type="text"/>	
SERVICE HP/kW	<input type="text"/>	<input type="text"/>		INTAKE	<input type="text"/>	
OVERLOAD HP/kW	<input type="text"/>	<input type="text"/>		EXHAUST	<input type="text"/>	
FIRING ORDER	<input type="text"/>					

P/N 211853

Figure 1.15-2. Nameplate - Current Production

MODEL	<input type="text"/>	<h1 style="margin: 0;">Waukesha</h1> <p style="margin: 0; font-size: small;">WAUKESHA ENGINE DIVISION DRESSER INDUSTRIES INC. WAUKESHA, WISCONSIN U.S.A.</p>		SAA #	<input type="text"/>	SERVICE TYPE	<input type="text"/>
SERIAL NUMBER	<input type="text"/>			DATE	<input type="text"/>		
COMP. RATIO	<input type="text"/>						
THIS ENGINE IS FACTORY EQUIPPED AS LISTED. HP(KW) ARE PER ISO 3046/1. CONSULT A W.E.D. AUTHORIZED DISTRIBUTOR OR W.E.D. APPLICATION ENGINEERING FOR ADDITIONAL INFORMATION.							
	PRIMARY	SECONDARY		ALTITUDE LIMIT FT/M	<input type="text"/>		
FUEL	<input type="text"/>	<input type="text"/>		GOVERNED SPEED RPM	<input type="text"/>		
MIN. OCTANE	<input type="text"/>	<input type="text"/>					
IGN. TIMING OBTDC	<input type="text"/>	<input type="text"/>					
CARB. ADJ.	<input type="text"/>	<input type="text"/>					
SERVICE HP/kW	<input type="text"/>	<input type="text"/>		VALVE CLEARANCE IN. /mm			
OVERLOAD HP/kW	<input type="text"/>	<input type="text"/>		INTAKE	<input type="text"/>	EXHAUST	<input type="text"/>
FIRING ORDER	<input type="text"/>						

P/N 211506-F

Figure 1.15-3. Nameplate - Previous Production

# GENERAL INFORMATION

## ENGINE IDENTIFICATION VIEWS

### SIX CYLINDER GL VIEWS

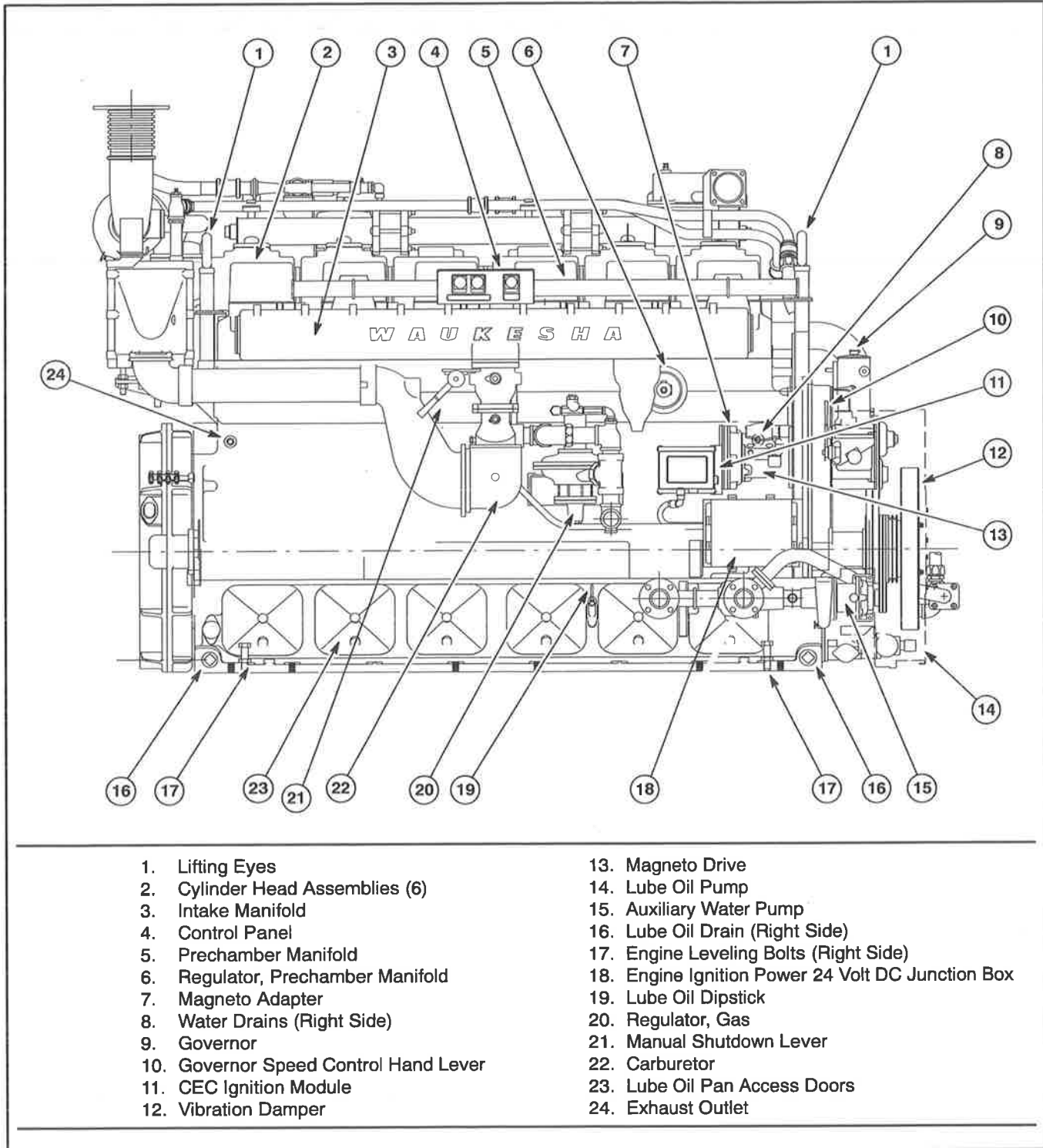
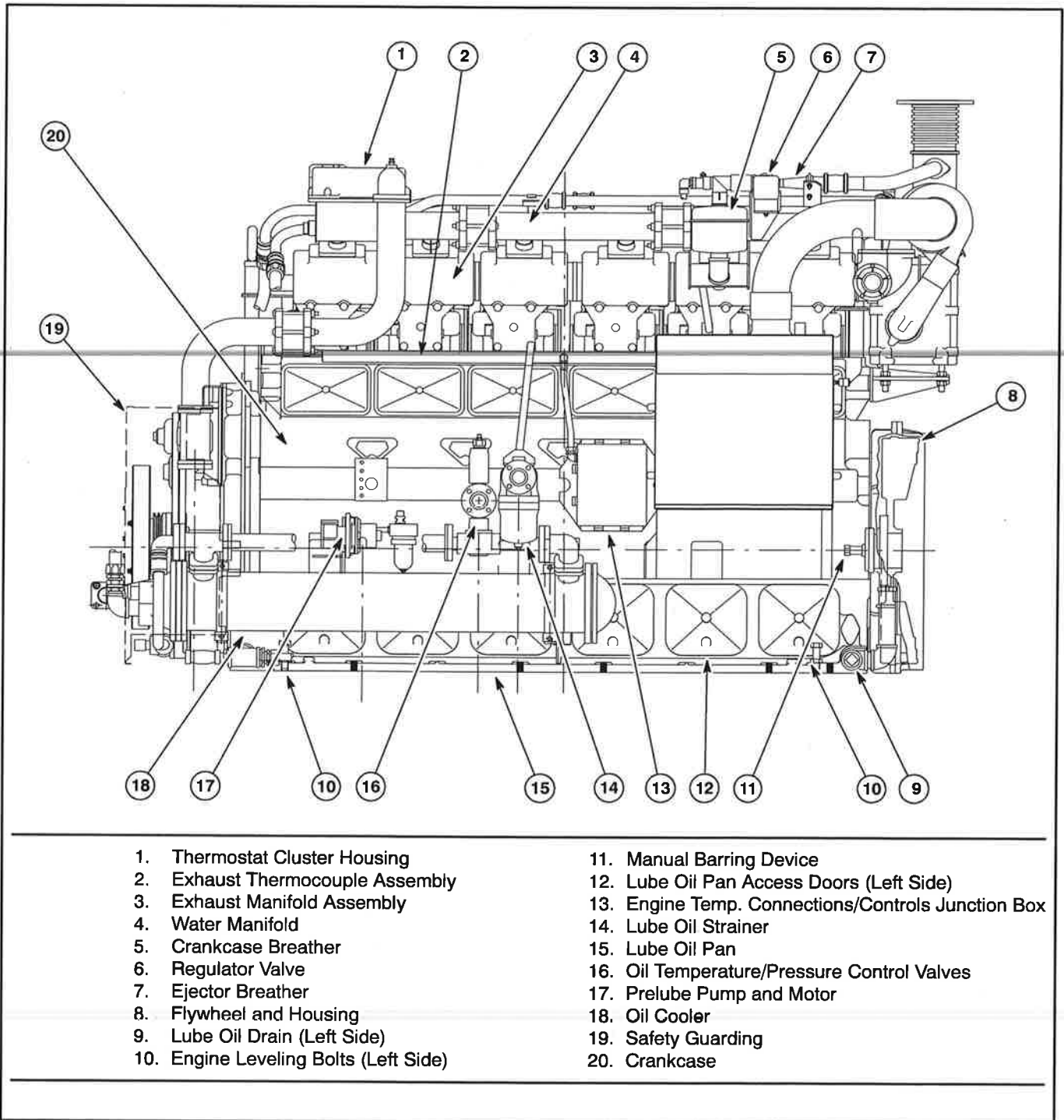


Figure 1.15-4. Right Side View - 6 Cylinder VHP GL



- |                                       |  |
|---------------------------------------|--|
| 1. Thermostat Cluster Housing         | 11. Manual Barring Device                          |
| 2. Exhaust Thermocouple Assembly      | 12. Lube Oil Pan Access Doors (Left Side)          |
| 3. Exhaust Manifold Assembly          | 13. Engine Temp. Connections/Controls Junction Box |
| 4. Water Manifold                     | 14. Lube Oil Strainer                              |
| 5. Crankcase Breather                 | 15. Lube Oil Pan                                   |
| 6. Regulator Valve                    | 16. Oil Temperature/Pressure Control Valves        |
| 7. Ejector Breather                   | 17. Prelube Pump and Motor                         |
| 8. Flywheel and Housing               | 18. Oil Cooler                                     |
| 9. Lube Oil Drain (Left Side)         | 19. Safety Guarding                                |
| 10. Engine Leveling Bolts (Left Side) | 20. Crankcase                                      |

Figure 1.15-5. Left Side View - 6 Cylinder VHP GL

## GENERAL INFORMATION

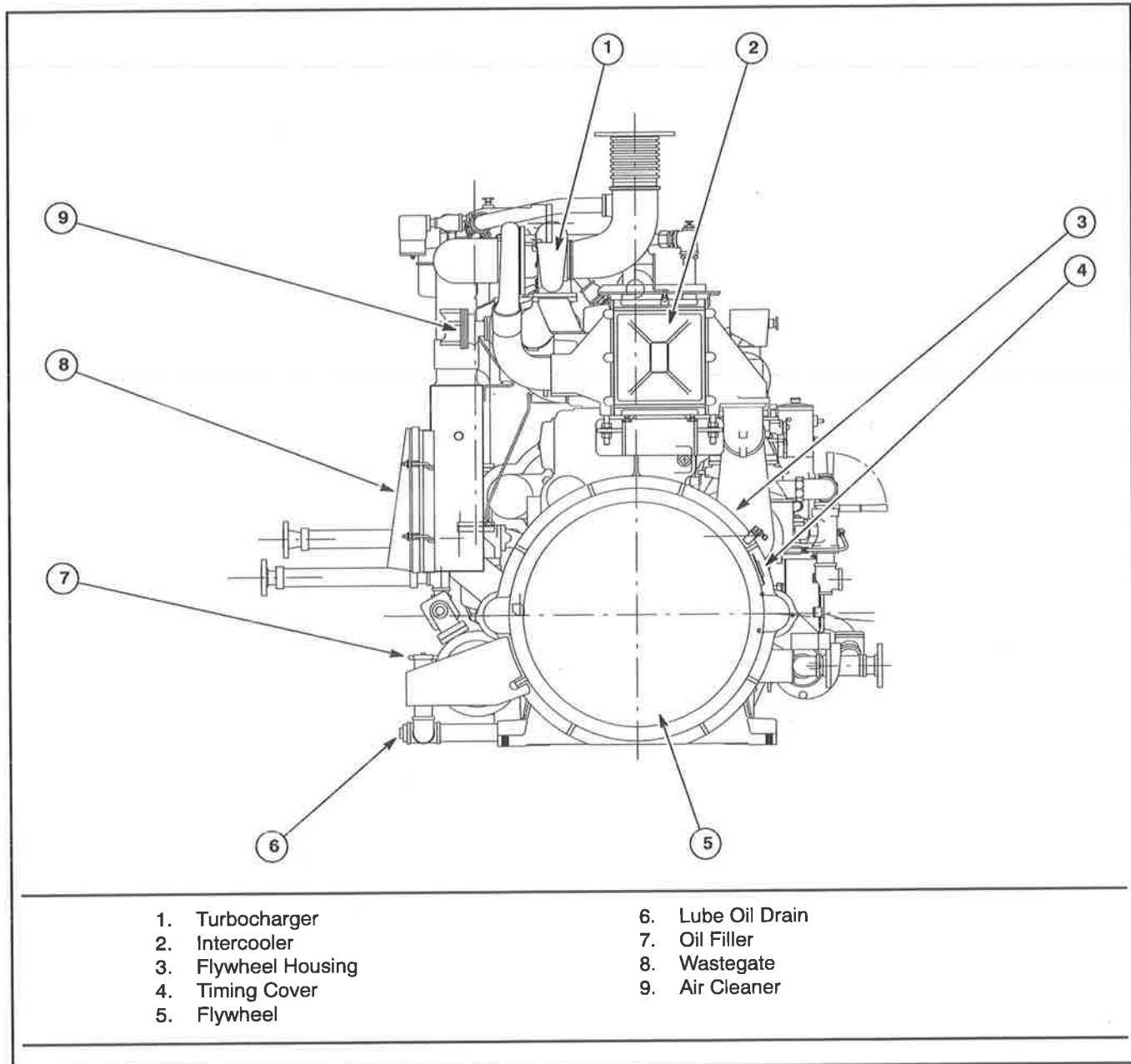
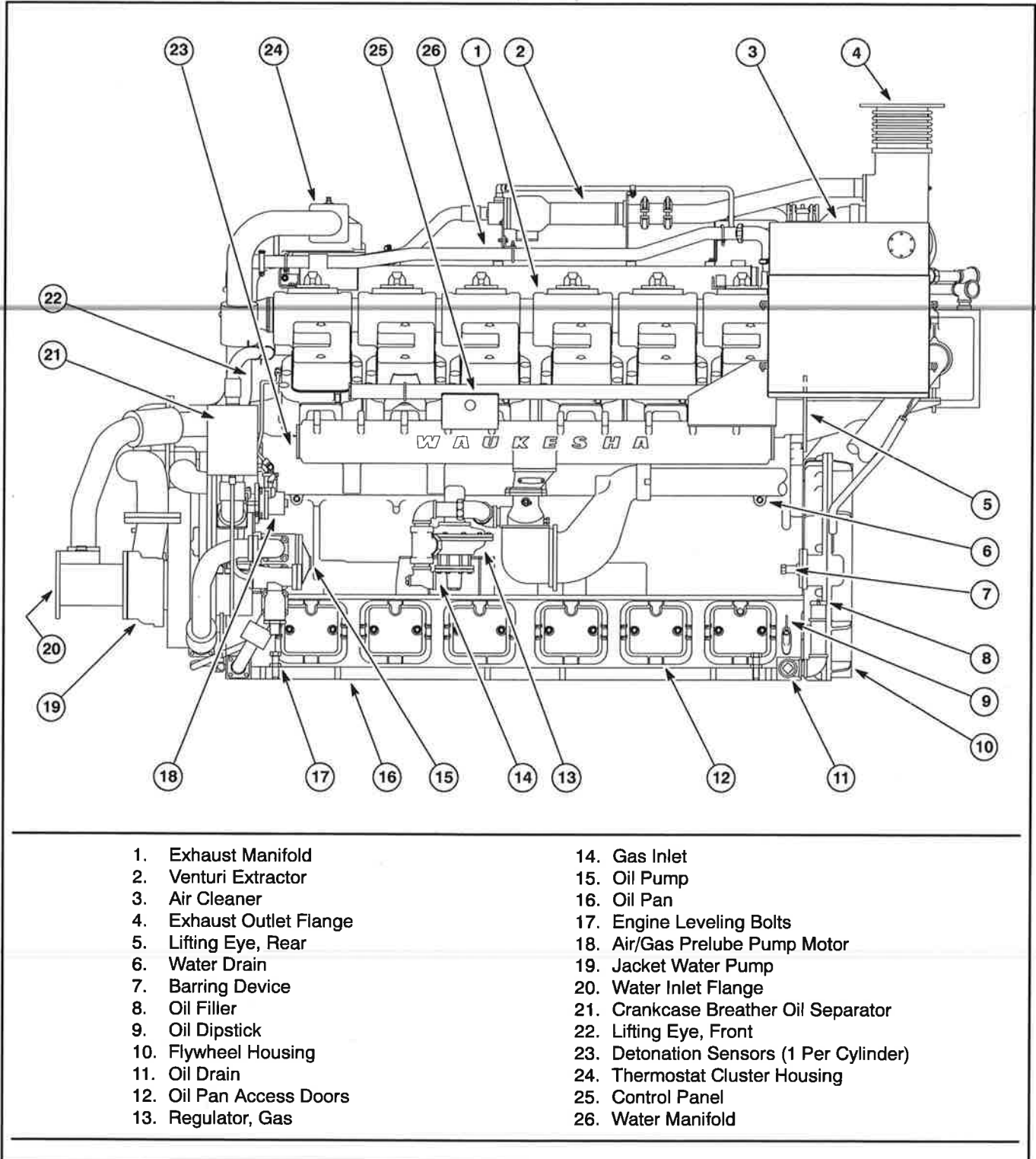


Figure 1.15-6. Rear View - 6 Cylinder VHP GL



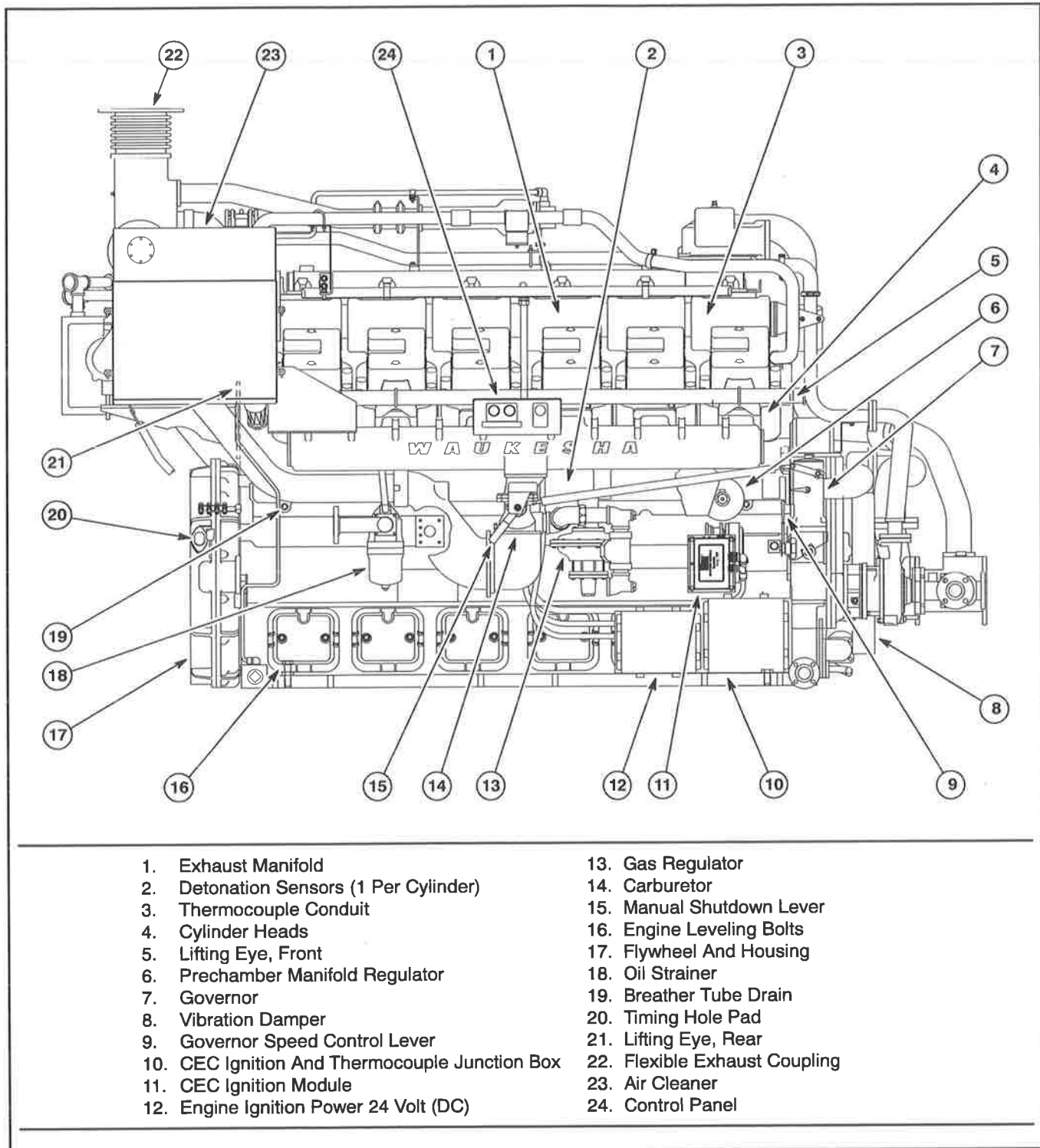
5115GL VIEWS



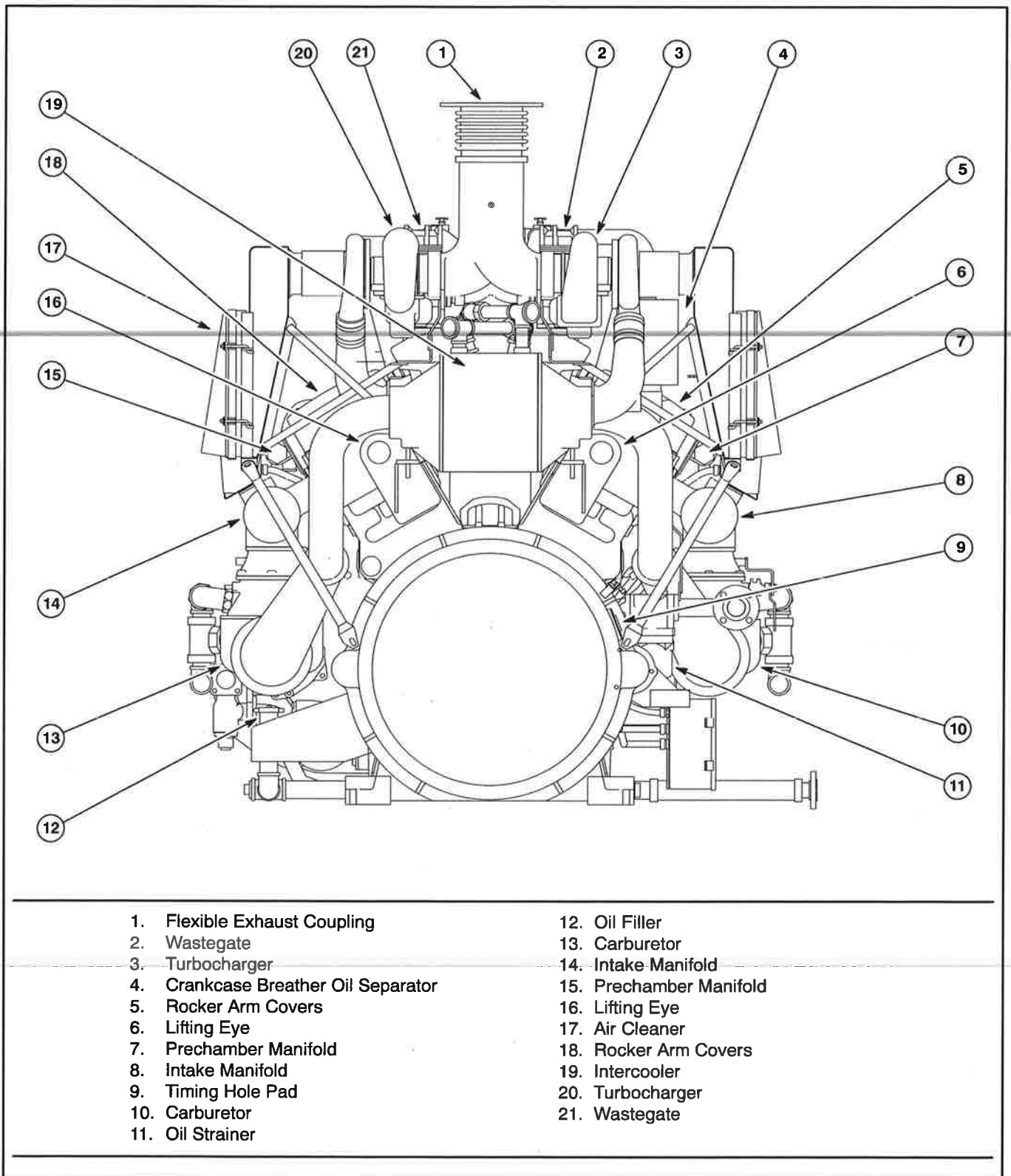
- |                          |   |
|--------------------------|---|
| 1. Exhaust Manifold      | 14. Gas Inlet                           |
| 2. Venturi Extractor     | 15. Oil Pump                            |
| 3. Air Cleaner           | 16. Oil Pan                             |
| 4. Exhaust Outlet Flange | 17. Engine Leveling Bolts               |
| 5. Lifting Eye, Rear     | 18. Air/Gas Prelube Pump Motor          |
| 6. Water Drain           | 19. Jacket Water Pump                   |
| 7. Barring Device        | 20. Water Inlet Flange                  |
| 8. Oil Filler            | 21. Crankcase Breather Oil Separator    |
| 9. Oil Dipstick          | 22. Lifting Eye, Front                  |
| 10. Flywheel Housing     | 23. Detonation Sensors (1 Per Cylinder) |
| 11. Oil Drain            | 24. Thermostat Cluster Housing          |
| 12. Oil Pan Access Doors | 25. Control Panel                       |
| 13. Regulator, Gas       | 26. Water Manifold                      |

Figure 1.15-7. Left Side View - 5115GL

## GENERAL INFORMATION



**Figure 1.15-8. Right Side View - 5115GL**

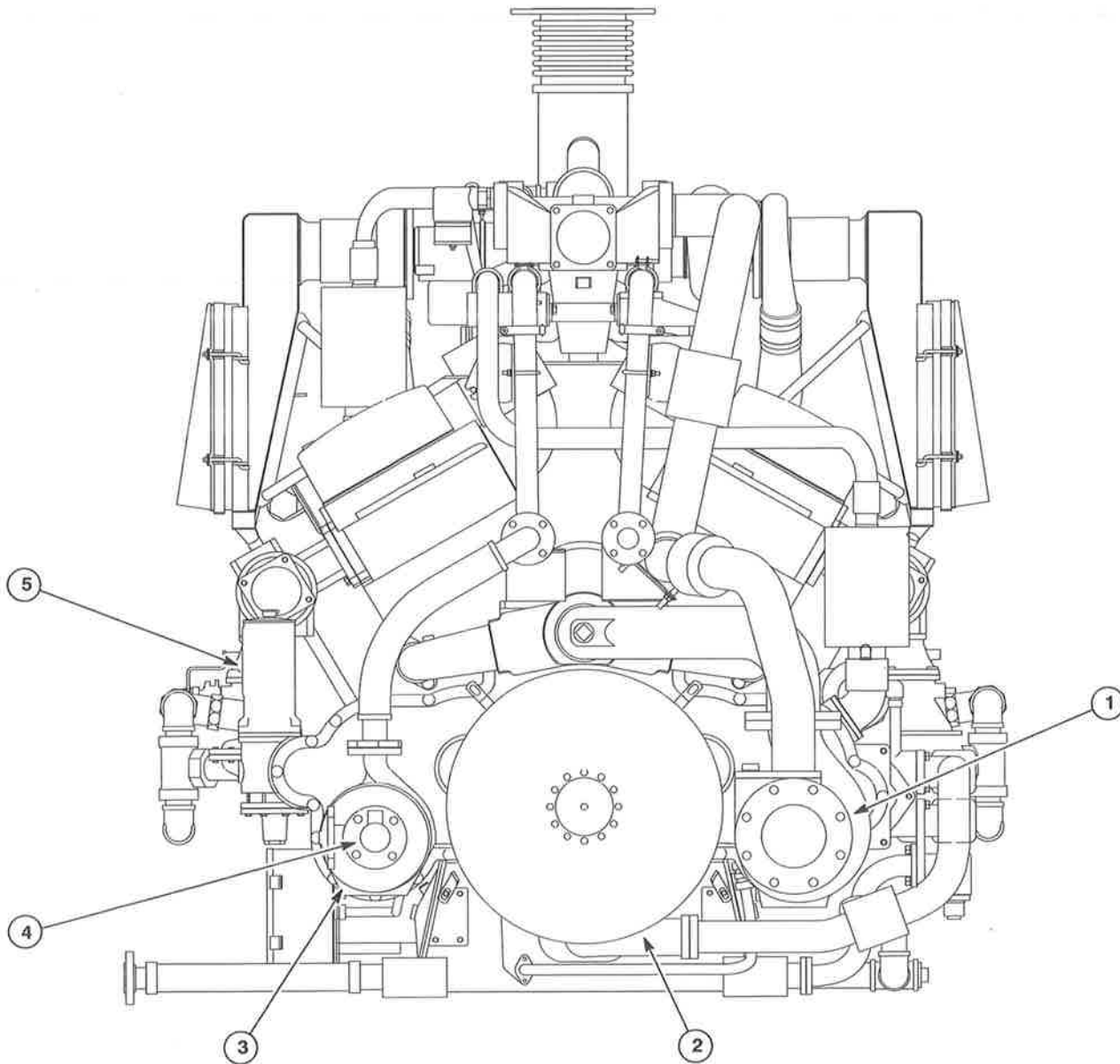


- |                                     |                         |
|-------------------------------------|-------------------------|
| 1. Flexible Exhaust Coupling        | 12. Oil Filler          |
| 2. Wastegate                        | 13. Carburetor          |
| 3. Turbocharger                     | 14. Intake Manifold     |
| 4. Crankcase Breather Oil Separator | 15. Prechamber Manifold |
| 5. Rocker Arm Covers                | 16. Lifting Eye         |
| 6. Lifting Eye                      | 17. Air Cleaner         |
| 7. Prechamber Manifold              | 18. Rocker Arm Covers   |
| 8. Intake Manifold                  | 19. Intercooler         |
| 9. Timing Hole Pad                  | 20. Turbocharger        |
| 10. Carburetor                      | 21. Wastegate           |
| 11. Oil Strainer                    |                         |

Figure 1.15-9. Rear View - 5115GL

## GENERAL INFORMATION

*NOTE: Front guard shown removed for clarity.*



1. Water Inlet Flange
2. Vibration Damper
3. Auxiliary Water Pump
4. Auxiliary Water Inlet
5. Governor

**Figure 1.15-10. Front View - 5115GL**

TWELVE CYLINDER GL VIEWS

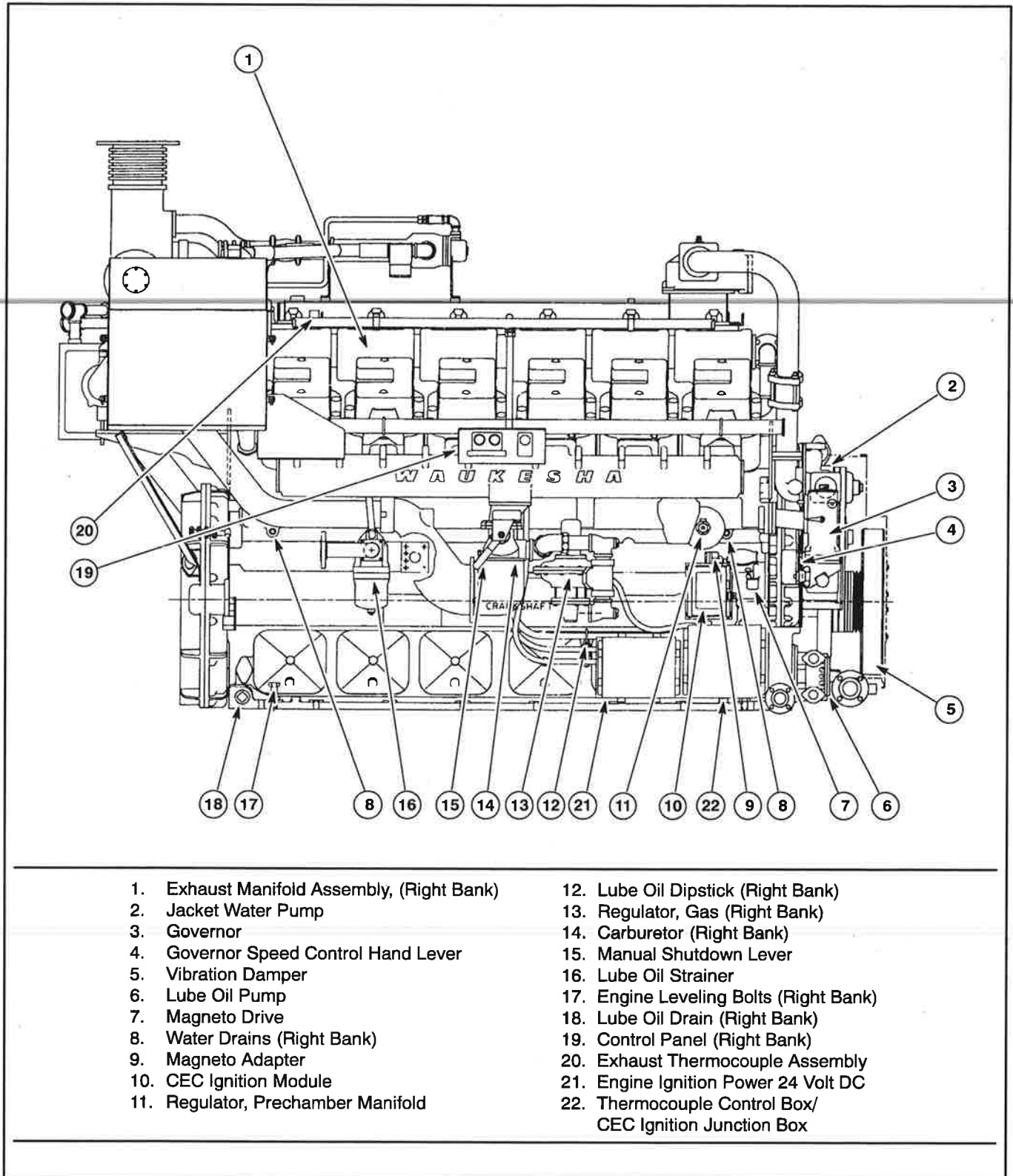
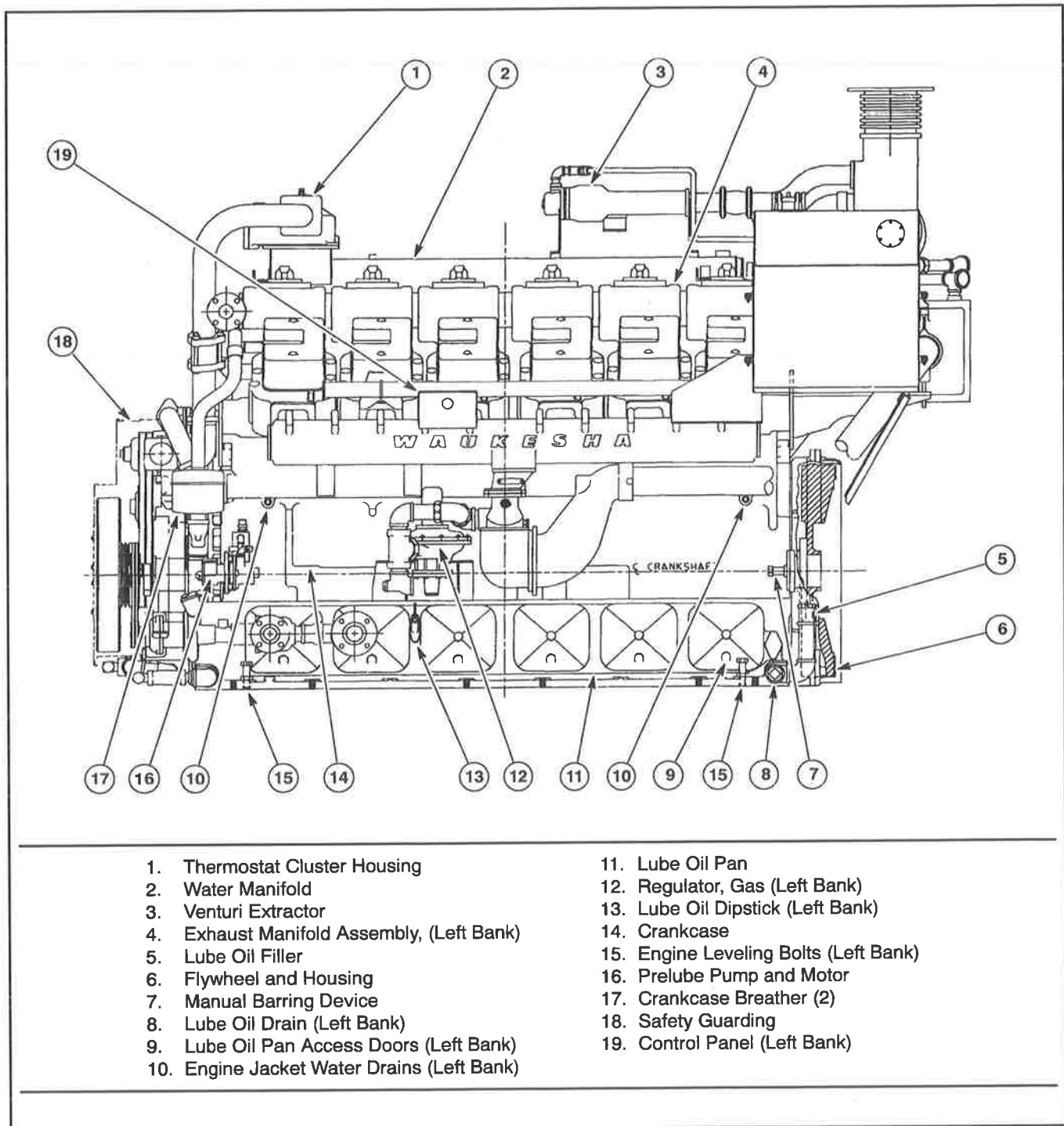
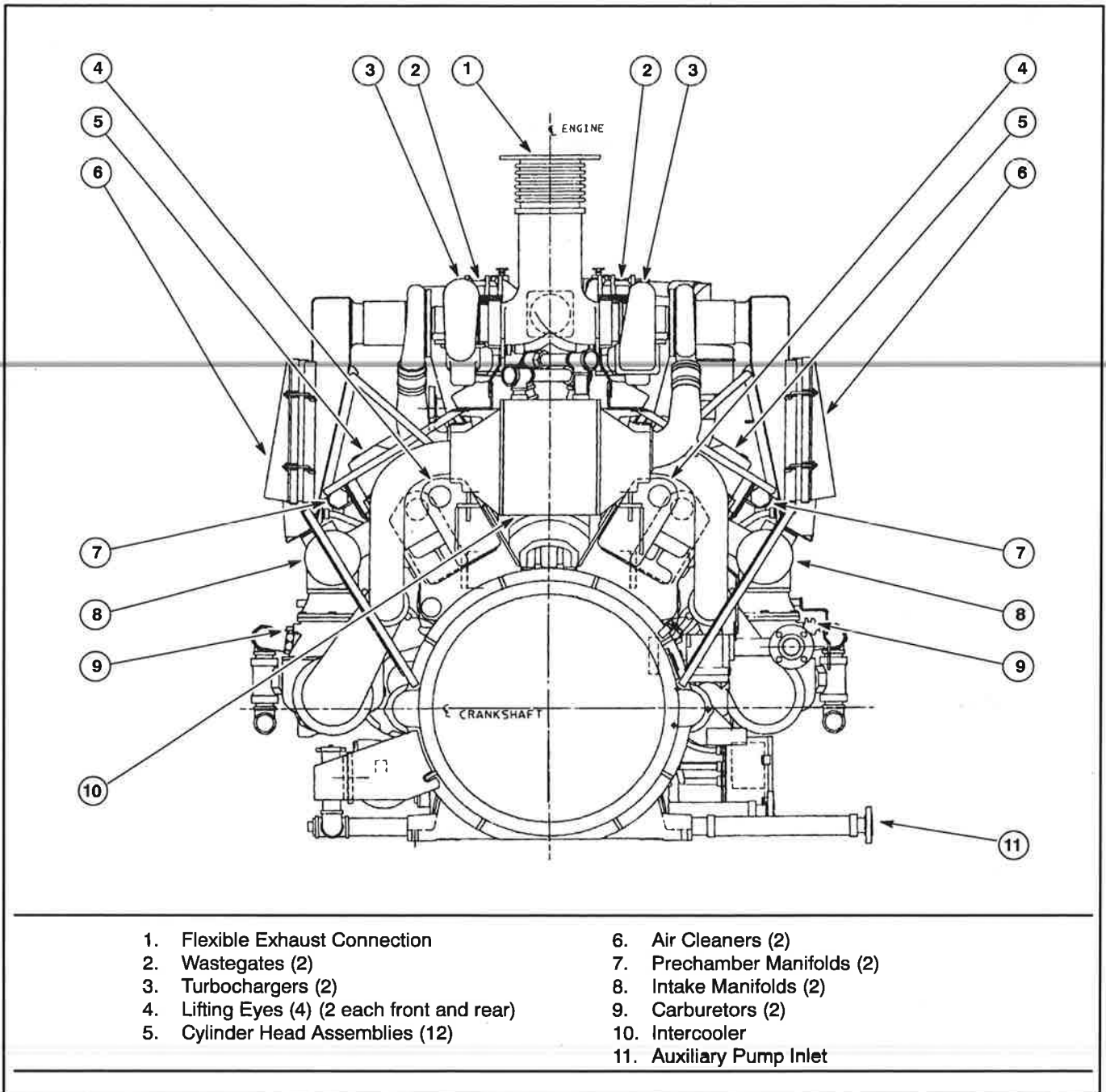


Figure 1.15-11. Right Side View - 12 Cylinder VHP GL

## GENERAL INFORMATION



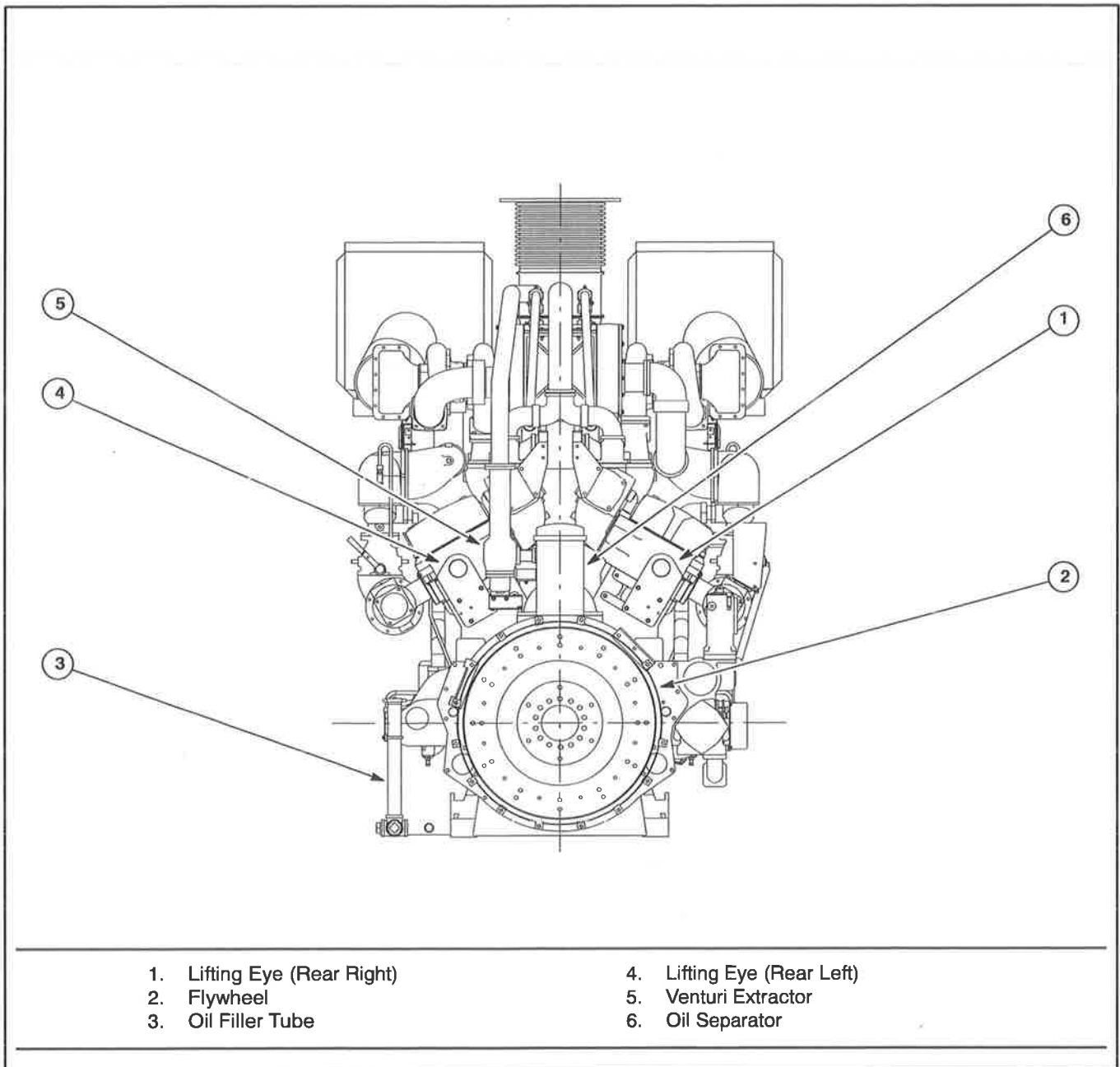
**Figure 1.15-12. Left Side View - 12 Cylinder VHP GL**



- |   |                             |
|---|-----------------------------|
| 1. Flexible Exhaust Connection              | 6. Air Cleaners (2)         |
| 2. Wastegates (2)                           | 7. Prechamber Manifolds (2) |
| 3. Turbochargers (2)                        | 8. Intake Manifolds (2)     |
| 4. Lifting Eyes (4) (2 each front and rear) | 9. Carburetors (2)          |
| 5. Cylinder Head Assemblies (12)            | 10. Intercooler             |
|   | 11. Auxiliary Pump Inlet    |

Figure 1.15-13. Rear View - 12 Cylinder VHP GL

## GENERAL INFORMATION



**Figure 1.15-16. Rear View - 16 Cylinder VHP GL**



ENGINE SPECIFICATIONS

**CAUTION** Alarm and shutdown valves are based on dry natural gas (900 Btu/cu. ft. SLHV). Refer to Gaseous Fuel Specification Sheet S7884C and Lube Oil Recommendations Sheet S1015Y or latest revisions for typical changes in operation temperatures for jacket water and lube oil when running on landfill or digester gas fuels. Disregarding this information could result in product damage.

Table 1.15-2. VHP Specifications

GENERAL SPECIFICATIONS				
Engine Model	6 Cylinder	12 Cylinder <sup>3</sup>	5115GL	16 Cylinder
Type	4-cycle	4-cycle	4-cycle	4-cycle
Aspiration, G	Naturally aspirated	Naturally aspirated	-	Naturally aspirated
Aspiration, GSI	Turbocharged, intercooled	Turbocharged, intercooled	-	Turbocharged, intercooled
Aspiration, GL	Turbocharged, intercooled, and lean burn	Turbocharged, intercooled, and lean burn	Turbocharged, intercooled, and lean burn	Turbocharged, intercooled, and lean burn
Number of cylinders	Inline-6, 4-valves per cylinder	V-12, 4-valves per cylinder	V-12, 4-valves per cylinder	V-16, 4-valves per cylinder
Bore x stroke	2895 8.50 x 8.50 in. (216 x 216 mm) 3521 9.375 x 8.50 in. (238 x 216 mm)	5108 8.50 x 7.50 in. (216 x 191 mm) 5790 8.50 x 8.50 in. (216 x 216 mm) 7042 9.375 x 8.50 in. (238 x 216 mm) 9390 9.375 x 8.50 in. (238 x 216 mm)	8.50 x 7.50 in. (216 x 191 mm)	9.375 x 8.50 in. (238 x 216 mm)
Displacement	2895G,GSI,GL 2894 cu. in. (47 litres) 3521G,GSI 3520 cu. in. (58 litres) 3521GL 3521 cu. in. (58 litres)	5108G,GSI,GL 5108 cu. in. (83.7 litres) 5790G,GSI 5790 cu. in. (115 litres) 5790GL 5788 cu. in. (95 litres) 7042G,GSI,GL 7040 cu. in. (115 litres) 9390G,GSI,GL 9388 cu. in. (154 litres)	5108 cu. in. (83.7 L)	9388 cu. in. (154 L)
Compression ratio G, GSI	2895G,GSI 8:1 optional 10:1 2895GL 10.5:1 3521G,GSI 8:1 optional 10:1 3521GL 10.5:1	5108 10:1 5790 8.2:1 7042 8.2:1	---	8:1
Compression ratio GL	2895GL 10.5:1 3521GL 10.5:1	5108 10.5:1 5790 10.5:1 7042 10.5:1	10.5:1	10.5:1
Speed range	700 - 1200 rpm (see engine nameplate)		1250 - 1500 rpm (see engine nameplate)	700 - 1200 rpm (see engine nameplate)
Low idle	450 rpm	450 rpm	450 rpm	450 rpm
Lubrication System				
Sump capacity, including filter and cooler*	72 gallons (272.5 litres)	99 gallons (375 litres)	99 gallons (376 litres)	165 gallons (625 litres)
Oil pan (Low level mark)	35 gallons (132.5 litres)	35 gallons (132.5 litres)	35 gallons (132.5 litres)	80 gallons (303 litres)
Oil pan (High level mark)	45 gallons (170.3 litres)	45 gallons (170.3 litres)	54 gallons (204.4 litres)	110 gallons (416 litres)

(Continued)

# GENERAL INFORMATION

GENERAL SPECIFICATIONS				
Engine Model	6 Cylinder	12 Cylinder <sup>3</sup>	5115GL	16 Cylinder
<b>Lubrication System (continued)</b>				
Lube oil filter capacity	20 gallons (75.7 litres)	36 gallons (136.3 litres)	36 gallons (136.3 litres)	45 gallons (170 litres)
Oil cooler capacity	(8 in.) 6.9 gal. (26.1 L) (10 in.) 10 gal. (37.8 L)	(8 in.) 6.9 gal. (26.1 L) (10 in.) 10 gal. (37.8 L)	9.0 gallons (34.1 litres)	10 gallons (38 litres)
Main filter	15 micron at @ 90% efficiency	15 micron at @ 90% efficiency	15 micron at @ 90% efficiency	15 micron at @ 90% efficiency
Strainer screen	74 micron	74 micron	74 micron	74 micron
Normal lube oil pressure	40 - 55 psi (275 - 380 kPa)	40 - 55 psi (275 - 380 kPa)	40 - 55 psi (275 - 380 kPa)	35 - 50 psi 240 - 345 kPa
Low oil pressure alarm setpoint	30 psi (207 kPa)	30 psi (207 kPa)	30 psi (207 kPa)	25 psi (173 kPa)
Low oil pressure shutdown setpoint	20 psi (138 kPa)	20 psi (138 kPa)	25 psi (172 kPa)	15 psi (103 kPa)
Minimum oil pressure at turbo	10 psi (69 kPa)	10 psi (69 kPa)	10 psi (69 kPa)	10 psi (69 kPa)
Prelube duration	5 minutes			
Postlube duration	5 minutes after operation			
Normal oil header temperature	180° F (82° C)	180° F (82° C)	180° F (82° C)	180° F (82° C)
Oil header temperature alarm setpoint	195° F (91° C)	195° F (91° C)	195° F (91° C)	195° F (91° C)
Oil header temperature shutdown setpoint	205° F (96° C)	205° F (96° C)	205° F (96° C)	205° F (96° C)
<b>Governor And Air Starter Capacities</b>				
UG8 governor oil reservoir	1.5 quart (1.1 litre)	1.5 quart (1.1 litre)	1.5 quart (1.1 litre)	1.5 quart (1.1 litre)
Air starter oil reservoir for one shot lubricator	2.0 pint (0.9 litre)	2.0 pint (0.9 litre)	2.0 pint (0.9 litre)	2.0 pint (0.9 litre)
Air motorized pre-lube motor, in-line lubricator	0.5 pint (0.2 litre)	0.5 pint (0.2 litre)	0.5 pint (0.2 litre)	0.5 pint (0.2 litre)
<b>Cooling System (Jacket Water And Auxiliary System)</b>				
Normal charge air cooler inlet temperature		130° F (54° C)		
Jacket water capacity, engine only	8.5 in. bore 52.5 gal. (198.7 L) 9.375 in. bore 48.5 gal. (183.6 L)	8.5 in. bore 107 gal. (405 L) 9.375 in. bore 100 gal. (387 L)	107 gallons (405 litres)	148 gallons (560 litres)
Surge tank capacity (optional)	23 gallons (87 litres)	45.5 gallons (183 litres)	45.5 gallons (183 litres)	45.5 gallons (183 litres)
Intercooler water capacity	2.75 gallon (10.4 litres)	5.50 gallons (20 litres)	5.5 gallons (20 litres)	11 gallons (42 litres)
Oil cooler water capacity	6 in. diameter 3.4 gal. (12 L) 8 in. diameter 5.5 gal. (20 L) 10 in. diameter 9.4 gal. (34 L)	6 in. diameter 3.4 gal. (12 L) 8 in. diameter 5.5 gal. (20 L) 10 in. diameter 9.4 gal. (34 L)	5.0 gallons (18.9 litres)	9.4 gallons (35.6 litres)
Total system capacity	Add appropriate options to obtain total capacity			
<b>Exhaust System</b>				
Maximum permissible backpressure @ rated load and speed			See Table 4.35-1 <i>Maximum Allowable Exhaust Backpressure And Reductions For Speed And Load</i> in Section 4.35 <i>Exhaust System Maintenance</i>	
<b>Crankcase Breather System</b>				
Crankcase vacuum	0 to -1 (negative) in. (0 to -25.4 mm (negative)) H <sub>2</sub> O			

(Continued)

## GENERAL INFORMATION

<b>GENERAL SPECIFICATIONS</b>	
Engine Model	6 Cylinder      12 Cylinder <sup>3</sup> 5115GL      16 Cylinder
<b>Jacket Water Outlet Temperature</b>	
<b>Standard Cooling System</b>	<b>Normal:</b> 180° F (82° C) for continuous rating 200° F (93° C) for intermittent rating
	<b>Alarm:</b> 10° F (5.5° C) above normal/design temperature
	<b>Shutdown:</b> 20° F (11° C) above normal/design temperature
<b>Elevated Temperature Solid Water Cooling System</b>	<b>Normal:</b> 210° - 235° F (99° - 113° C) solid water
	<b>Alarm:</b> 5° F (3° C) above normal/design temperature <sup>1</sup>
	<b>Shutdown:</b> 10° F (5.5° C) above normal/design operating temperature <sup>1</sup>
<b>Ebullient Cooling System</b>	<b>Normal:</b> 212° - 250° F (100° - 121° C)
	<b>Alarm:</b> See Note <sup>2</sup> below
	<b>Shutdown:</b> See Note <sup>2</sup> below
<b>Intake Manifold Temperature</b>	
<b>GSI &amp; GL Engines</b>	<b>Normal:</b> Up to 10° F (5.5° C) above design intercooler water inlet temperature
	<b>Alarm:</b> 15° F (8.5° C) above design intercooler water inlet temperature
	<b>Shutdown:</b> 20° F (11° C) above design intercooler water inlet temperature
<b>Intake Manifold Pressure</b>	
Contact Waukesha Engine Application Engineering Department	
<b>Fuel System</b>	
Natural gas pressure at regulator "G" Models	5 - 10 psi (34.5 - 69 kPa)
Natural gas pressure at regulator "GSI" Models	20 - 25 psi (138 - 172 kPa)
Natural gas pressure at regulator "GL" Models	35 - 50 psi (241 - 345 kPa)
Natural gas pressure at regulator Draw-thru models	GSI - 6 in. (152 mm) of water column GL - 6 in. (152 mm) of water column at regulator and 30 psig (206.8 kPa) prechamber fuel supply
<b>Air Induction System</b>	
Maximum permissible restriction @ rated load and speed	15 in. (381 mm) of H <sub>2</sub> O
Required filtering efficiency (coarse dust test per SAE726C)	99.7%
<b>Starting System</b>	
Electric starting	24 volts DC
Air pressure starting	150 psi (1043 kPa)(MAX) Pressure is based on 50° F (10° C) lube oil temperature
<b>Miscellaneous</b>	
Park plug gap	See Table 1.15-4 and Table 1.15-5
Engine timing	Refer To Engine Name Plate
Main bearing temp shutdown	250° F (121° C)
Overspeed shutdown	10% over governed speed
<b>Valve Train</b>	
Valve Clearance - Hydraulic lifters 6, 12, and 16 cylinder engines - excluding 5115GL	Not applicable - 0.000
Valve Clearance - 5115GL engines Only, non-hydraulic lifters Intake Exhaust	0.016 in (0.406 mm) (5115GL only) 0.036 in (0.914 mm) (5115GL only)

**NOTE:** \*Total capacity of lube oil system. Fill oil pan, filter, cooler, etc., run engine, then add oil as required to bring oil level in oil pan back to high mark. Record total amount for future reference.

<sup>1</sup> Waukesha Power Systems Code 1105, 1105A, or equivalent shutdown system recommended when jacket water temperature exceeds 210° F (99° C).

<sup>2</sup> Waukesha Power Systems Code 1106, 1106A, or equivalent shutdown system is recommended for ebulliently cooled engines.

<sup>3</sup> Does not include 5115GL model.

## GENERAL INFORMATION

### TORQUE VALUES

Table 1.15-3 lists the torque values needed for the basic maintenance of VHP engines.

**Table 1.15-3. Torque Values**

DESCRIPTION	ft-lb	N-m
Spark Plugs <b>CAUTION</b> 13/16 inch reach spark plugs must be used with 13/16 inch reach carriers and 1/2 inch reach spark plugs must be used with 1/2 inch reach carriers. Mixing carrier and spark plug components will cause damage to equipment.	40 - 45 (dry)	54 - 61 (dry)
Spark Plug Carriers <b>CAUTION</b> Stainless steel prechamber seal (P/N 209562D) must be used with the prechamber cup when torquing the spark plug carrier to 275 - 280 ft-lb (373 - 380 N-m) (with FEL-PRO® C5-A®, P/N 51005 anti-seize compound applied to threads) or damage to equipment will result.	275 - 280 (with FEL-PRO® C5-A®, P/N 51005 anti-seize compound applied to threads)	373 - 380 (with FEL-PRO® C5-A®, P/N 51005 anti-seize compound applied to threads)
Gas Admission Valve (P/N 211587A used with stainless steel washer P/N 28357)	65 - 70	88 - 95
Rocker Arm Support Capscrews 1/2-13	55 - 60	75 - 81
Fixed Valve Lifter Screws	55 - 60	75 - 81
Rocker Arm Cover Capscrews	30 - 35	41 - 47
Oil Pan Access Covers (Current P/N E200224 with two capscrews)	18 - 20	24 - 27
Pressure Relief Valve Equipped Oil Pan Access Covers	18 - 20	24 - 27
Previous Oil Pan Access Covers (with one capscrew)	18 - 20	24 - 27

**NOTE:** All torques oiled unless specified.

**CAUTION** 1/2 Inch reach spark plugs must be used with 1/2 inch reach spark plug carriers. Mixing spark plug carrier and spark plug components will cause damage to equipment.

**Table 1.15-4. 1/2 Inch Reach Spark Plugs (Used On G and GSI, and 1/2 Inch Reach Spark Plug Carriers on GL Only)**

COMPONENT	P/N	REMARKS
<b>SPARK PLUG CARRIERS</b>		
Carrier 1/2 inch plug reach	209567J*	Used on 5108GL only
Carrier 1/2 inch plug reach	209567E*	Used on 2895GL, 3521GL, 7042GL, 9390GL
<b>SPARK PLUGS</b>		
<b>Standard</b>	60999F (Nickel) (Gap 0.020 in. (0.508 mm))	G,GSI - Used with P/N 208338A spark plug recess cover and P/N 69694 "Blue coil"
	60999M (Nickel) (Gap 0.010 in. (0.254 mm))	GL - Used with P/N 208338A spark plug recess cover and P/N 69694 "Blue coil"
<b>CSA (Shielded)</b>	60999H (Nickel) (Gap 0.020 in. (0.508 mm))	CSA G,GSI - Use with P/N 208338B spark plug recess cover, P/N 69772A extension and current P/N 60615F coil
	60999R (Nickel) (previous production - see Table 1.15-5 for current production) (Gap 0.010 in. (0.254 mm))	CSA GL - Used with P/N 69694D (previous production CSA "long coil") and P/N 208338B spark plug recess cover
<b>SPARK PLUG EXTENSIONS</b>		
Extension	211357H (current) A211357 (previous)	G,GSI,GL - Use with P/N 208338A spark plug recess cover and P/N 69694 "Blue coil"
Extension CSA	69772A (current production)	CSA G,GSI - Use with P/N 208338B spark plug recess cover and current P/N 60615F coil
Boot **	740011	Replace boot as required

**NOTE:** \* 1/2 inch reach spark plugs are used with 1/2 inch reach spark plug carriers only.

\*\* Service P/N 211357H spark plug connectors with P/N 740011 Boot.

**CAUTION** VHP GL 13/16 inch reach spark plugs must be used with 13/16 inch reach spark plug carriers. Mixing spark plug carrier and spark plug components will cause damage to equipment.

**Table 1.15-5. VHP GL 13/16 Inch Reach Spark Plugs (Used With 13/16 Inch Reach Spark Plug Carriers Only)**

COMPONENT	P/N	REMARKS
<b>SPARK PLUG CARRIERS</b>		
Carrier 13/16 inch plug reach	209567M*	Used on 5108GL and 5115GL only
Carrier 13/16 inch plug reach	209567K*	Used on 2895GL, 3521GL, 7042GL, 9390GL
Carrier 13/16 inch plug reach (CSA)	209567S - (CSA)*	Used on 5108GL and 5115GL (CSA) Used with current CSA spark plug carrier, coil adapter and P/N 69694G Blue CSA flanged coil
Carrier 13/16 inch plug reach (CSA)	209567R - (CSA)*	Used on 2895GL, 3521GL, 7042GL, 9390GL (CSA) Used with current CSA spark plug carrier, coil adapter and P/N 69694G Blue CSA flanged coil
<b>SPARK PLUGS</b>		
<b>Standard</b>	60999S (4 ground) (Nickel) (Gap 0.010 in. (0.254 mm))	Used with P/N 69694 "Blue coil"
	60999W (J-Type) (Platinum) (service option) (Gap 0.010 in. (0.254 mm))	Used with P/N 69694 "Blue coil"
	60999T*** (J-Type) (Iridium/Platinum) (service option and CSA and Non - CSA current production) (Gap 0.010 in. (0.254 mm))	Used with P/N 69694 "Blue coil" in Non CSA applications, and current CSA spark plug carrier, coil adapter and P/N 69694G Blue CSA flanged coil in CSA applications
	60999X*** (J-Type) (Iridium/Platinum) (5115GL current production) (Gap 0.010 in. (0.254 mm))	5115GL used with P/N 69694 "Blue coil" Non CSA applications and and current CSA spark plug carrier, coil adapter and P/N 69694G Blue CSA flanged coil in CSA applications
<b>CSA (Shielded)</b>	60999U (4 ground) (Nickel) (service option) (Gap 0.010 in. (0.254 mm))	Used with P/N 69766A (previous production CSA "long coil") and 208338B spark plug recess cover
<b>SPARK PLUG EXTENSIONS</b>		
Extension	211357H (current production)	G, GSI, GL - Use with P/N 208338A spark plug recess cover and P/N 69694 "Blue coil"
Extension CSA	211357P (current production)	CSA GL - Use with P/N 208338A spark plug recess cover and current CSA spark plug carrier, coil adapter and P/N 69694G Blue CSA flanged coil in CSA applications
Boot **	740011	Replace boot as required

**NOTE:** \* 13/16 inch reach spark plugs are used with 13/16 inch reach spark plug carriers only.

\*\* Service P/N 211357H and P/N 211357P spark plug connectors with P/N 740011 Boot.

\*\*\* P/N 60999X spark plugs can be used in place of P/N 60999T spark plugs, but P/N 60999T spark plugs **cannot** be used in place of the P/N 60999X spark plugs on 5115GL engines, because of manufacturing differences.

## GENERAL INFORMATION

### ENGINE TIMING DATA

**CAUTION** Detonation is NOT allowed at any time during engine operation, regardless of the specified timing. If detonation occurs at the specified timing, a timing adjustment must be made to retard the ignition timing until NO audible detonation exists. Engine damage may result if detonation occurs.

Refer to the engine nameplate for the proper engine timing value.

**NOTE:** Changing the engine timing will also change the exhaust emissions and fuel economy.

**WAUKESHA KNOCK INDEX™ (WKI™)** The WKI™, developed by Waukesha Engine, represents a major leap forward in field gas analysis. This new method replaces the Octane Method analysis method previously used.

The WKI™ greatly improves the accuracy of calculating fuel knock resistance of field gas, natural gas, and low Btu gases. In addition, the WKI™ is able to account for the "knock improver" characteristics of inert gases which are often found in gaseous fuels. When used in conjunction with the Waukesha Custom Engine Control® Detonation Sensing Module, Waukesha is often able to maximize power ratings and optimize performance on poor quality fuels while maintaining an adequate knock safety margin.

### SERVICE TOOLS LIST

You will need the following special tools to perform the operator tasks on VHP engines (see Table 1.15-6). In some instances, substitute items may be used but only if specifically approved by Waukesha. To order these special tools, contact your local Waukesha Engine Distributor.

**Table 1.15-6. Service Tools**

WAUKESHA TOOL P/N	TOOL DESCRIPTION
167164D	Spark Plug Socket/Ext. (1 inch socket with 10 inch extension, for Shielded, CSA w/F.M. coils)
474016	VHP V- Belt Tester
474022	Timing Tool
175006	Spark Plug Spreading Tool
475037	Spark Plug Socket (NEW) (7/8 inch Socket 15-1/2 inch long w/rubber O-ring insert)
475028	Digital Manometer/Calibrator Kit
475029	O-Ring Lube
494087	Spark Plug Thread and Seat Cleaner (18 mm) for 1/2 inch reach spark plug bores
475065	Spark Plug Thread and Seat Cleaner (18 mm) for 13/16 inch reach spark plug bores
494227	Explosion Proof Timing Light
494258	Slack Tube Manometer
494287	Valve Adjusting Wrench
494338	Induction Timing Light
494421	Spark Plug Gapping Tool - 0.010 - 0.013 in. (0.254 - 0.330 mm)(4 prong)(not recommended for gapping used plugs)
494422	Spark Plug Gapping Tool - 0.018 - 0.022 in. (0.457 - 0.559 mm)(4 prong)(not recommended for gapping used plugs)
475033	Spark Plug Gapping Kit (4 prong) Contains gap setting tool for closing the gaps, a gap spreading tool, and two gap setting tools, 0.011 in. (0.279 mm) and 0.020 in. (0.508 mm)
489341	KRYTOX® GPL-206 grease - for spark plug boot and extension

### **CONTENTS**

- SECTION 2.00 - SPEED GOVERNING SYSTEM DESCRIPTION**
- SECTION 2.05 - FUEL SYSTEM DESCRIPTION**
- SECTION 2.10 - IGNITION SYSTEM DESCRIPTION**
- SECTION 2.15 - AIR INTAKE SYSTEM DESCRIPTION**
- SECTION 2.20 - TURBOCHARGER SYSTEM DESCRIPTION**
- SECTION 2.25 - COOLING SYSTEM DESCRIPTION**
- SECTION 2.30 - LUBRICATION SYSTEM DESCRIPTION**
- SECTION 2.35 - EXHAUST SYSTEM DESCRIPTION**
- SECTION 2.40 - CRANKCASE BREATHER SYSTEM DESCRIPTION**
- SECTION 2.45 - PRELUBE AND STARTING SYSTEM DESCRIPTION**
- SECTION 2.50 - ENGINE PROTECTION SHUTDOWN SYSTEM DESCRIPTION**

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## SECTION 2.00

### SPEED GOVERNING SYSTEM DESCRIPTION

#### SPEED GOVERNING SYSTEM DESCRIPTION

The engine speed governing system consists of the following components. Components may vary with the engine model:

- Governor Options
  - Woodward UG-8L Governor
  - Woodward UG-8 Dial Governor
  - Woodward UG-Actuator
  - Woodward EG-3P Electronic Governor
- Governor Linkage
- Magnetic Pickup (for electronic governors)
- Control Panels (for electric units)
- Overspeed Governor (optional)

#### WOODWARD UG-8L GOVERNOR

The Woodward UG-8L Governor, capable of isochronous operation (will maintain the same engine speed regardless of engine load) is a mechanical-hydraulic device (see Figure 2.00-1).

#### WOODWARD UG-ACTUATOR GOVERNOR

The Woodward UG-Actuator Governor, is a proportional electric/hydraulic actuator. The UG-Actuator converts an electrical input signal to a proportional hydraulic output-shaft position to control engine fuel flow. The UG-Actuator provides the advantages of electronic control while using the same linkages as the UG-8 governors. The UG-Actuator is outwardly similar to the UG-8L governor.

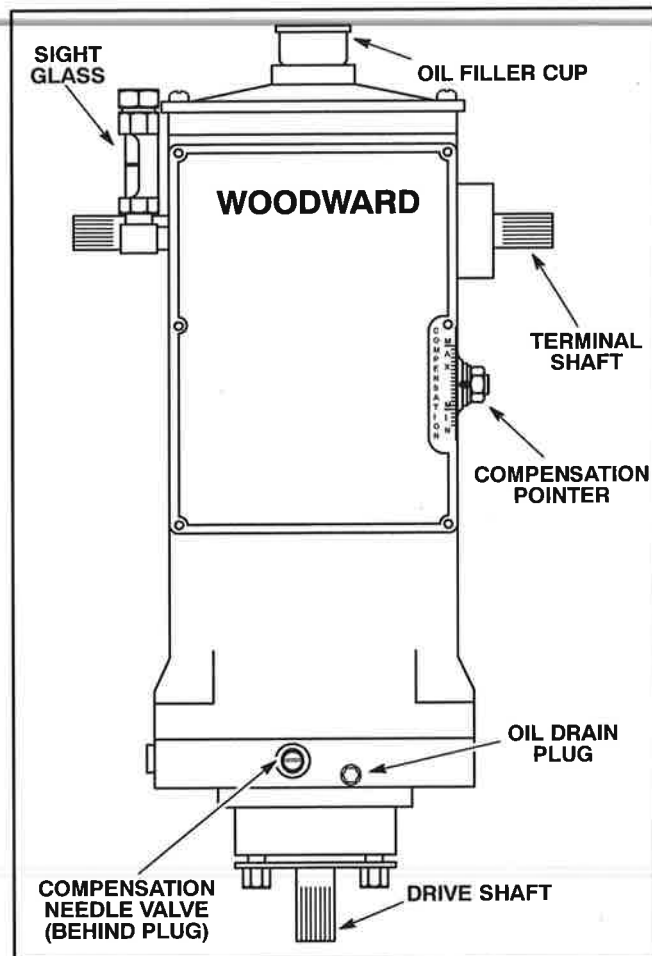


Figure 2.00-1. Woodward UG-8L Governor

#### WOODWARD UG-8 DIAL GOVERNOR

The Woodward UG-8 Dial Governor, is a mechanical-hydraulic device mechanically linked to the fuel system. The governor operates isochronously (will maintain the same engine speed regardless of engine load), except during transient load conditions. The UG-8 Dial Governor has dial adjustments on the face of the gear (see Figure 2.00-2). These dials are the Speed Droop control knob, the Load Limit control knob, the Synchronizer, and the Syn. Indicator. The speed droop control can be set to

## SPEED GOVERNING SYSTEM DESCRIPTION

automatically divide and balance the load between engines driving the same shaft, or paralleled in an electrical system.

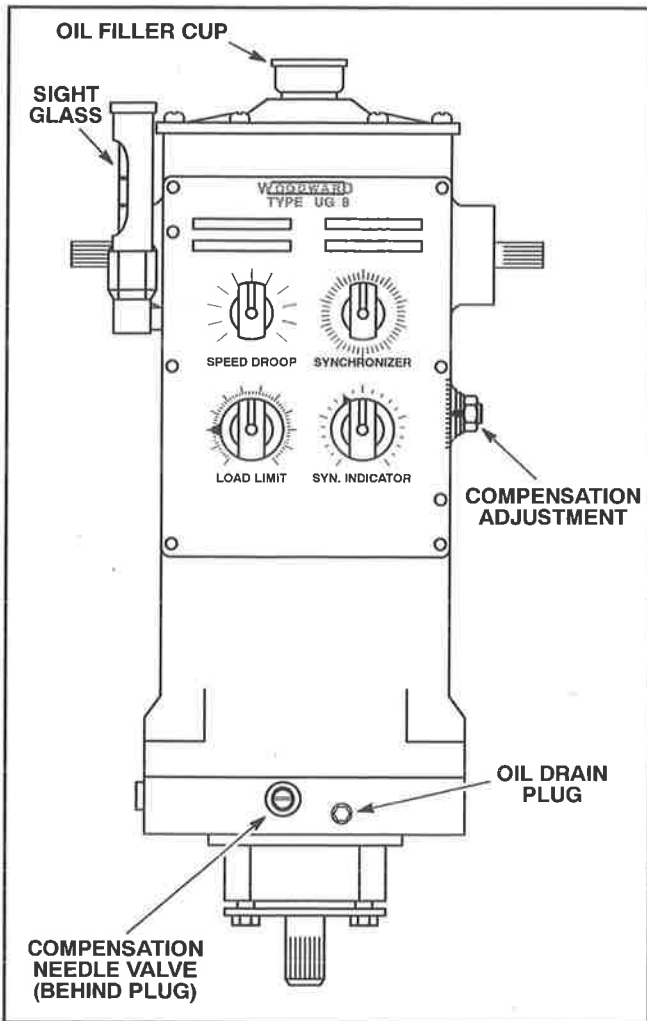


Figure 2.00-2. Woodward UG-8 Dial Governor

### WOODWARD EG-3P ELECTRONIC GOVERNING SYSTEM

The Woodward EG-3P electronic governing system (see Figure 2.00-3) consists of three components, the magnetic pickup, the control unit and the actuator. The system is capable of isochronous operation (will maintain the same engine speed regardless of engine load). The control unit is off-engine mounted and is usually in the control room. It is the device that interrupts the signal that is sent from the magnetic pickup. The control unit then compares the the magnetic signal through circuitry and makes the proper adjustments through the actuator. The governor actuator is engine mounted, and is the mechanical device that physically moves the carburetor butterflies. The governor actuator is driven from the accessory drive gear.

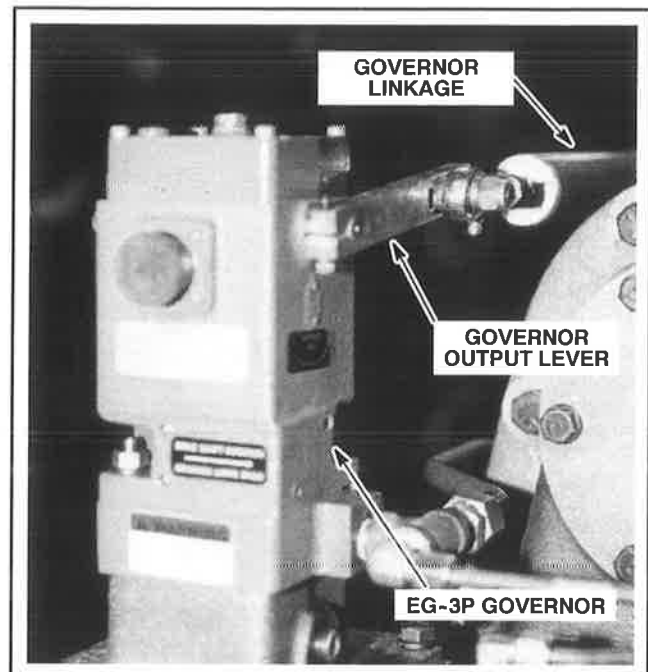


Figure 2.00-3. EG-3P Governor - 6 Cylinder Shown

### OVERSPEED GOVERNOR

The overspeed governor is a safety device that protects the engine from overspeed damage (see Figure 2.00-4). The overspeed governor is activated when the engine speed rises approximately 10 percent above the maximum high idle speed. The overspeed governor functions only if the regular governor fails to operate.

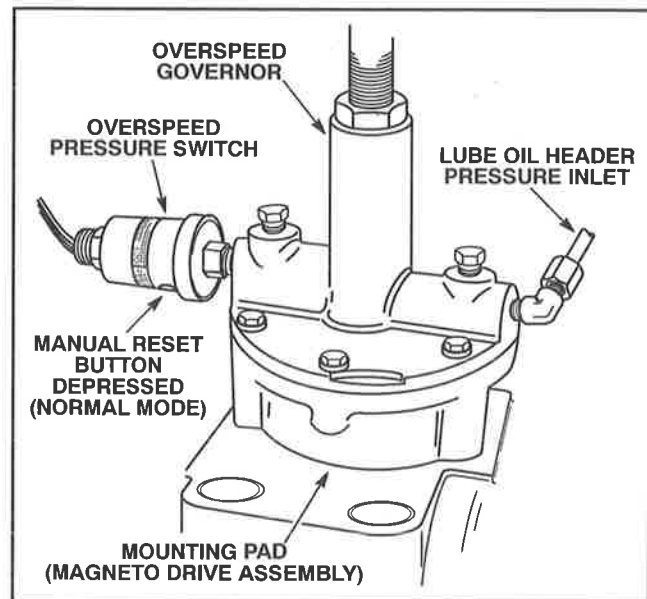
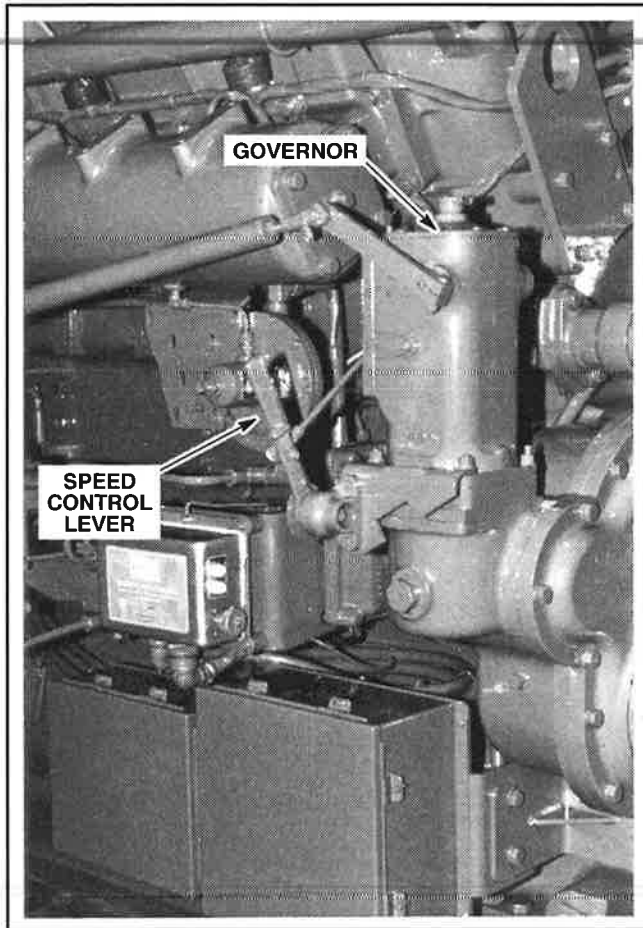


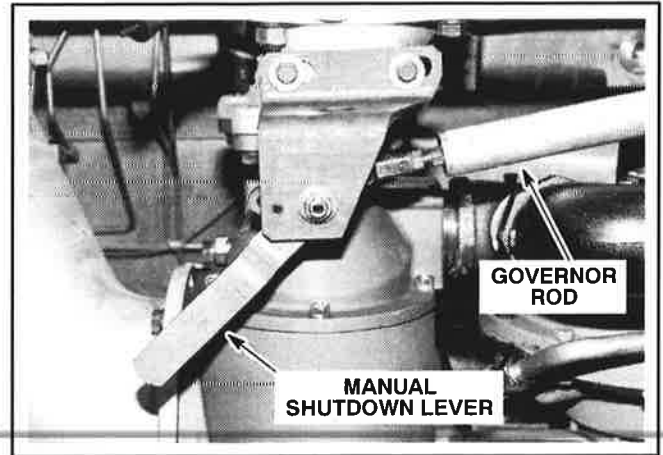
Figure 2.00-4. Overspeed Pressure Switch

## GOVERNOR LINKAGE

The governor linkage (see Figure 2.00-3) connects the governor output shaft with the carburetor butterfly shaft. UG-8L governors (see Figure 2.00-5) have a hand lever on the side of the governor to manually set engine speed. UG-8 dial governors (see Figure 2.00-2) manually control engine speed with a dial control. All engines have a manual shutdown lever (see Figure 2.00-6) added to the linkage on the carburetor side, that enables the operator to manually return the engine to idle in the event of an emergency.



**Figure 2.00-5. Governor Speed Control Lever - 5115GL**



**Figure 2.00-6. Manual Shutdown Lever - 5115GL**

## MAGNETIC PICKUP

The engine speed is detected by a magnetic pickup threaded into the flywheel housing above the flywheel ring gear.

# SPEED GOVERNING SYSTEM DESCRIPTION

## CONTROL PANEL

A control unit (see Figure 2.00-7 and Figure 2.00-8), used with electric units, is off-engine mounted, usually in the control room, and is the device that receives the signal that is sent from the magnetic pickup. The control unit then compares the magnetic pickup signal to the predetermined engine rpm signal through circuitry and makes the proper adjustments through the actuator. The engine rpm is set with the rated speed potentiometer located on the control unit, or by the optional external speed trim potentiometer. The rpm setting voltage is

compared at the control unit between the control amplifier voltage and the rpm voltage. The control amplifier sends an appropriate voltage to the actuator. For example, if the speed was greater than the speed setting, the control amplifier would decrease its output and the actuator would decrease fuel to the engine. Load sharing between two or more engine-generator sets is accomplished via the load sensing circuitry. Each generator's load is electronically measured continuously to other units on the same bus via parallel lines. Continuous correction to control loop gives load sharing.

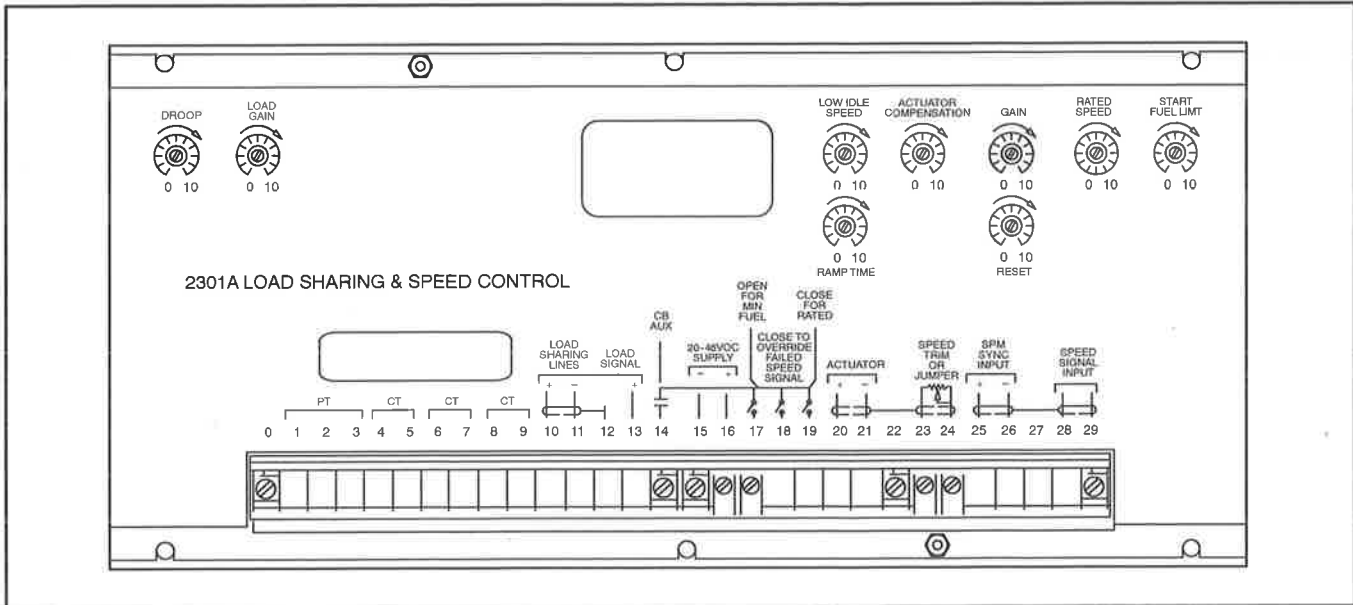


Figure 2.00-7. 2301A Load Sharing And Speed Control

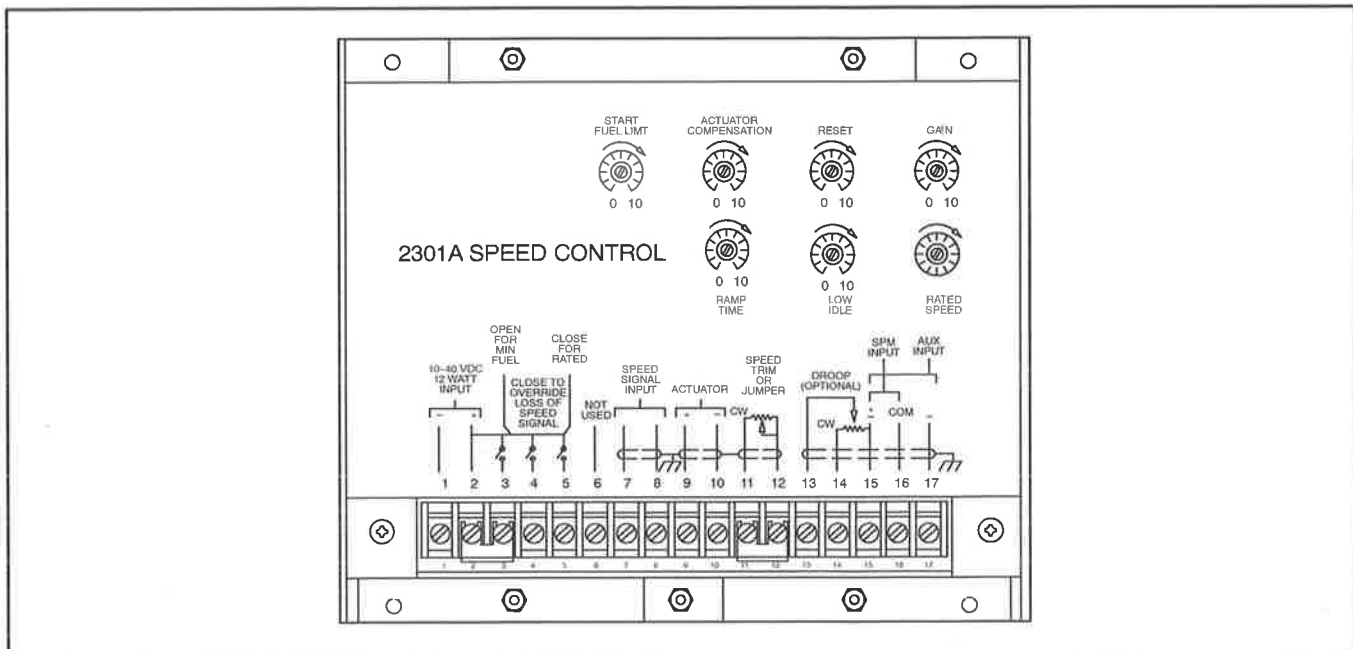


Figure 2.00-8. 2301A Speed Control

## SECTION 2.05

### FUEL SYSTEM DESCRIPTION

#### FUEL SYSTEM DESCRIPTION

The function of the fuel system is to maintain a constant air/fuel ratio throughout the load range of the engine and to deliver the air/fuel mixture in the proper quantities. See following components and Figure 2.05-1 for G/GSI/GL engine fuel components. See *Draw-thru Engines* in this Section, for draw-thru components.

- Main Fuel Gas Pressure Regulator(s)
- Carburetor(s)
- Pilot-Operated Prechamber Gas Valve (GL engines)
- Prechamber Gas Safety Shutdown Valve (GL engines)
- Prechamber Regulator (GL engines)
- Prechamber Manifolds (2) (GL engines)
- Fuel Admission Valves (one per cylinder) (GL engines)
- Custom Engine Control® Air/Fuel Module (AFM) System (Optional)

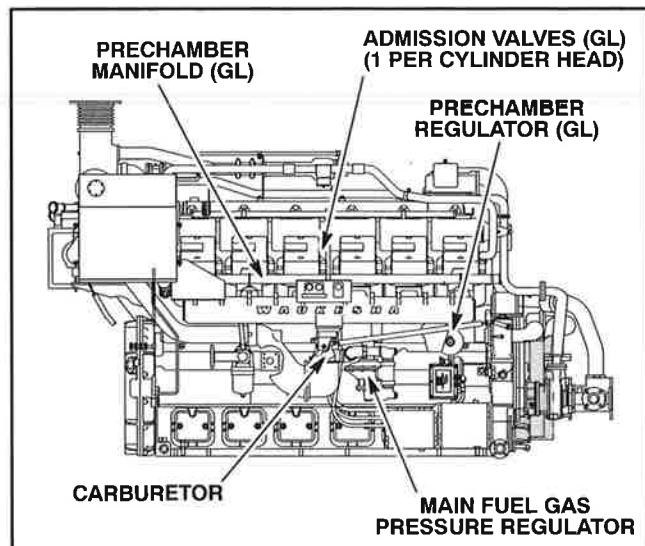


Figure 2.05-1. 5115GL Right Side Engine View

#### MAIN FUEL GAS PRESSURE REGULATORS

To ensure a steady fuel supply to the carburetor(s), all engines have one main fuel gas pressure regulator for each bank (see Figure 2.05-2).

The main fuel gas pressure regulator(s) reduce the incoming fuel supply pressure to the carburetor(s).

**NOTE:** The actual carburetor inlet fuel pressure will depend on the heating value of the fuel.

From the main fuel gas pressure regulator(s) the fuel flows into the carburetor(s) where it is mixed with air to provide a very lean mixture to the combustion chambers.

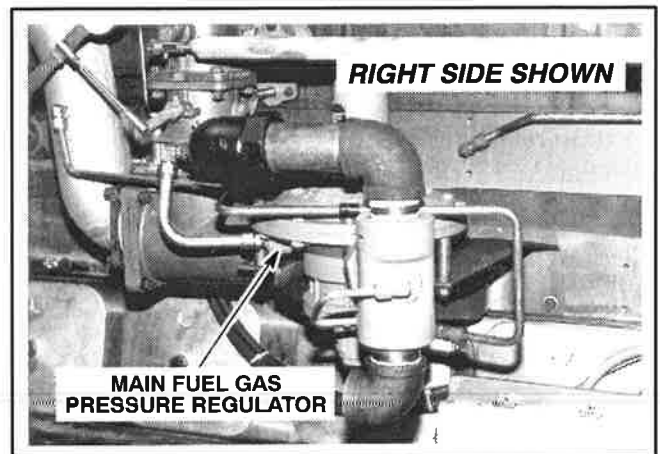


Figure 2.05-2. Fisher 99 Main Fuel Gas Pressure Regulator - 12 Cylinder GSI

## FUEL SYSTEM DESCRIPTION

### CARBURETOR(S)

All engines have a carburetor, mounted just below the center of each intake manifold (see Figure 2.05-3).

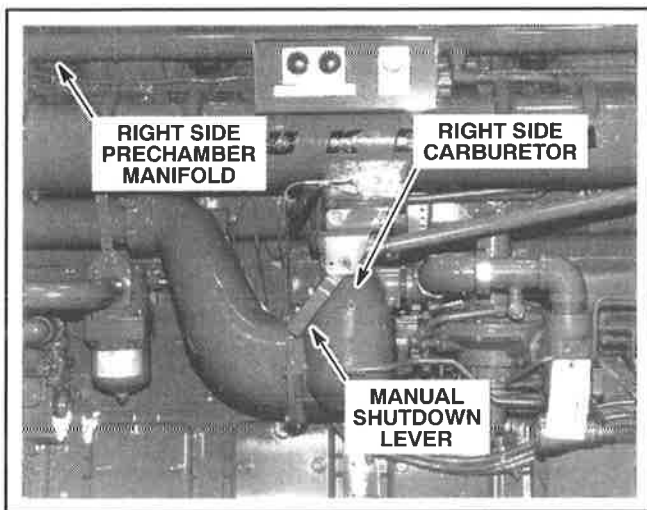


Figure 2.05-3. Carburetor - 5115GL Right Side View

The carburetor(s) produce a combustible mixture by automatically mixing air and fuel in the proper proportions.

### PRECHAMBER REGULATOR

On GL engines, the prechamber regulator (see Figure 2.05-4) controls the amount of fuel available to the prechamber manifolds. The flow to the prechamber manifolds is fuel only. All of the air needed for combustion is pushed into the prechamber by the piston on its compression stroke.

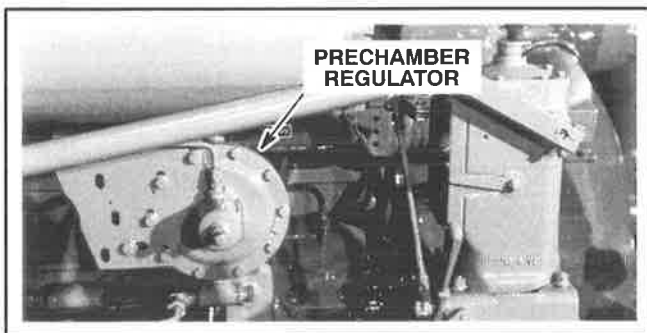


Figure 2.05-4. Prechamber Regulator 5115GL

### PRECHAMBER GAS VALVE

On GL engines, the prechamber gas valve (see Figure 2.05-5), located on a line off the main fuel gas pressure regulator gas inlet pipe tee, admits high pressure gas to the prechamber fuel regulator.

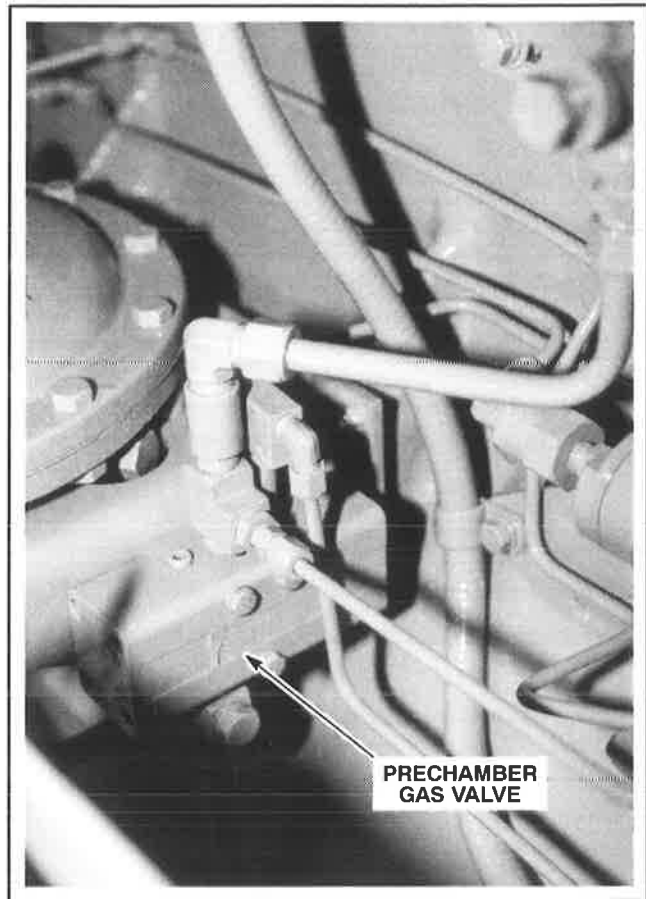
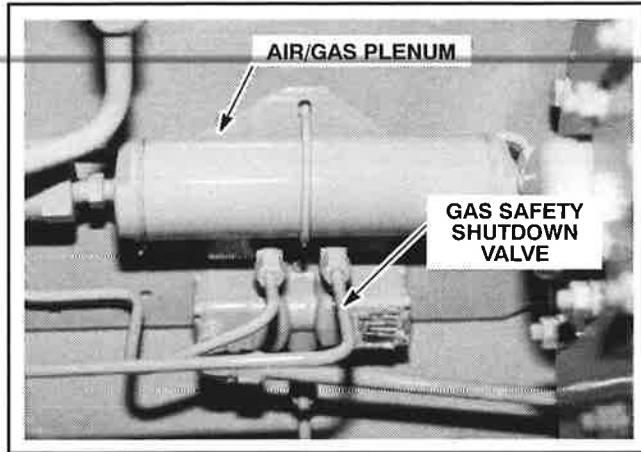


Figure 2.05-5. Prechamber Gas Valve - 6 Cylinder GL Engine Shown

### PRECHAMBER GAS SAFETY SHUTDOWN VALVE

On GL engines, the prechamber gas safety shutdown valve (see Figure 2.05-6) admits gas pressure once engine lube oil pressure reaches or exceeds 20 psi (138 kPa). Lube oil pressure continues to admit gas to the prechamber regulator, while the engine is running.

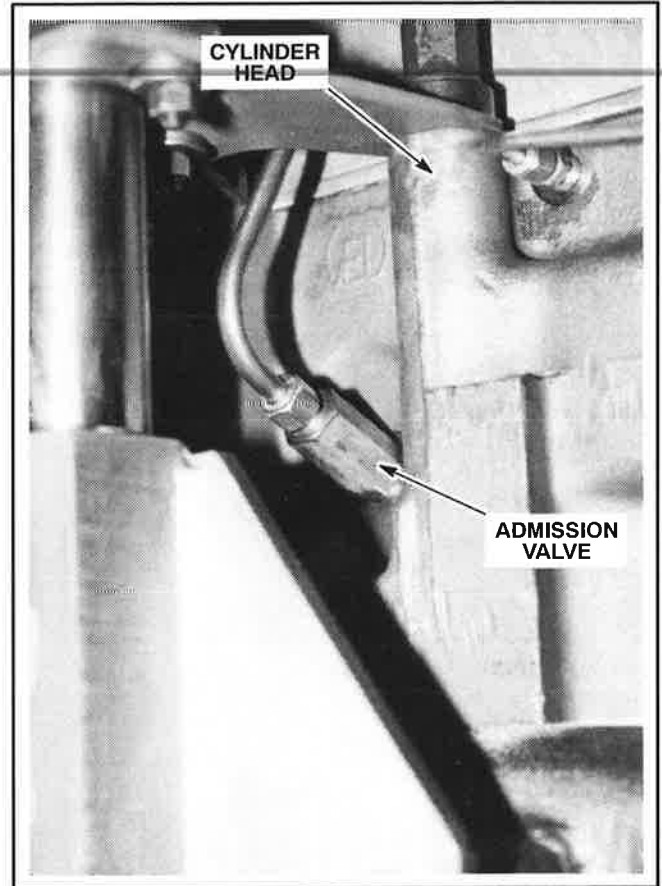
If the engine stops, loss of engine oil pressure automatically causes the prechamber gas safety shutdown valve to stop the flow of gas to the prechamber gas valve, which shuts off the supply of gas to the prechamber regulator.



**Figure 2.05-6. Prechamber Gas Safety Shutdown Valve - 6 Cylinder Engine GL Shown**

### ADMISSION VALVE ASSEMBLIES

On GL engines, each admission valve assembly (1 per cylinder head) is mounted at a 45 degree angle on the side of each cylinder head (see Figure 2.05-7). The admission valve directs the flow of fuel to the prechamber (see Figure 2.05-8). During the compression stroke, the air/fuel mixture flows into the prechamber through the prechamber torch holes and mixes with the prechamber gas. The spark plug ignites the near stoichiometric mixture.



**Figure 2.05-7. Admission Valves - 6 Cylinder GL Shown**

## FUEL SYSTEM DESCRIPTION

### PRECHAMBERS AND SPARK PLUG CARRIERS

On GL engines, the air/fuel mixture in the main combustion chamber is so lean that it can't be ignited with a spark plug alone. With the prechamber design, the prechamber receives a rich fuel mixture that is easily ignited. The resulting flame ignites the lean mixture in the main chamber.

The top half of the prechamber is located in the bottom of the spark plug carrier. The lower portion of the prechamber is a separate piece with a six-hole nozzle (see Figure 2.05-8). The prechamber is filled with the rich air/fuel mixture through the admission valve. The prechamber fuel charge is leaned out by air flow into the prechamber during the compression stroke. This process is designed to be highly turbulent, ensuring good mixing of each prechamber charge. The spark plug then ignites the prechamber mixture, which directs a flame torch through the nozzle holes into the lean mixture in the main combustion chamber. The main chamber fuel charge then ignites.

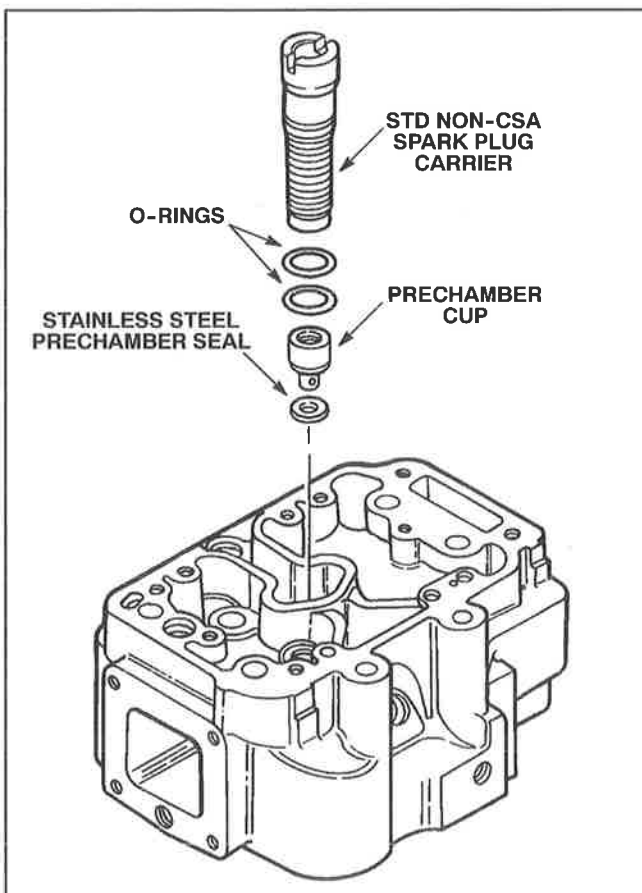


Figure 2.05-8. Prechamber/Spark Plug Carrier Assembly GL Engines

### CUSTOM ENGINE CONTROL® AIR/FUEL MODULE SYSTEM

The Custom Engine Control® (CEC) Air/Fuel Module (AFM) system is designed to control the air/fuel ratio of Waukesha's gaseous fueled, industrial engines (see Figure 2.05-9). An engine's air/fuel ratio defines the amount of air in either weight or mass in relation to a single amount of fuel supplied to an engine for combustion. Air/fuel ratio influences engine power, emissions, and fuel economy. By controlling an engine's air/fuel ratio with the AFM system, you will benefit in fuel savings, emissions control, and/or peak engine performance. The AFM system regulates and maintains the engine's air/fuel ratio even with changes in engine load, speed, fuel pressure, and fuel quality.

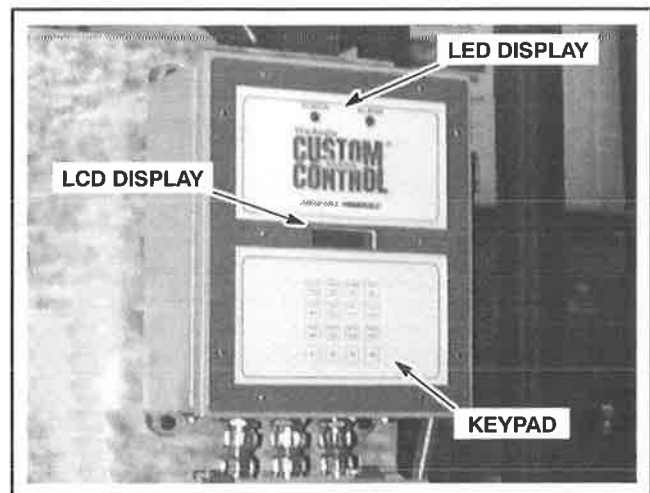


Figure 2.05-9. Air/Fuel Module Front Panel

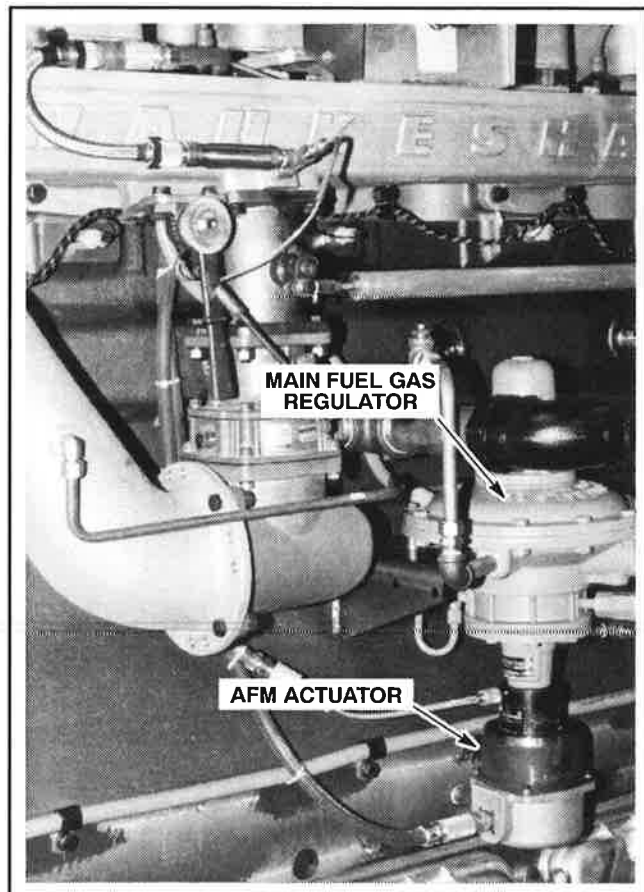
The AFM system is programmed at the engine site and is customized for the engine based on site specific information with a personal computer (PC). Form 6263, *AFM Custom Engine Control® Air/Fuel Module Second Edition*, provides information on the operation and programming of the AFM.

The basic AFM system consists of an oxygen sensing system, intake manifold pressure transducer (catalyst and lean burn only), electronic control module (AFM module), actuator (see Figure 2.05-10), and exhaust thermocouple. The oxygen sensor continually reports the concentration of oxygen in the exhaust to the AFM module. Based on this signal, the AFM module then determines if a correction to the air/fuel ratio is required. If a change is needed, a command is sent to a stepper motor (installed on the fuel regulator) which influences the fuel flow to the engine. The exhaust thermocouple ensures exhaust temperatures are high enough to permit correct system operation.



The AFM module is equipped with several features to inform site personnel of system status. These features include:

- “Power” and “Alarm” lights (LED display) on the front panel of the AFM module (see Figure 2.05-9)
  - The green “Power” LED is lit any time power is applied to the AFM module
  - The yellow “Alarm” LED is lit any time the AFM system’s diagnostic functions are activated or when AFM execution has been stopped by the operator (such as during the saving of a data-set)
- An alpha-numeric liquid crystal display (LCD display) visible from the front of the AFM module allows the operator to monitor important system parameters
- A sealed membrane keypad located on the front of the AFM module

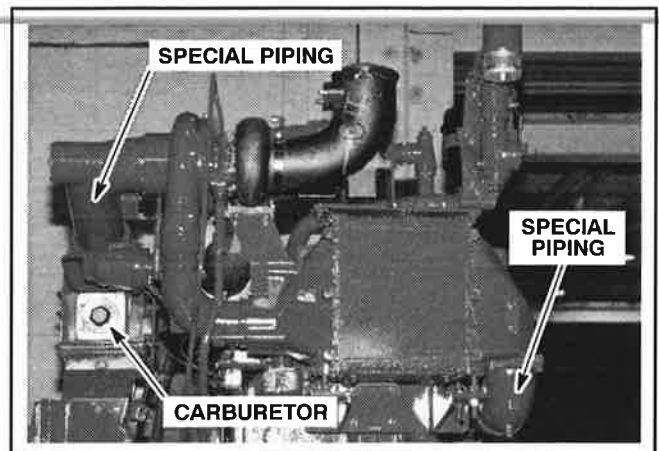


**Figure 2.05-10. AFM Actuator -  
6 Cylinder Engine Shown**

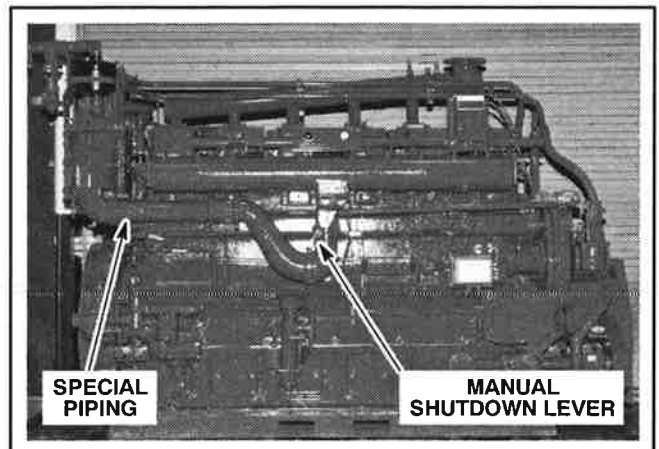
### DRAW-THRU ENGINES

Draw-thru engines are capable of using low pressure fuel. Characteristic that are unique to these engines are listed below:

- Main Fuel Gas Pressure Regulator(s) mounted off engine
- Carburetor(s) mounted in plenum(s) on top of the air filter housing(s) (see Figure 2.05-11)
- Special piping that allows the air fuel mixture to be delivered to the intake manifold (see Figure 2.05-12)



**Figure 2.05-11. Draw-thru Engine -  
6 Cylinder Engine Shown**



**Figure 2.05-12. Draw-thru Engine -  
6 Cylinder Engine Shown**

## FUEL SYSTEM DESCRIPTION

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## SECTION 2.10

### IGNITION SYSTEM DESCRIPTION

#### IGNITION SYSTEM DESCRIPTION

The ignition system consists of the following components:

- Custom Engine Control® (CEC) Ignition Module (Standard) used with the following components:
  - Magnetic Timing Disc
  - Hall-effect Pickup Sensor
  - Cable Assemblies
- Spark Plugs (One per cylinder) and Spark Plug Carriers (GL)
- Spark Plug Connectors (One per cylinder)
- Ignition Coils (one per cylinder)
- Custom Engine Control® Detonation Sensing Module (Also described in this Section with *Engine Protection Equipment*)
- Wiring
- Magneto Ignition System (Optional)
- CSA Ignition (Optional)

#### SPARK PLUGS, SPARK PLUG CARRIERS, AND CONNECTORS

**CAUTION** 13/16 inch reach spark plugs must be used with 13/16 inch reach carriers, and 1/2 inch reach spark plugs must be used with 1/2 inch reach carriers. Mixing carrier and spark plug components will cause damage to equipment and/or personal injury.

One spark plug is provided for each of the cylinders. On G and GSI engines, 1/2 inch reach spark plugs are used. On these engines, the spark plug is threaded directly into the cylinder head. GL engines may be equipped with either 1/2 inch or 13/16 inch reach spark plugs and spark plug carriers (one per cylinder), however 1/2 inch reach spark plugs must be used with 1/2 inch reach spark plug carriers and 13/16 inch reach spark plugs must be used with 13/16 inch reach spark plug carriers. The spark plug carriers (see Figure 2.10-1), are stamped to identify the spark plug reach. If a Waukesha spark plug carrier is not marked, it is 1/2 inch reach. The spark plug carriers are threaded directly into the cylinder head and the spark plug is threaded into the spark plug carrier. The GL engines use spark plug carriers because of the special combustion characteristics of these engines (see Figure 2.10-2).

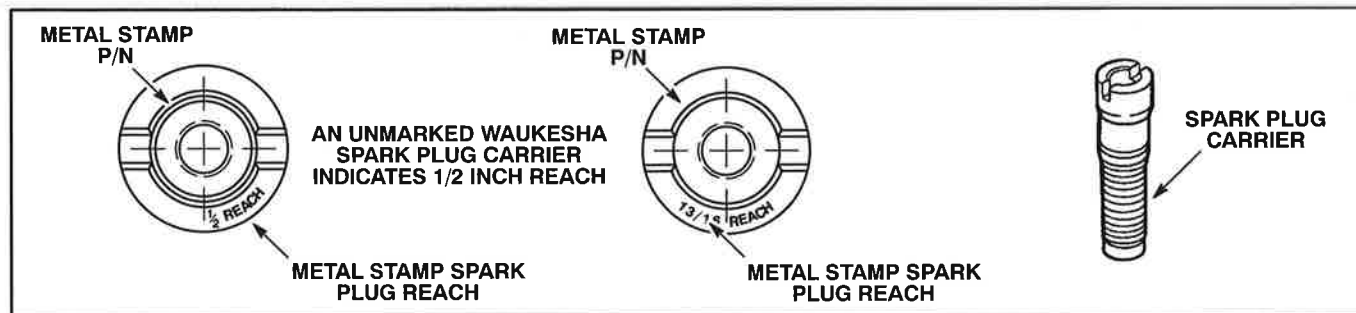
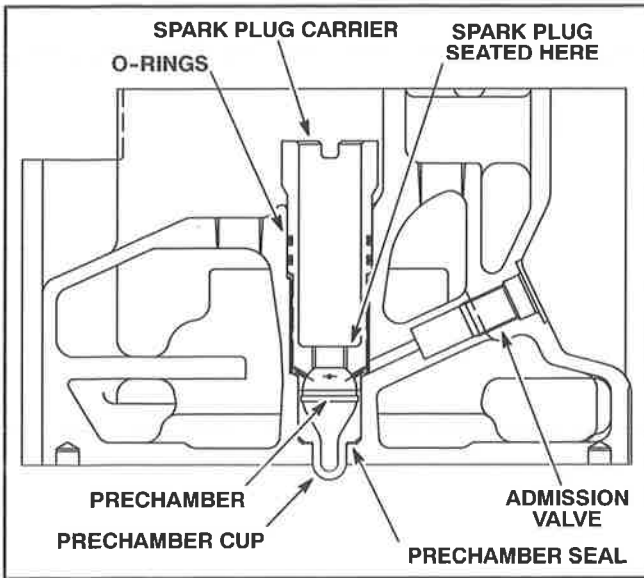


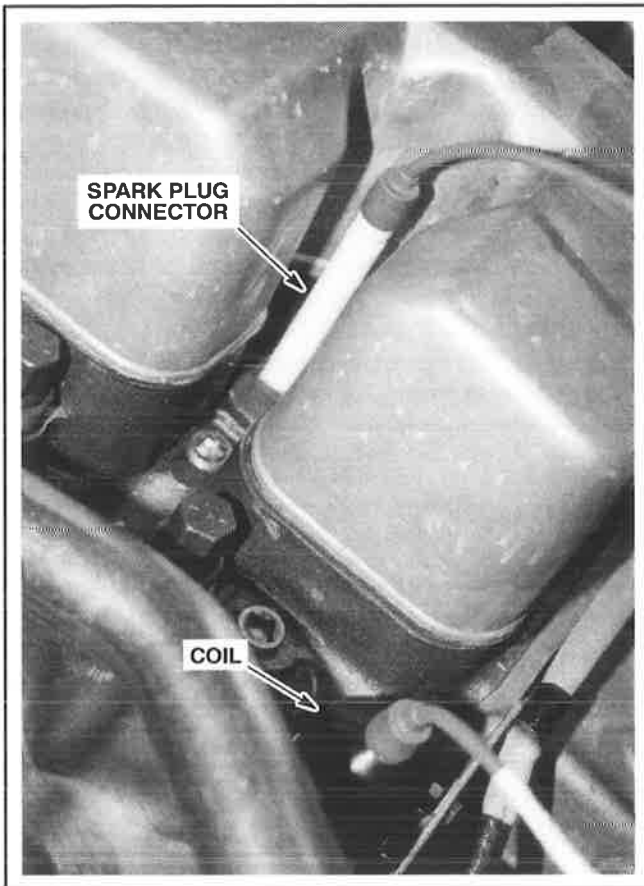
Figure 2.10-1. Spark Plug Carriers

# IGNITION SYSTEM DESCRIPTION



**Figure 2.10-2. Spark Plug Carrier And Prechamber Design - GL Engine Cylinder Head Cutaway View**

Spark plug connectors, (made of white Teflon, except for G, GSI and previous GL CSA engines) extend from the spark plug to above the rocker arm covers (see Figure 2.10-3).



**Figure 2.10-3. Spark Plug, Connector, And Ignition Coil - Standard Ignition**

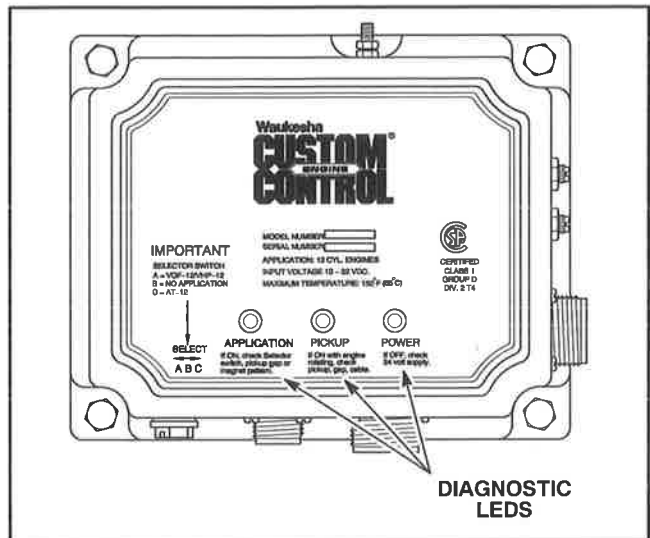
## IGNITION COILS

One ignition coil is provided for each of the cylinders. Each coil is attached to a base that is securely mounted between the intake manifold runners (see Figure 2.10-2 and Figure 2.10-3).

## CUSTOM ENGINE CONTROL® IGNITION MODULE

The Custom Engine Control® (CEC) Ignition Module (IM) (see Figure 2.10-4) and its associated components are described in the following paragraphs. Refer to Form 6253 (Previous Model) or Form 6272 (Current Model) *IM Custom Engine Control® Ignition Module Installation Operation And Maintenance* for further information concerning the IM.

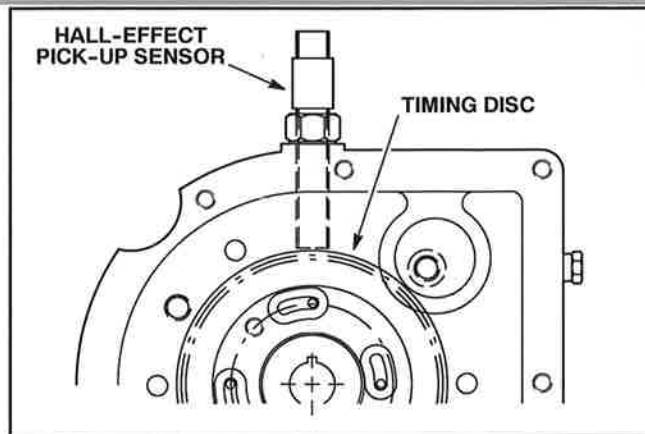
The current IM is equipped with three diagnostic LEDs on front of the die cast IM housing: "Power," "Pickup," and "Application" (see Figure 2.10-4). These LEDs give operators visual confirmation on (1) incoming power, (2) Hall-effect pickup signal, and (3) proper application settings. The previous IM did not have diagnostic LEDs.



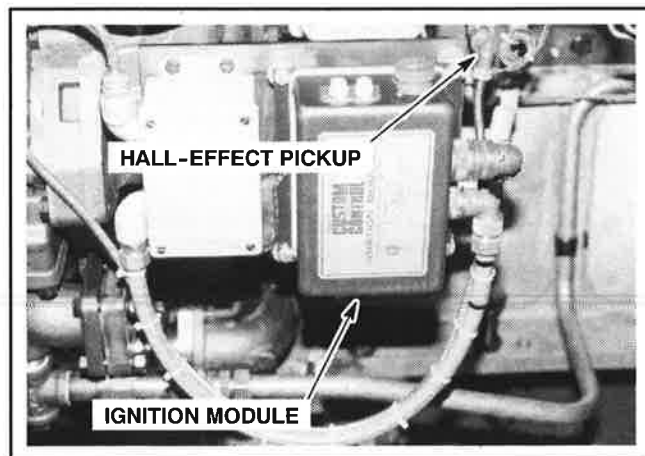
**Figure 2.10-4. IM Diagnostic LEDs**

## IGNITION SYSTEM DESCRIPTION

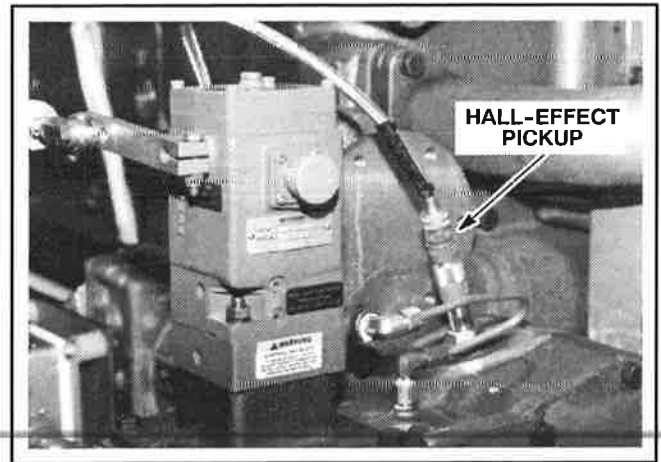
The Custom Engine Control® (CEC) Ignition Module functions by using a Hall-effect pickup to read magnetic reference marks on a timing disc to determine the exact position of the crankshaft (see Figure 2.10-5, Figure 2.10-6, and Figure 2.10-7). The signals sent from the Hall-effect pickup to the IM, allow the IM to tell the correct cylinder, exactly when to fire. Your engine may be equipped with the Custom Engine Control® Detonation Sensing Module (DSM). The DSM system is connected to the IM system by a cable connector. The two systems, when connected together, provide defense against combustion detonation, which can lead to severe engine damage.



**Figure 2.10-5. Hall-effect And Timing Disc - Internal View 5115GL**



**Figure 2.10-6. Hall-effect Sensor And Timing Disc - P9390**



**Figure 2.10-7. Hall-effect Pickup Location - 6 and 12 Cylinder Engines - 12 Cylinder Shown**

On 5115GL and P9390 engines, the timing disc is located in the magneto adaptor housing attached to the governor drive gear hub. The Hall-effect pickup sensor is installed in the magneto adaptor housing with the 5115GL mounted vertically and the P9390 mounted horizontally. On all other models the timing disc is located in the governor drive housing and the Hall effect pickup is located next to the governor.

The ignition module can be set for dual fuel applications, two distinct fuel gases, or load conditions. Refer to Form 6253 (Previous Model) or Form 6272 (Current Model) *IM Custom Engine Control® Ignition Module Installation Operation And Maintenance* for further information concerning the IM.

## IGNITION SYSTEM DESCRIPTION

### MAGNETO IGNITION SYSTEM

The magneto ignition system consists of the following components:

- Magneto
- Spark Plugs (One per cylinder) and Spark Plug Carriers (GL)
- Spark Plug Connectors (One per cylinder)
- Ignition Coils (one per cylinder)
- Wiring

The magneto is driven from the accessory (magneto) drive gear (see Figure 2.10-8). The magneto uses solid state electronic components. Self-generated alternating current is rectified to direct current and stored within a capacitor. Silicon controlled rectifiers (SCR's) function as switches to release the stored energy to the ignition coils. A trigger coil arrangement produces the voltage needed to turn the SCR on.

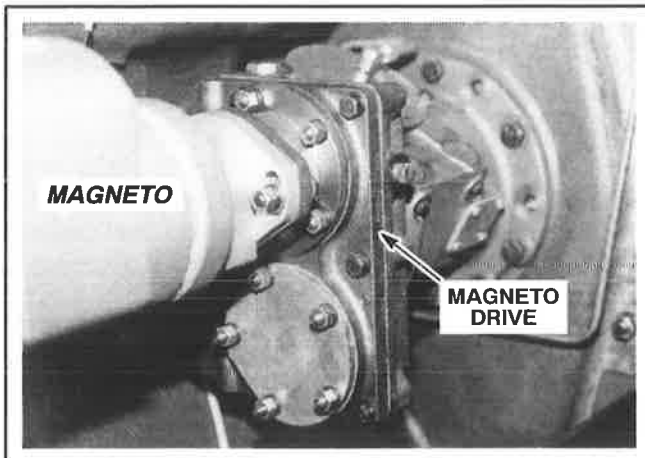


Figure 2.10-8. Magneto

### CSA IGNITION SYSTEM

Engines may be equipped with special sealed CSA ignition systems. These units have special sealed switches and wiring. G and GSI engines have a special coil that is installed in place of the standard spark plug connector (see Figure 2.10-9). GL engines have a special longer spark plug carrier that has the ignition coil mounted directly to it (see Figure 2.10-10).

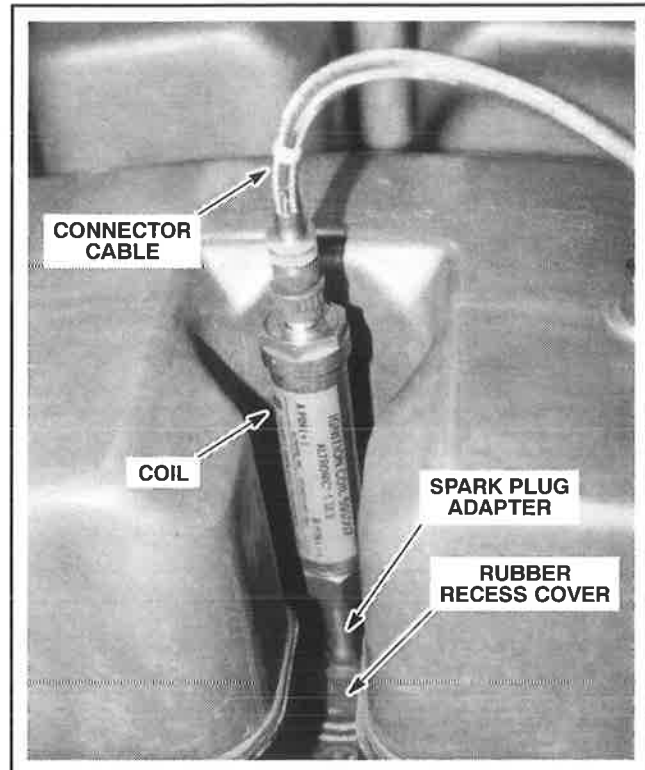


Figure 2.10-9. CSA Spark Plug Adapter And Coil - G, GSI

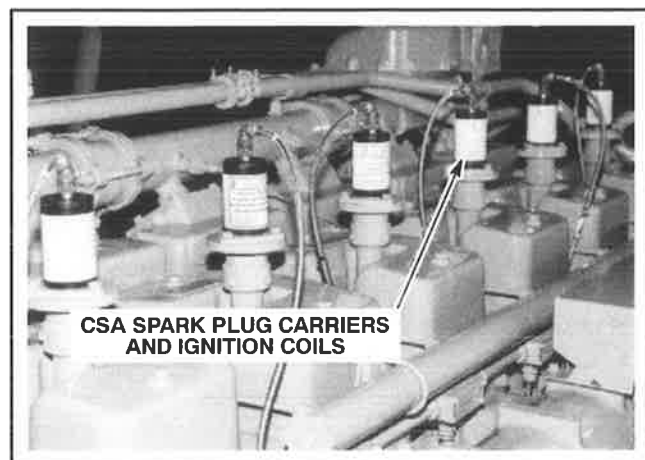
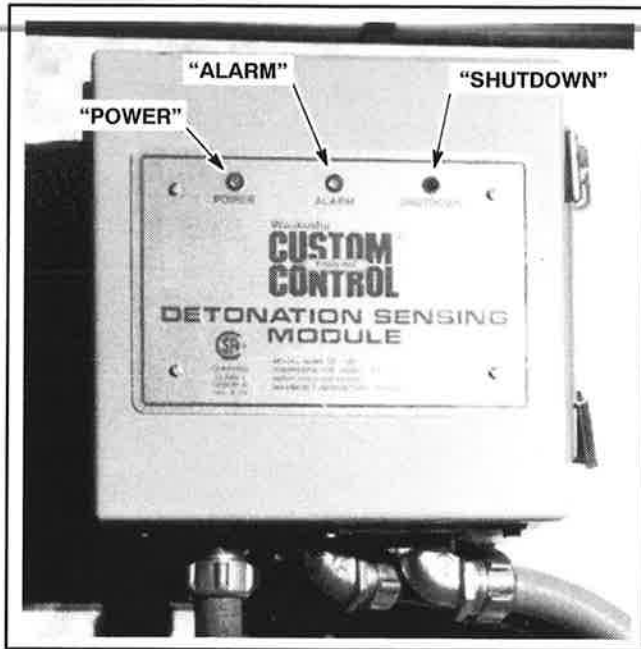


Figure 2.10-10. CSA Ignition - GL Engines - 6 Cylinder Shown

### CUSTOM ENGINE CONTROL® DETONATION SENSING MODULE

To prevent detonation from occurring, Waukesha Engine has developed an electronic Custom Engine Control® Detonation Sensing Module (DSM) system that is designed to function with Waukesha spark ignited AT and VHP engines (see Figure 2.10-11 and Form 6268, *DSM Custom Engine Control® Detonation Sensing Module Installation Operation And Maintenance*). The DSM system protects Waukesha spark ignited gas engines from damage due to detonation on an individual cylinder basis.



**Figure 2.10-11. Detonation Sensing Module Front Panel**

The DSM, and its related system, must function with a CEC Ignition Module with a 14 pin DSM expansion port. The DSM system also includes a Waukesha designed electronic filter, a detonation sensor mounted at each engine cylinder, and a number of interconnecting cables and harnesses that may vary depending on the application.

The DSM system is customized for each application with a personal computer. Refer to Form 6268, *DSM Custom Engine Control® Detonation Sensing Module Installation Operation And Maintenance* for further programming information.

The DSM module is equipped with several features to inform site personnel of system status. These features include:

- "Power", "Alarm", and "Shutdown" lights (LED display) on the front panel of the DSM module (see Figure 2.10-11)

- a liquid crystal display (LCD) located inside the DSM module which continually shows the current status of the system through diagnostic codes (see Figure 2.10-11)
- the capability to drive remote alarms or lights

For example, the DSM module can detect if a sensor has been damaged or disconnected. In either event, a default timing value is imposed for the cylinder associated with the lost signal. In addition to imposing the default timing, the DSM module will also illuminate the yellow alarm LED on the front cover, provide a signal for a remote alarm, and will display the error code on the LCD within the DSM module.

# IGNITION SYSTEM DESCRIPTION

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## SECTION 2.15

### AIR INTAKE SYSTEM DESCRIPTION

#### AIR INTAKE SYSTEM DESCRIPTION

The air intake system consists of the following components:

- Carburetor(s) G,GSI,GL
- Intake Manifold(s) G,GSI,GL
- Air Filtration System (Air Cleaner(s))
- Turbocharger(s) GSI,GL
- Intercooler(s) GSI,GL

#### CARBURETOR(S) AND INTAKE MANIFOLD(S)

Both the carburetor(s) and air intake manifold(s) are mounted to the outside of the cylinder bank(s). The carburetor produces a combustible mixture by automatically mixing air and fuel in the proper proportions (see Figure 2.15-1, Figure 2.15-2, and Figure 2.15-3).

Intake manifold(s) connect the intake ports of the cylinders and equally distribute the air/fuel mixture to each.

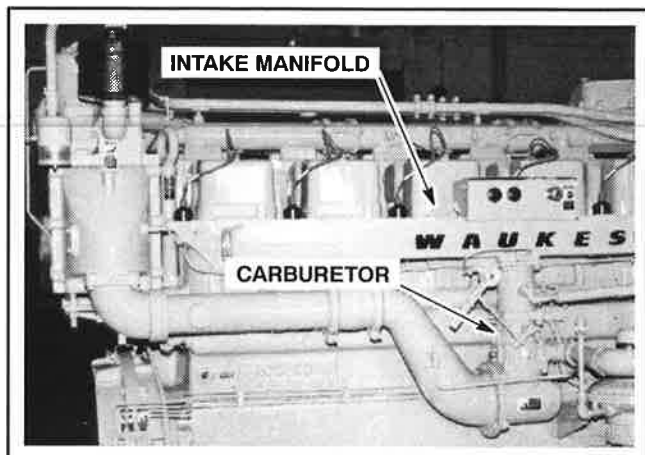


Figure 2.15-1. 6 Cylinder GSI

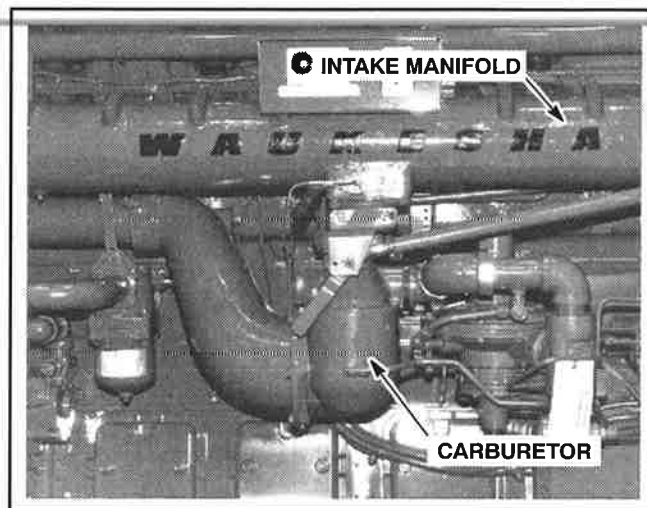


Figure 2.15-2. 12 Cylinder GL

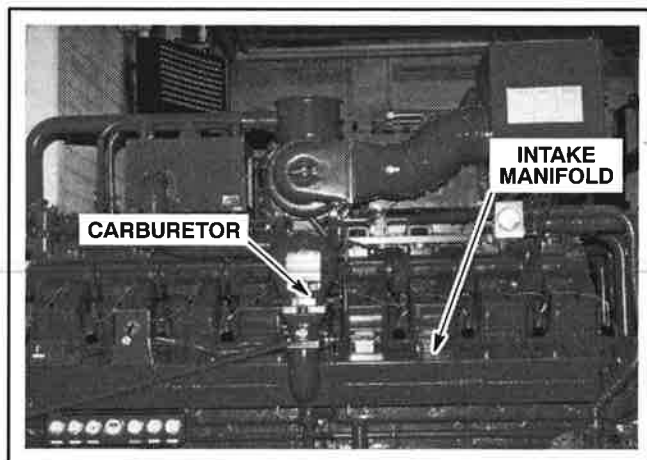


Figure 2.15-3. 16 Cylinder GSI

#### AIR CLEANER(S)

6 cylinder engines have one air cleaner (see Figure 2.15-4), while 12 and 16 cylinder engines have two air cleaners (see Figure 2.15-5 and Figure 2.15-6). Each air cleaner consists of the air filter frame, main air filter element, prefilter pad, air intake restriction indicator and rain shield.

## AIR INTAKE SYSTEM DESCRIPTION

The air restriction indicator on 6 and 12 cylinder engines, will "pop red" if the air intake restriction is 15 in. (381 mm) of water. This indicates a clogged or dirty main air filter element and/or clogged or dirty precleaner element. On 16 cylinder engines, gauges mounted on each air cleaner register the condition of the air filters. The air restriction gauge must show in the green, for both the prefilter and final filter. A toggle switch allows the operator to select the filter reading desired.

### TURBOCHARGER(S)

6 cylinder GSI and GL engines have one turbocharger (see Figure 2.15-4), all other VHP GSI and GL engines have two turbochargers, one for each bank (see Figure 2.15-5 and Figure 2.15-6).

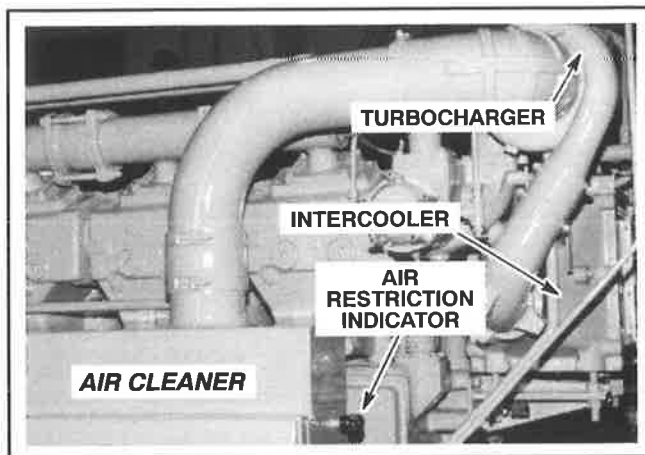


Figure 2.15-4. 6 Cylinder GSI - Rear View

### INTERCOOLER(S)

Box-type intercooler(s), used on GSI and GL engines, are mounted on the rear of the engine on 6 and 12 cylinder models (see Figure 2.15-4 and Figure 2.15-5) and on top of the engine, on 16 cylinder models (see Figure 2.15-6). Heated compressed air from the turbocharger(s) enters the intercooler(s) and flows over a series of tubes through which the auxiliary water system coolant is circulated. The temperature of the compressed air is reduced, which makes it denser.

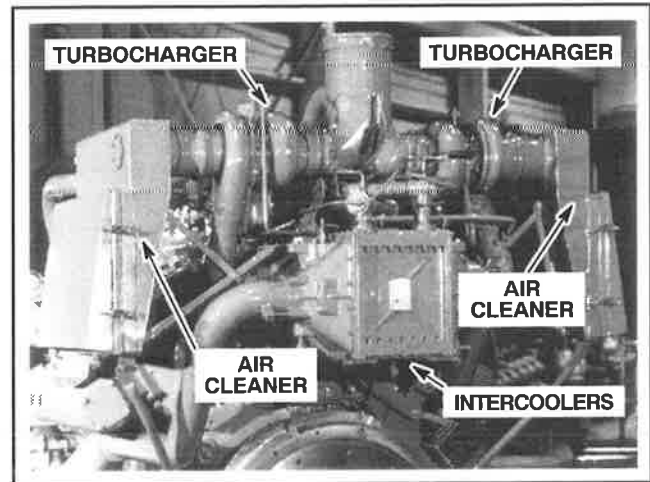


Figure 2.15-5. 12 Cylinder GL - Rear View

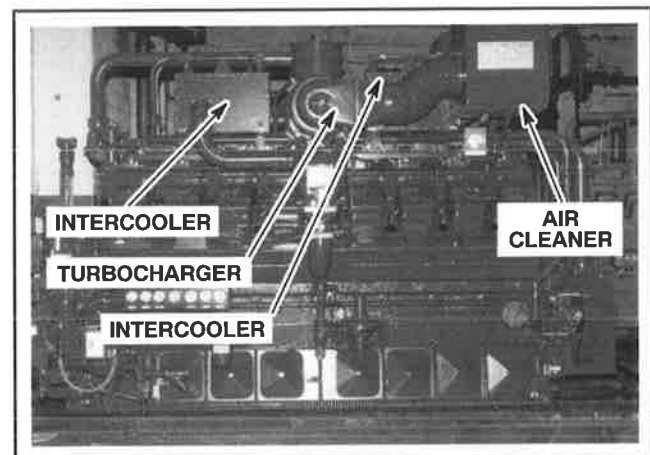


Figure 2.15-6. 16 Cylinder GSI

## SECTION 2.20

### TURBOCHARGER SYSTEM DESCRIPTION

#### TURBOCHARGER SYSTEM DESCRIPTION

GSI and GL engines are turbocharged. The turbocharger system consists of the following components:

- Turbocharger(s)
- Connecting Hose(s)
- Connecting Piping

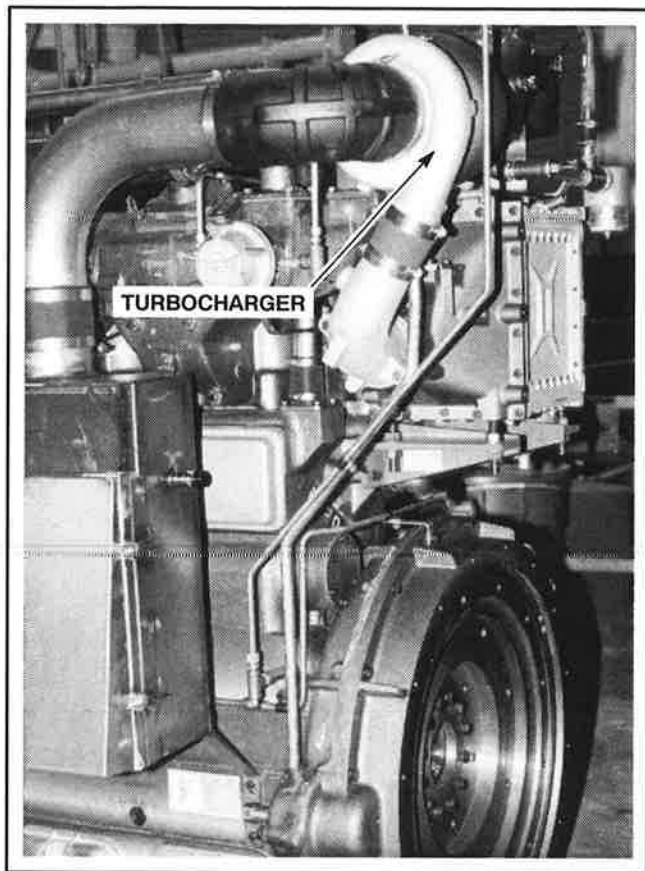


Figure 2.20-1. Turbocharger - 6 Cylinder Rear View

#### TURBOCHARGER(S)

6 cylinder GSI and GL engines have one turbocharger (see Figure 2.20-1), all other VHP GSI and GL engines have two turbochargers, one for each bank

(see Figure 2.20-2 and Figure 2.20-3). While the turbine side of each turbocharger is part of the exhaust system, the compressor side is part of the air intake system; a shaft connects the two. When the turbine is caused to spin from the expansion of exhaust gases exiting the engine, the movement of the compressor wheel causes the air passing through the air cleaner enroute to the carburetor, to be compressed.

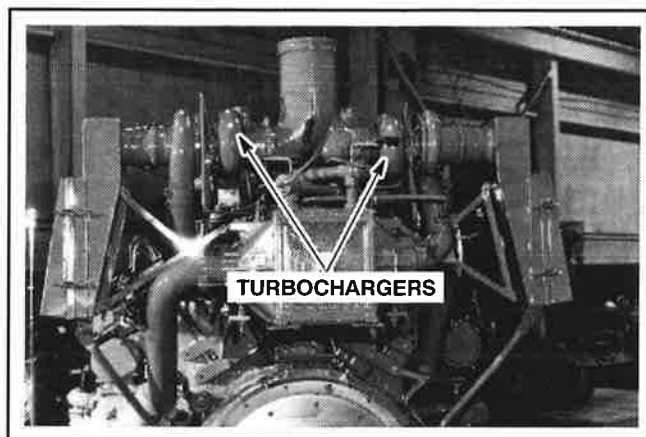


Figure 2.20-2. Turbochargers - 12 Cylinder GL Rear View

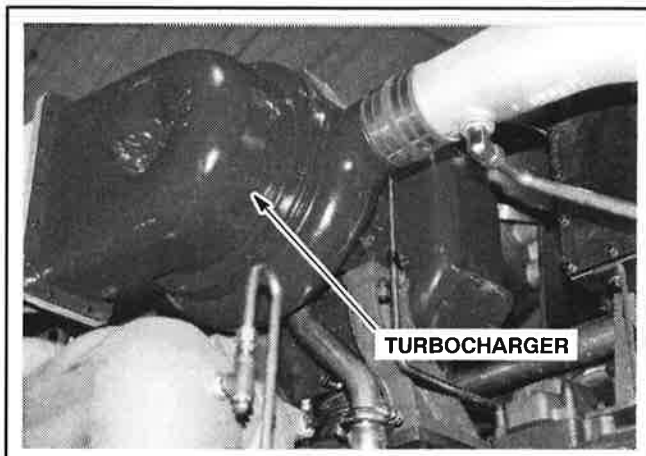


Figure 2.20-3. Turbochargers - 16 Cylinder GSI Side View

# TURBOCHARGER SYSTEM DESCRIPTION

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## SECTION 2.25

### COOLING SYSTEM DESCRIPTION

#### COOLING SYSTEM DESCRIPTION

The cooling system consists of the following components:

##### Jacket Water Circuit

- Jacket Water Header/Jacket Water
- Exhaust Manifold
- Jacket Water Pump
- Water Manifold
- Jacket Water Temperature Control Valve
- Surge Tank (Optional)
- Remote Heat Transfer Device (Customer Supplied)

##### Auxiliary Cooling Water Circuit

- Auxiliary Water Pump
- Intercoolers
- Oil Cooler
- Auxiliary Water Temperature Control Valve
- Auxiliary Water Heat Transfer Device (Customer Supplied)

#### JACKET WATER HEADER/JACKET WATER

The cooling water passageways in both the crankcase and cylinder heads comprise the jacket water system. The jacket water header is integrally cast within the crankcase. Cooling water circulates around the cylinder sleeves inside the cylinder block. Water flows up through the water passage openings in the deck of each cylinder head, flows around the valve seats and exhaust guides, and up to the water-cooled exhaust manifold(s).

#### EXHAUST MANIFOLD

From each cylinder head, water passes up through the water outlet elbow connection (see Figure 2.25-1) to one segment of the water-jacketed exhaust manifold(s) and exits through the water outlet port, to the water manifold. (see Figure 2.25-2 and Figure 2.25-3). Each exhaust manifold assembly is comprised of individual water-cooled segments.

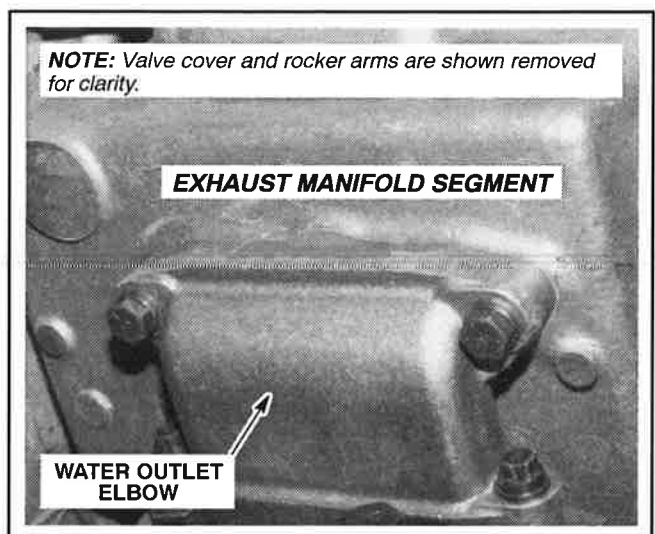


Figure 2.25-1. Water Outlet Elbows

## COOLING SYSTEM DESCRIPTION

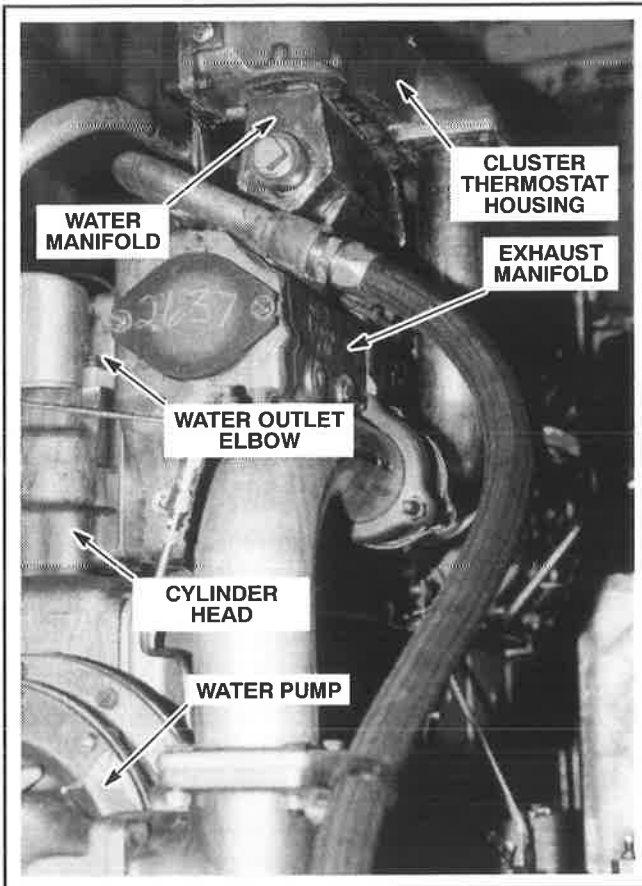


Figure 2.25-2. 6 Cylinder Engine Cooling Components

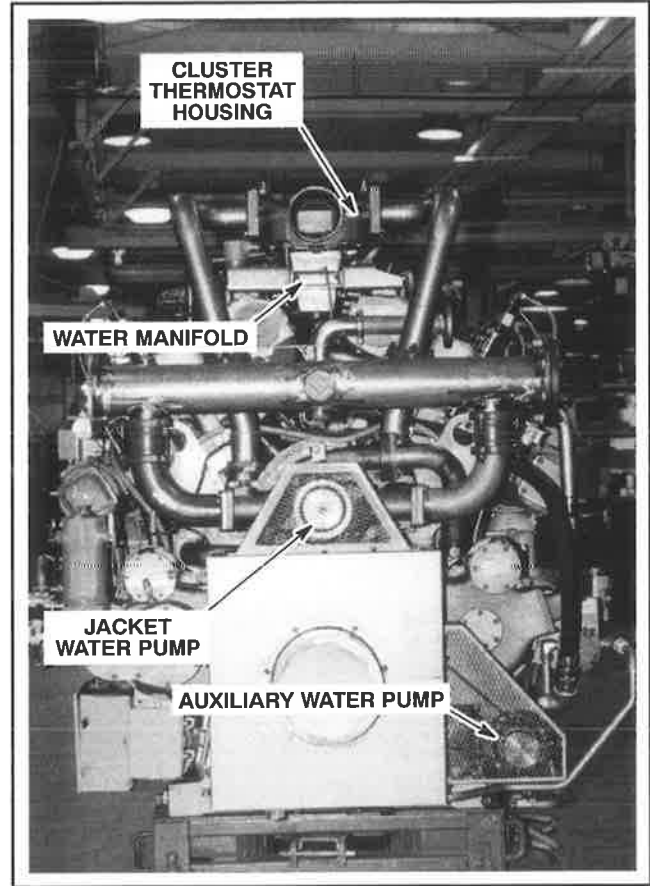


Figure 2.25-3. 12 Cylinder Engine Cooling Components

### JACKET WATER PUMP

On 5115GL engines (see Figure 2.25-4), a gear driven water pump is mounted at the left side (as viewed from the flywheel end of the engine) of the gear cover. On 6, 12, and 16 cylinder engines (see Figure 2.25-2 Figure 2.25-3, and Figure 2.25-5) a belt driven water pump is mounted on the front of the engine. Cooling water exiting the pump is piped to the jacket water headers.

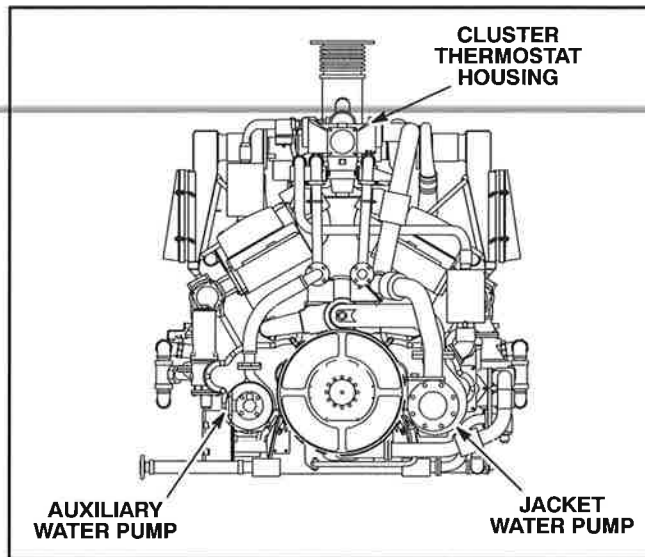


Figure 2.25-4. 5115GL Engine Cooling Components

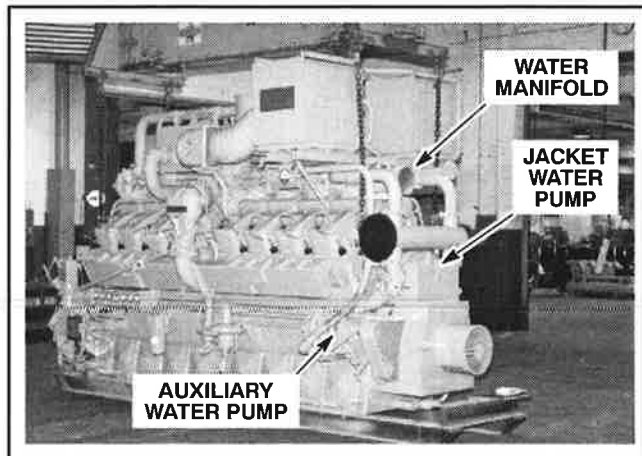


Figure 2.25-5. 16 Cylinder Engine Cooling Components

### WATER MANIFOLD

The water manifold (see Figure 2.25-2, Figure 2.25-3, Figure 2.25-4, and Figure 2.25-5) receives the cooling water flowing out of each segment of the exhaust manifold and routes it to the cluster thermostat housing on 6 and 12 cylinder engines. On 16 cylinder engines, the thermostats are located in the connector elbows between the exhaust manifold segments and the water manifold.

### CLUSTER THERMOSTAT HOUSING

The thermostatic valves are enclosed in the cluster thermostat housing at the outlet end (front) of the water manifold on 6 and 12 cylinder engines (see Figure 2.25-2, Figure 2.25-3, and Figure 2.25-4) and on 16 cylinder engines, located in the connector elbows between the exhaust manifold segments and the water manifold. By regulating the circulation of coolant, the thermostatic valves, control the jacket water temperature. The thermostatic valves remain closed while the engine is warming up, so cooling water is circulated through the engine water jacket only.

The thermostats start to open as the engine warms up to its normal operating temperature. A portion of the coolant is diverted to the remote heat transfer device, which absorbs the heat and directs the coolant back to the jacket water pump. The coolant supply from the heat transfer device mixes with that portion of the coolant that continues to flow down the bypass tube(s) to provide a blend that is within the normal range.

## COOLING SYSTEM DESCRIPTION

### SURGE TANK

The optional surge tank provides a coolant reservoir for the engine. A sight gauge on the side of the surge tank allows the operator to easily view the coolant level (see Figure 2.25-6).

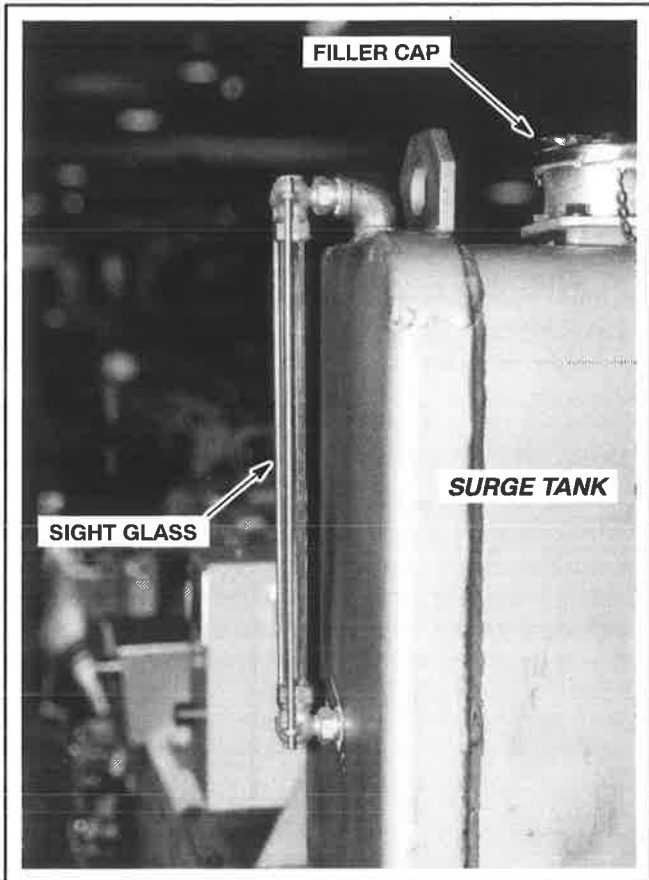


Figure 2.25-6. Surge Tank (Optional)

### REMOTE HEAT TRANSFER DEVICE

The remote heat transfer device may be a radiator, cooling fan, cooling tower, heat exchanger or some other device.

### AUXILIARY WATER PUMP

On 5115GL engines the gear driven auxiliary water pump is mounted at the right front of the gear cover (see Figure 2.25-4). All other VHP engines are belt driven. The 6 cylinder and 16 cylinder engines have the auxiliary water pump located on the lower right front of the engine (see Figure 2.25-2), while 12 cylinder engine auxiliary water pumps are located on the lower right front side (see Figure 2.25-3).

### INTERCOOLER(S)

On GSI, and GL models, the intercooler(s) cool the inlet air to the turbochargers, to provide denser air to the turbochargers. The intercooler(s) are located at the rear of the engine on 6 and 12 cylinder engines (see Figure 2.25-7), and on top of the engine on 16 cylinder engines (see Figure 2.25-8).

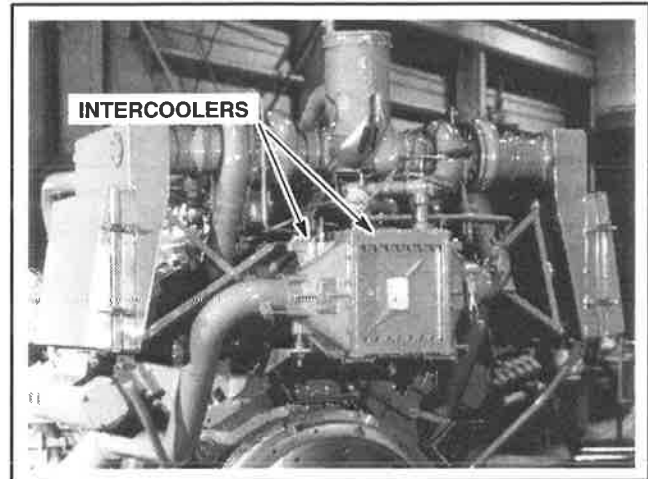


Figure 2.25-7. Intercoolers - 12 Cylinder Engine

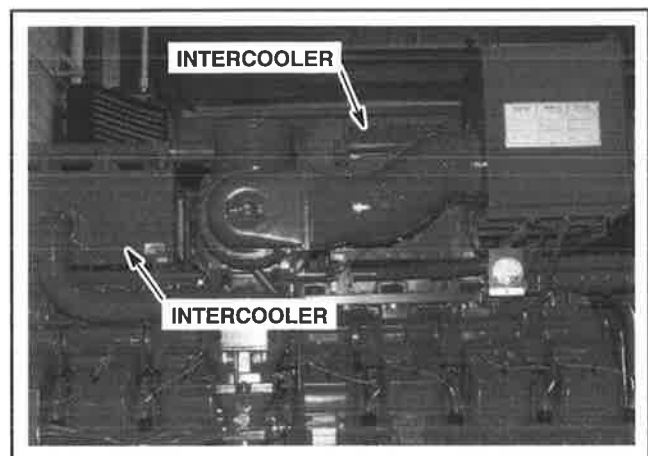


Figure 2.25-8. Intercoolers - 16 Cylinder Engine



### OIL COOLER

The coolant flows from the intercooler(s) to the oil cooler. The oil cooler is a tube and baffle type assembly (see Figure 2.25-9). While the coolant flows through a bundle of tubes in the oil cooler, the lube oil circulates around them. Heat from the oil passes through the tubes to the coolant which carries it to a heat transfer device for dissipation. From the heat transfer device, the coolant passes back to the auxiliary water pump to repeat the circuit.

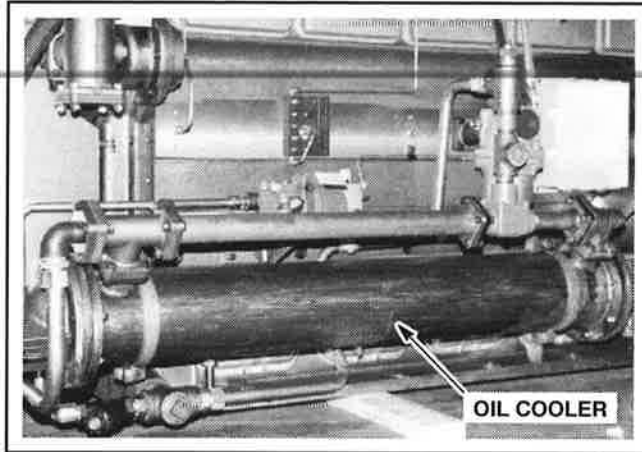


Figure 2.25-9. Oil Cooler - 6 Cylinder Engine Shown

### AUXILIARY WATER REMOTE HEAT TRANSFER DEVICE

The auxiliary or secondary heat transfer device, may be a radiator, cooling fan, cooling tower, heat exchanger or some other device. The heat transfer device provides cooling for the auxiliary system coolant.

## COOLING SYSTEM DESCRIPTION

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## SECTION 2.30

### LUBRICATION SYSTEM DESCRIPTION

#### LUBRICATION SYSTEM DESCRIPTION

The lubrication system consists of the following components:

- Oil Pan and Pickup Screen
- Oil Pump
- Oil Cooler
- Temperature Control Valve
- Pressure Regulating Valve
- Full-Flow Lube Oil Filter
- Filter Relief Valve(s)
- Oil Strainer
- External Piping (customer supplied)

#### PRELUBE SYSTEM COMPONENTS

- Prelube Pump and Prelube Motor
- Prelube Pushbutton Valve
- Pilot-Operated Prelube Valve
- In-line Lubricator
- Oil Pressure Gauge

#### INTERNAL OIL CONTROL

The main oil header is an integral part of the crankcase casting (see Figure 2.30-1). Internal passages in the crankcase direct the flow of pressurized oil to the main bearings, via drillings in the main bearing saddles.

The flow of oil passes from the main bearing journals into the T-drilled crankshaft and then up through drilled passages in the connecting rods. After lubricating the connecting rod bearing, piston pin bushing and piston pin, the pressurized oil passes through an opening in the top of the rod. The oil spray exiting the rod cools the underside of the piston crown and drains back to the oil pan.

Oil supply tubes tapped off the internal oil passage leading to the front main bearing, supply a continuous spray of oil to the gear train.

Internal passages in the crankcase casting also direct the flow of pressurized oil to the camshaft bearing saddles to provide lubrication of the main camshaft bearings (bushings). Oil flows through holes in the cam bearing caps and down passageways in the valve lifter housing. This lubricates the roller followers and cam lobes, after which it drops back to the oil pan.

An external oil supply line off the main oil header carries oil to a separate external rocker arm oil header. Supply tubes from the rocker arm oil header direct the flow of oil to the rocker arm assemblies and valves.

Excess oil drains down a cored passage in the cylinder head and runs down the outside of the pushrod tubes to a drainage passage in the valve lifter guides. The passage directs the flow of oil to a drainage hole in the valve lifter housing where it flows back to the oil pan via the camshaft recess.

The flow of pressurized oil through the fixed valve lifter screws of the rocker arm assemblies also supplies oil to the lifters, where the excess oil joins the flow from the cored passage in the cylinder head.

The flow of pressurized oil through the external system, is depicted in Figure 2.30-2.

## LUBRICATION SYSTEM DESCRIPTION

### OIL PAN AND PICKUP SCREEN

The bottom of the crankcase is enclosed by the oil pan. The oil pump draws oil from the lowest point in the oil pan and delivers it to the oil cooler. The oil pickup screen (see Figure 2.30-3) prevents foreign material in the oil pan from entering the lube oil circuit.

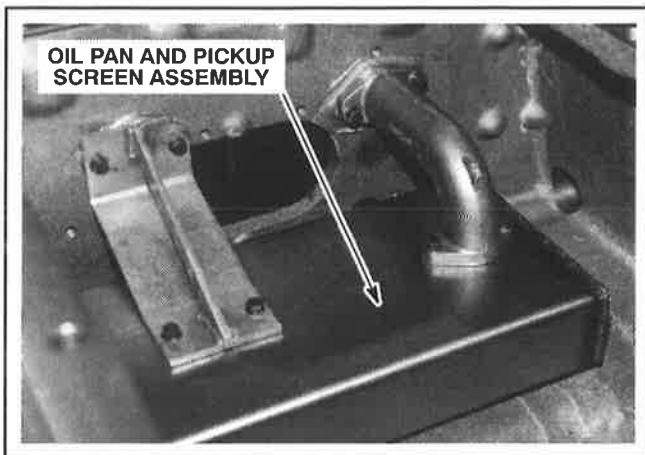


Figure 2.30-3. 6 Cylinder Engine Oil Pan And Pickup Screen Assembly

### OIL PUMP

The lube oil pump, gear-driven by the gear train, is externally mounted. On 6 and 12 cylinder engines, the oil pump is located on the front of the engine, below the crankshaft (see Figure 2.30-4). On 5115GL engines, the oil pump is located on the front left side of engine on the back side of the gear housing (see Figure 2.30-5). On 16 cylinder engines, the oil pump is located on the right rear of the engine, mounted on the flywheel housing (see Figure 2.30-6).

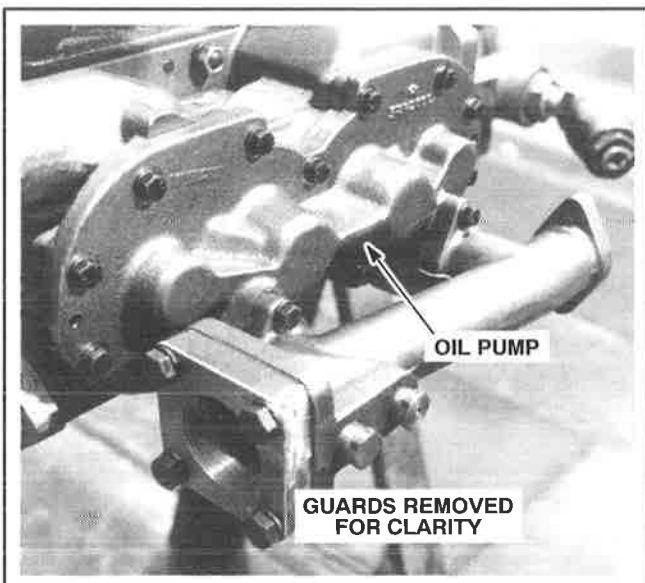


Figure 2.30-4. 6 And 12 Cylinder Engine Oil Pump - 6 Cylinder Shown

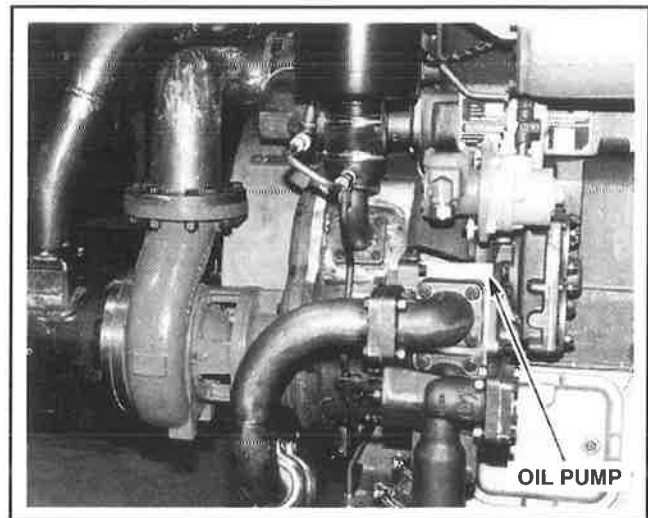


Figure 2.30-5. 5115GL Oil Pump

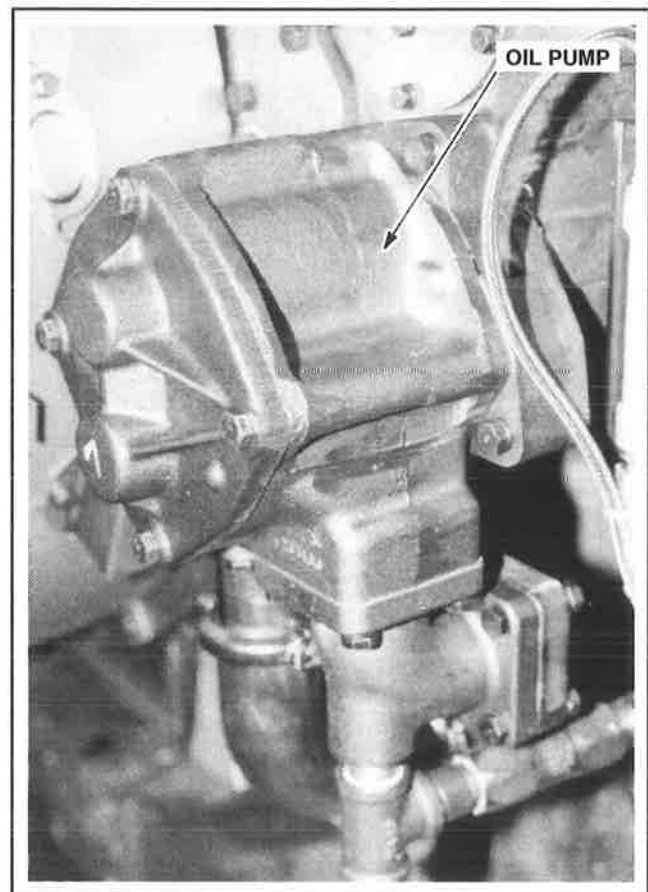
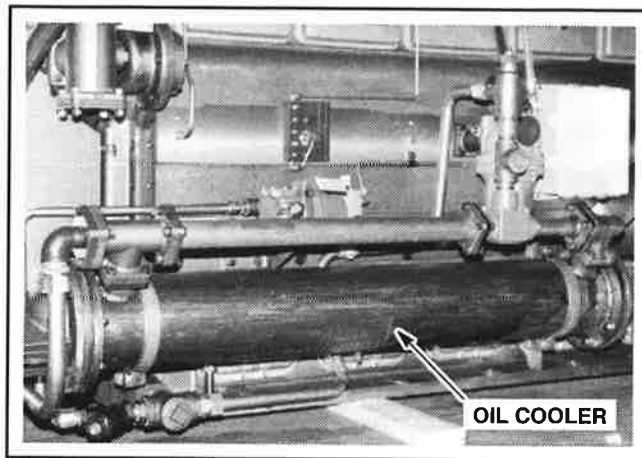


Figure 2.30-6. 16 Cylinder Engine Oil Pump

### OIL COOLER

**NOTE:** The oil cooler assembly is shipped loose on 12 and 16 cylinder engines, and must be either skid or remote mounted by the customer. The assembly consists of the oil cooler, temperature control valve and pressure regulating valve.

The oil cooler (see Figure 2.30-7) is a tube and baffle type assembly. Coolant is pumped through the cooler by the auxiliary water pump. While the coolant flows through a bundle of tubes in the oil cooler, the lube oil circulates around them. Heat from the oil passes through the tubes to the coolant which carries it to a heat transfer device for dissipation.

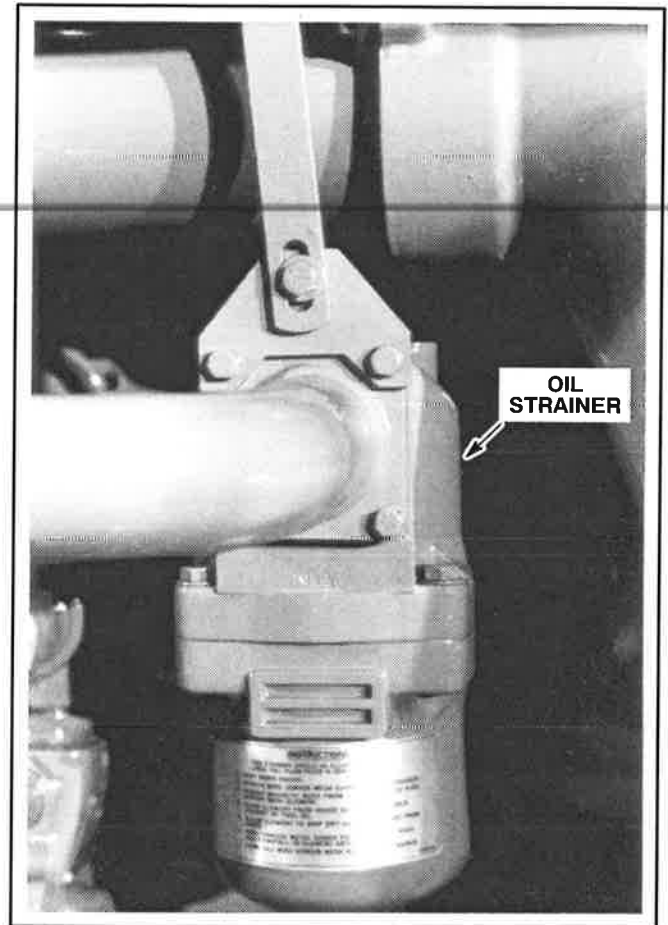


**Figure 2.30-7. Oil Cooler - 6 Cylinder Engine Shown**

Thermostatic valve(s) are enclosed in a housing mounted at the oil cooler outlet (see Figure 2.30-7).

### OIL STRAINER

The lube oil strainer contains one bypass pressure relief valve. A pressure differential of 15 psi (103 kPa) opens the valve and allows the oil flow to bypass the strainer element enroute to the main oil header (see Figure 2.30-8).



**Figure 2.30-8. Lube Oil Strainer - 5115GL Engine Shown**

## LUBRICATION SYSTEM DESCRIPTION

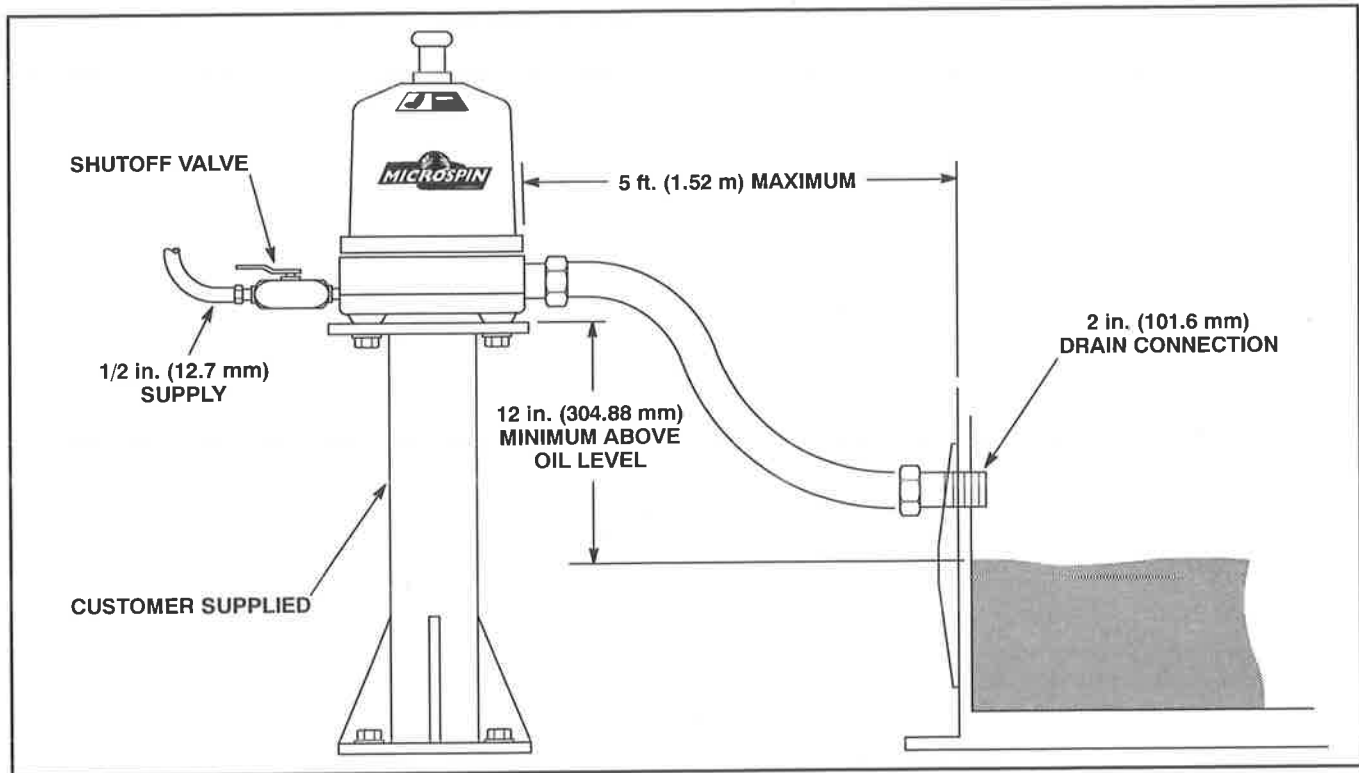


Figure 2.30-9. MICROSPIN™ Centrifuge Assembly

### MICROSPIN™ CLEANABLE LUBE OIL FILTERING SYSTEM

The MICROSPIN™ cleanable lube oil filtering system, consists of two major components, cleanable oil filter elements (see Figure 2.30-10), and a centrifuge, using a removable paper insert (see Figure 2.30-9). The MICROSPIN™ system cleanable filter elements, are installed in the existing lube oil filtration canister. The centrifuge is installed as a bypass system, working in conjunction with the cleanable filter elements. The centrifuge is driven by the engine's oil pressure. The spinning action of the centrifuge's internal turbine assembly develops a force that exceeds 2000 G's, which compacts the contaminants against the turbine's housing. The centrifuge will remove oil contaminating particles as small as 0.5 microns. The cleanable filter elements remove remaining particles as small as 25 microns absolute. The MICROSPIN™ system is more environmentally friendly than systems that utilize disposable elements. Cleaning the elements eliminates the expense of replacement elements and the cost of hazardous waste disposal. Refer to Service Bulletin 12-2698B or latest revision, for further information.

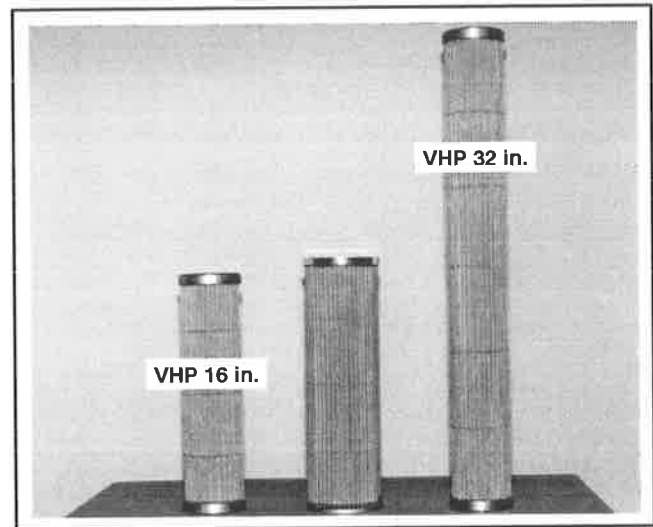


Figure 2.30-10. Cleanable Oil Filter Elements - All VHP, AT, F817G, F1197G, And VGF (Vee) Engines

### PRELUBE PUSHBUTTON VALVE

The air/gas supply from the bulkhead is connected to the the pushbutton valve (see Figure 2.30-11). Depressing the prelube pushbutton activates the prelube function.

### **⚠ WARNING**

From the bulkhead, all gas vented from the system must be piped to a safe area in conformance with all applicable codes. Improper venting may result in severe personal injury or death.

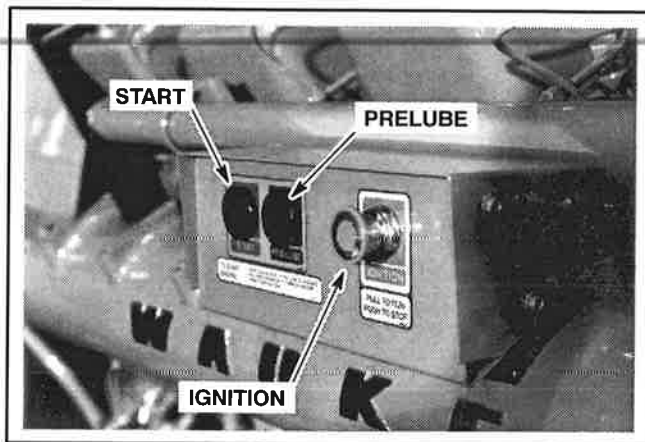


Figure 2.30-11. Prelube Pushbutton Valve

### PRELUBE PUMP/MOTOR

**⚠ CAUTION** Oil drains back into the oil sump after engine shutdown, leaving a minimal amount of oil at key wear points. Since the crankshaft starts to turn before the oil pump begins to circulate oil, failure to prelube the engine will result in “dry” starts, resulting in bearing damage and an accelerated wear rate.

The function of the prelube pump/motor is to purge the lubrication system of air and to ensure that all moving parts, especially the turbochargers, are properly lubricated before the engine is started (see Figure 2.30-12).

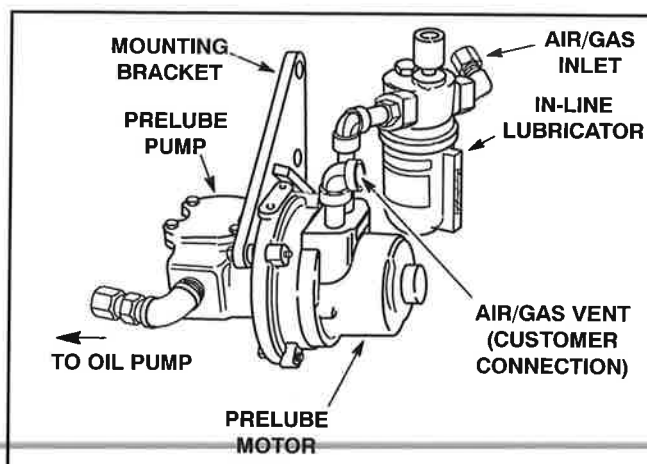


Figure 2.30-12. Prelube Motor/Pump Assembly - Similar All Engines

### PRELUBE VALVE

The prelube valve opens to admit air from a branch of the main air/gas supply line, which turns the prelube pump air motor to activate the prelube pump (see Figure 2.30-13).

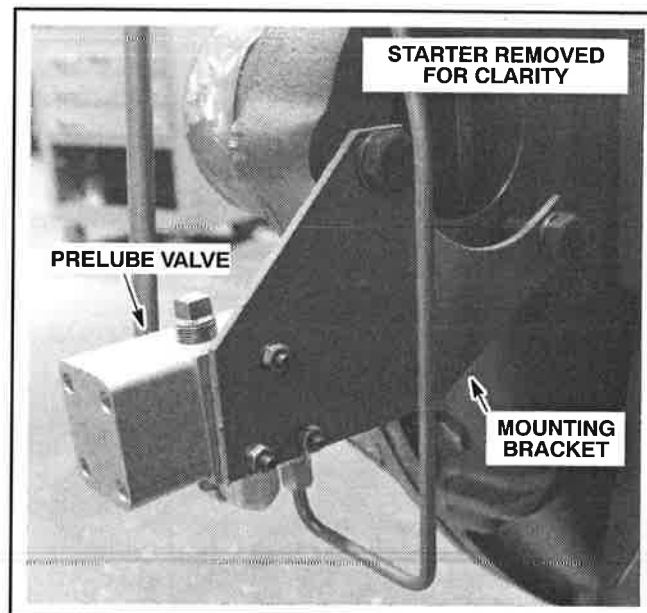


Figure 2.30-13. Prelube Valve - 6 Cylinder Engine Shown

## LUBRICATION SYSTEM DESCRIPTION

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### IN-LINE LUBRICATOR

#### WARNING

If high pressure gas is used to drive the air/gas prelude pump motor, vent the motor exhaust to a safe area in conformance with all applicable codes. Improper venting may result in severe personal injury or death.

**NOTE:** The air/gas starting system also has a lubrication reservoir. See Starting Systems for information on this reservoir.

The in-line lubricator injects oil into a stream of compressed air/gas to automatically provide the proper internal lubrication for the vanes of the air/gas operated prelude pump motor (see Figure 2.30-14).

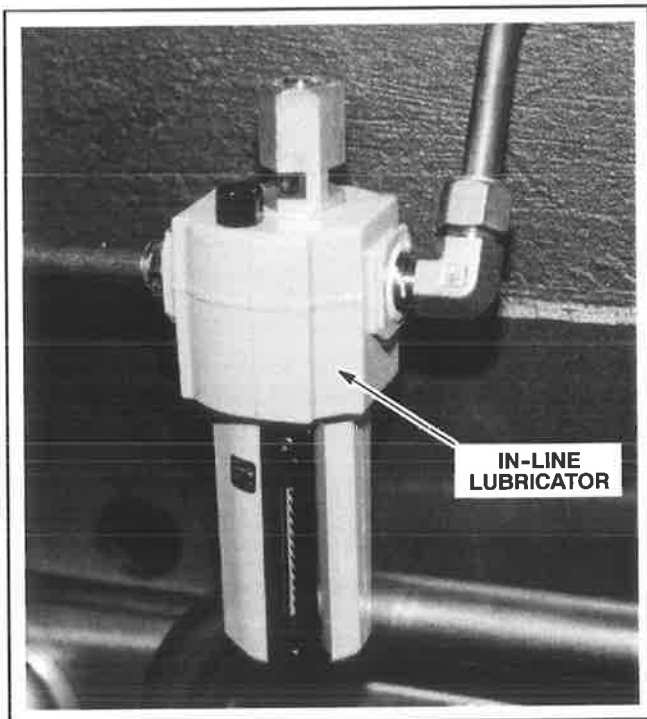


Figure 2.30-14. In-line Lubricator



## SECTION 2.35

### EXHAUST SYSTEM DESCRIPTION

#### EXHAUST SYSTEM DESCRIPTION

#### **⚠ WARNING**

**Do not inhale engine exhaust gases. Do not open exhaust system while the engine is running. Exhaust gases are highly toxic and could cause severe personal injury or death.**

The exhaust system consists of the following components (see Figure 2.35-1):

- Exhaust Manifolds
- Turbochargers (GSI and GL engines)
- Exhaust Wastegates (GSI and GL engines)
- Exhaust Piping and Flexible Connections (customer supplied)

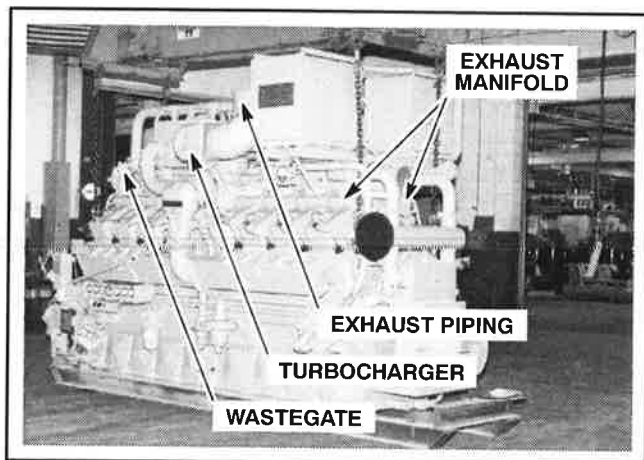


Figure 2.35-1. Exhaust System Components

#### EXHAUST MANIFOLD(S)

Each water-cooled exhaust manifold assembly is comprised of individual segments (see Figure 2.35-2). The exhaust port of each cylinder head is connected to one water-jacketed segment of the exhaust manifold. Water outlet elbows (see Figure 2.35-2) connect the water outlet hole in each cylinder head with the exhaust manifold segments.

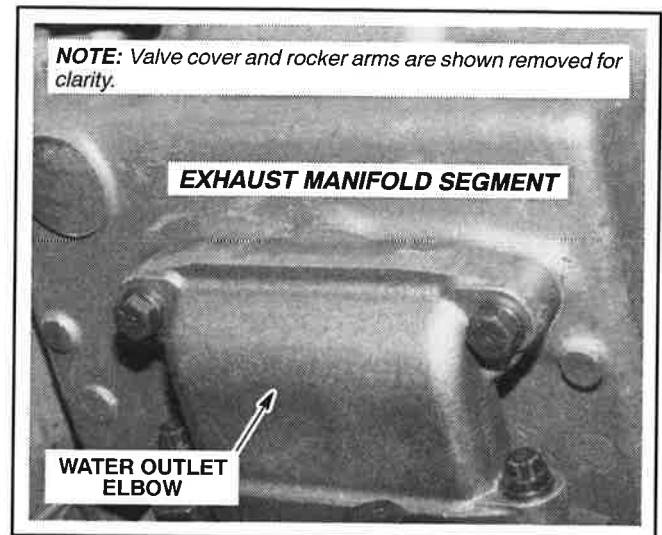


Figure 2.35-2. Water Outlet Elbows

## EXHAUST SYSTEM DESCRIPTION

### TURBOCHARGERS(S)

A wastegate-controlled turbocharger (see Figure 2.35-3) is provided for each cylinder bank. The compressor side of the turbocharger is part of the air induction system; the turbine side is part of the exhaust system. When the turbine spins through the expansion of exhaust gases exiting the engine, the movement of the compressor wheel causes the air passing through the air cleaner enroute to the carburetor, to be compressed.

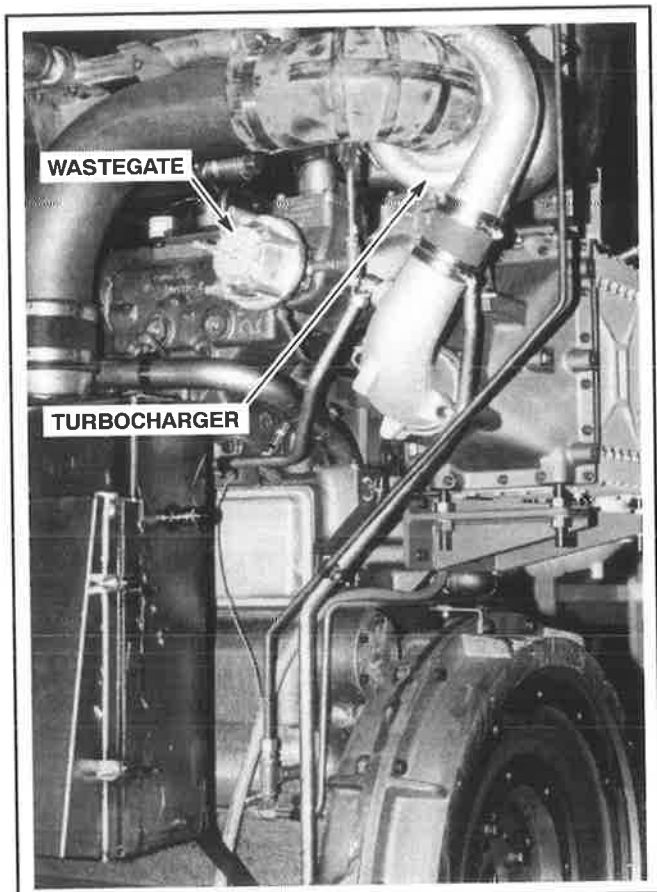


Figure 2.35-3. Turbocharger and Wastegate - 6 Cylinder Engine Shown

### WASTEGATE(S)

A water-cooled exhaust wastegate (see Figure 2.35-3) is mounted at the outlet of each exhaust manifold. The wastegate is a load limiting device. At a predetermined point, intake manifold pressure counteracts the tension of a spring, and a valve opens to bypass a portion of the engine exhaust around the turbocharger turbine. In this way, the air intake boost pressure is held within an acceptable range.

Exhaust gases driving (or bypassing) the turbocharger turbine, exit the engine through the exhaust stack. Exhaust gases passing through the flexible exhaust connection, are directed into the atmosphere through customer supplied exhaust piping.

## SECTION 2.40

### CRANKCASE BREATHER SYSTEM DESCRIPTION

#### CRANKCASE BREATHER SYSTEM DESCRIPTION

The purpose of the crankcase breather system is to maintain a slight negative pressure in the crankcase. The negative pressure rids the crankcase of harmful water vapors and combustion gases, and helps to prevent sludge buildup and oil contamination. The breather system is also designed to separate the oil from the vapors before the discharge is released into the atmosphere.

All engines are provided with manual crankcase pressure adjustment. The adjustment is accomplished by admitting more or less outside air into the breather system. All manual adjustment devices are externally controlled and easily accessible.

The components of the crankcase breather system are as follows:

- Crankcase Separator Screen (6 and 12 Cylinder Engines)
- Oil Separators
- Vacuum Valve/Choke Valve
- Breather Regulator
- Venturi Extractor
- Crankcase Pressure Relief Valves

#### SEPARATOR SCREEN MAINTENANCE

6 and 12 cylinder engines have a crankcase separator screen. On six cylinder engines, the separator screen is located in the firing deck of the crankcase at the rear of the engine (see Figure 2.40-1) On 12 cylinder engines, the separator screen is located in the rear right side of the engine on the cylinder firing deck (see Figure 2.40-2). 16 cylinder engines do not have separator screens.

The crankcase separator screen allows vapors to be vented from the crankcase. It also serves to stop a portion of the oil carried by these vapors from reaching the oil separator. As the oil mist and vapors pass out of the crankcase, the expanded metal elements in the separator screen restrict the flow of much of the oil, dropping the surplus back into the oil pan.

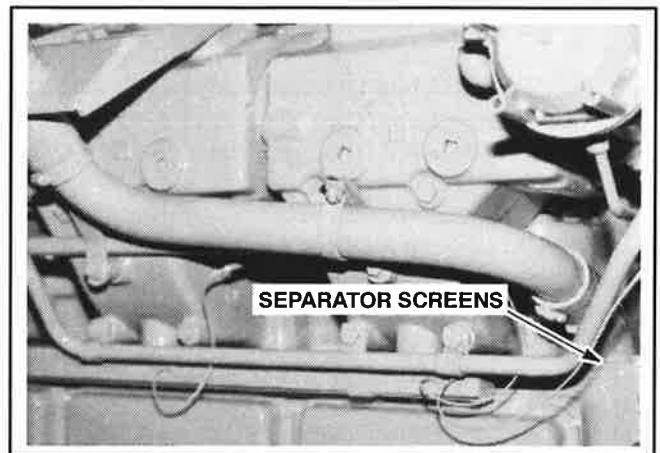


Figure 2.40-1. Crankcase Separator Screen - 6 Cylinder Engine Shown

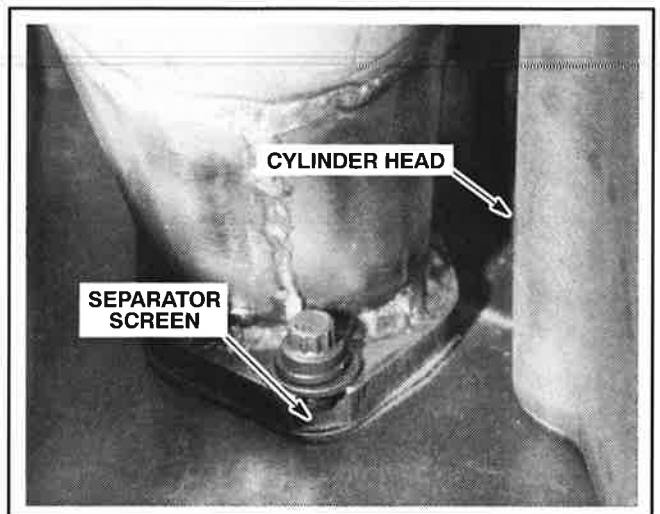
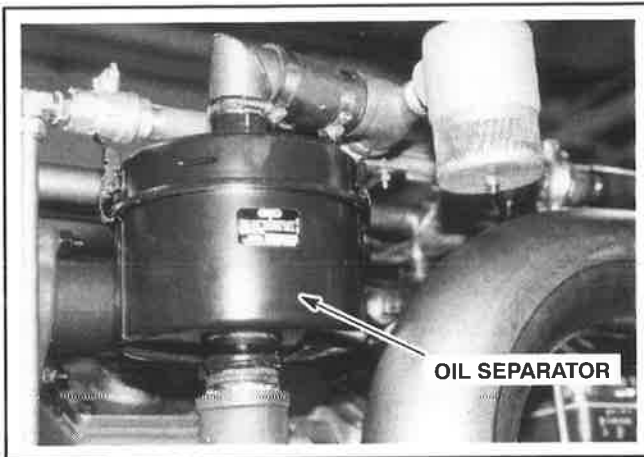


Figure 2.40-2. Crankcase Separator Screen - 12 Cylinder Engine Shown

## CRANKCASE BREATHER SYSTEM DESCRIPTION

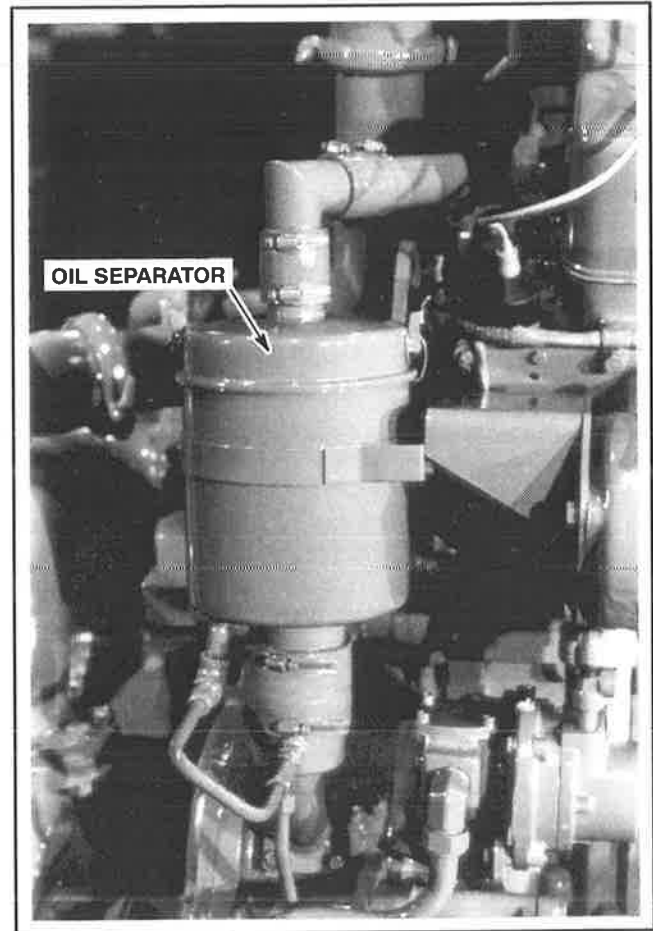
### OIL SEPARATOR(S)

6 cylinder and 12 cylinder G engines, have one oil separator located at the rear of the engine (see Figure 2.40-3).

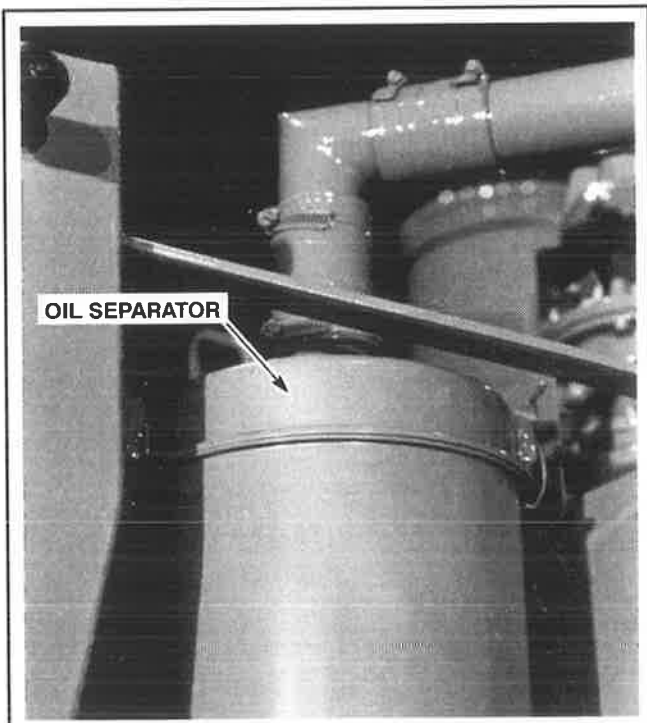


**Figure 2.40-3. Oil Separator Assembly -  
6 Cylinder Engine Shown**

The 5115GL engine, and 12 cylinder GSI and GL engines, have two oil separators. One oil separator is connected by an elbow to the vent in the gear housing cover on the front left side of the engine (see Figure 2.40-5). The second oil separator is mounted above the crankcase at the rear right side of the engine (see Figure 2.40-4). This oil separator is connected by a breather tube to the crankcase separator screen in the top of the crankcase.



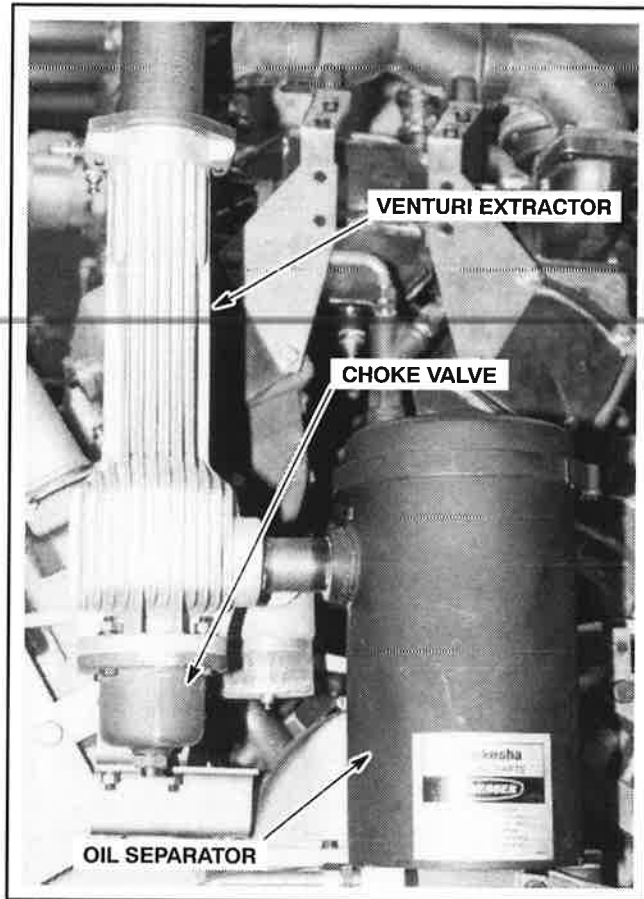
**Figure 2.40-5. Oil Separator Assembly - 5115GL  
Engine Front Left**



**Figure 2.40-4. Oil Separator Assembly - 5115GL  
Engine Rear Right**

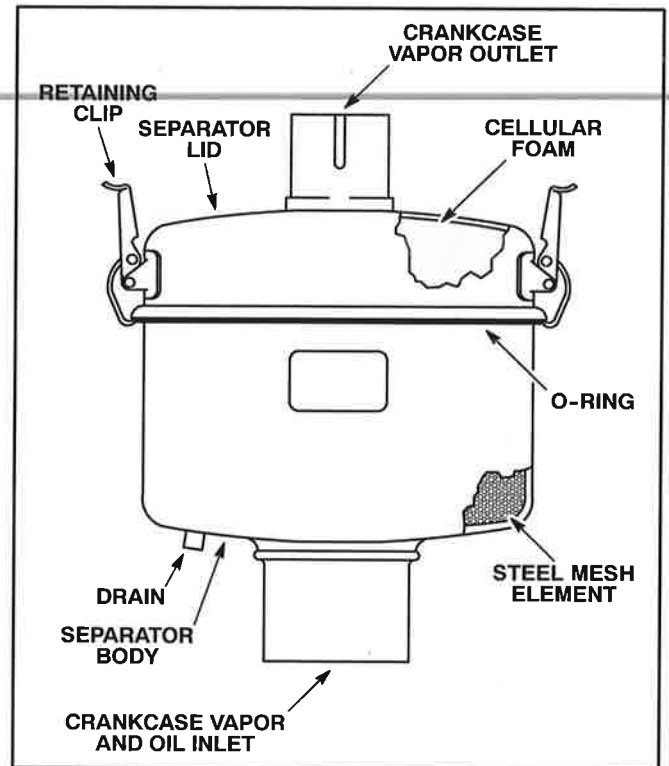
## CRANKCASE BREATHER SYSTEM DESCRIPTION

16 cylinder engines have one oil separator located on the rear of the engine directly above the flywheel (see Figure 2.40-6).



**Figure 2.40-6. Oil Separator Assembly - 16 Cylinder Engine Shown**

As the crankcase vapors and oil mist pass through the oil separator, much of the oil adheres to the steel mesh element contained in the inlet side of the separator housing. This surplus oil condenses, drops into the base of the separator and returns to the oil pan through a drain tube in the base of the separator housing (see Figure 2.40-7). The crankcase vapors pass into the venturi extractor, where they are drawn into the exhaust stack and discharged into the atmosphere.



**Figure 2.40-7. Oil Separator - 6 And 12 Cylinder Engine**

## CRANKCASE BREATHER SYSTEM DESCRIPTION

### CHOKE VALVE/VACUUM VALVE

The choke valve/vacuum valve, allows the crankcase pressure to be adjusted externally. Refer to *Crankcase Pressure Adjustment* in Chapter 4, for procedures to adjust the crankcase pressure.

On 6 cylinder models, crankcase pressure is adjusted with either a venturi/adjusting screw assembly (see Figure 2.40-8), an ejector breather/adjusting valve assembly (see Figure 2.40-9) or a vacuum valve (see Figure 2.40-10).

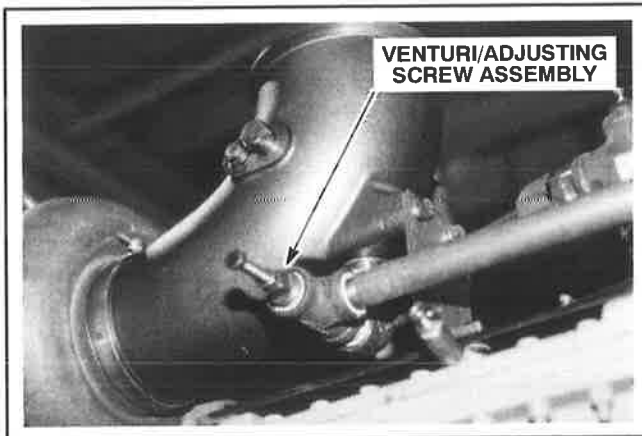


Figure 2.40-8. Venturi/Adjusting Screw Assembly - 6 Cylinder GSI Shown

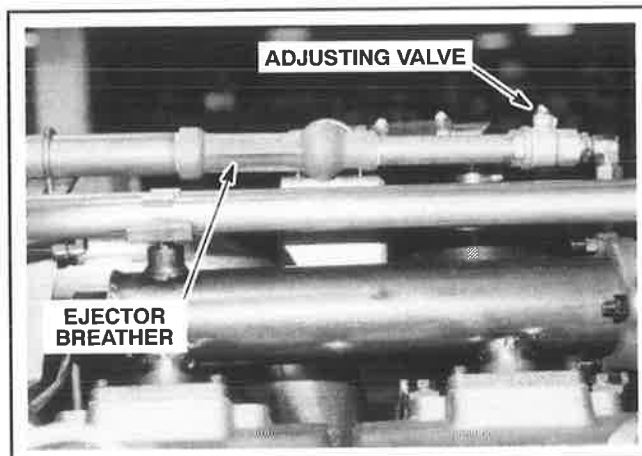


Figure 2.40-9. Ejector Breather/Adjusting Valve Assembly - 6 Cylinder Shown

On 12 cylinder models that are not equipped with venturi extractor, the crankcase pressure is adjusted with a vacuum valve assembly of which there are different configurations. (see Figure 2.40-10 and Figure 2.40-11). On 12 cylinder models equipped with a venturi extractor, the choke valve is located on the end of the venturi extractor (see Figure 2.40-12).

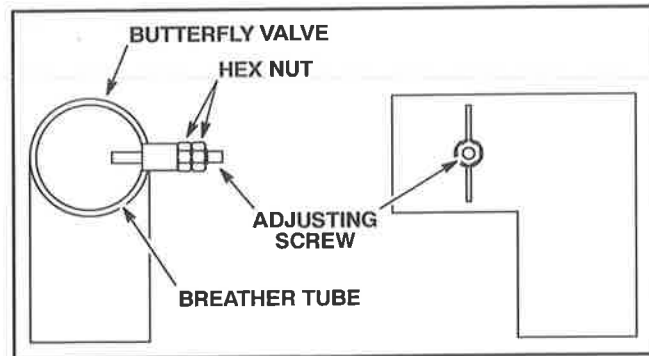


Figure 2.40-10. Vacuum Valve Assembly

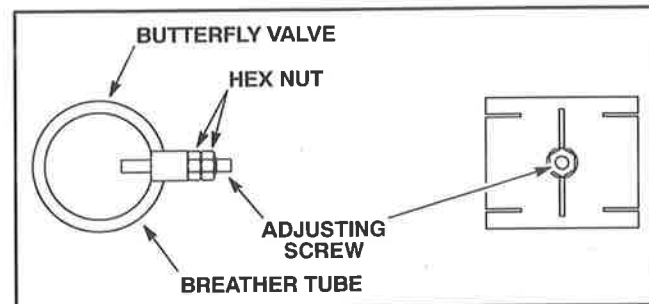


Figure 2.40-11. Vacuum Valve Assembly

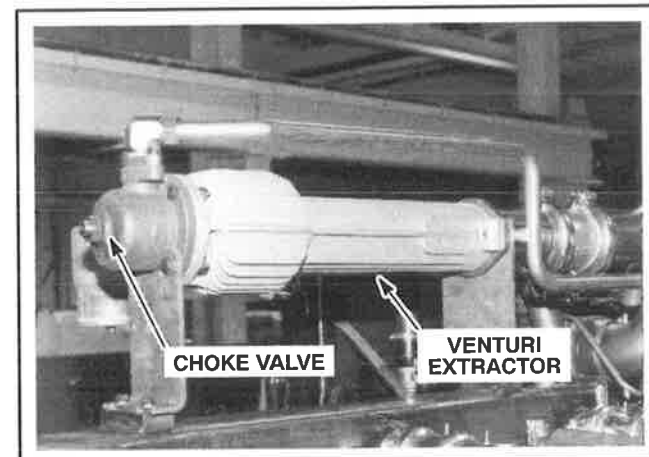


Figure 2.40-12. Venturi Extractor/Choke Valve Assembly - 12 Cylinder GL Shown

On 16 cylinder engines, the crankcase pressure is adjusted with a vacuum valve that is similar in appearance to the valve shown in Figure 2.40-8, or a venturi extractor/choke valve assembly similar to the one shown in Figure 2.40-12.

## CRANKCASE BREATHER SYSTEM DESCRIPTION

### BREATHER REGULATOR

The crankcase breather regulator assembly (see Figure 2.40-13) automatically performs fine adjustments to maintain a negative crankcase pressure to as the engine changes speed and load. Maintaining a negative crankcase pressure is important to prevent oil leaks and vacate harmful vapors, but too much pressure pulls in environmental dust and dirt. With less load, less vacuum is required to vacate crankcase vapors.

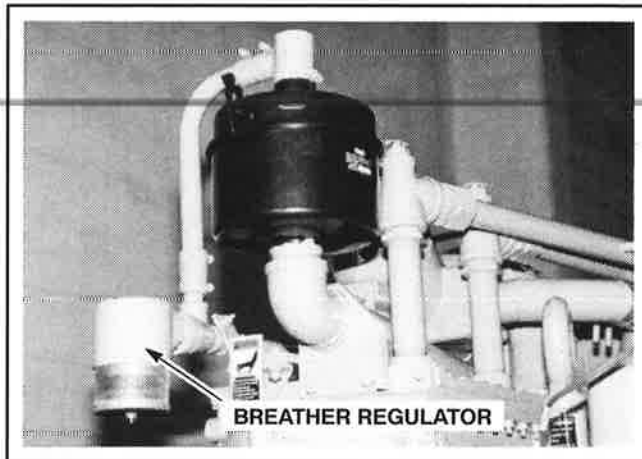


Figure 2.40-13. Breather Regulator

With an increase in load, the amount of compressor discharge air from the turbochargers increases and the plate within the regulator floats up. More outside air is sucked in as the plate rises, which allows the breather system to draw a greater vacuum.

### VENTURI EXTRACTOR

Some models are equipped with a venturi extractor (see Figure 2.40-12). The venturi extractor creates a vacuum at the exhaust pipe connection to draw the crankcase vapors from the oil separator(s) into the exhaust stack.

### CRANKCASE PRESSURE RELIEF VALVES

Some customers may require crankcase pressure relief valves as a safety precaution, in lieu of the standard oil pan door (see Figure 2.40-14). The valves open fully when the pressure in the crankcase exceeds one pound per square inch and close tightly and quickly to prevent the inflow of air after the internal pressure has been relieved. The possibility of combustion is prevented, since no oxygen is allowed to enter the crankcase to support new combustion. The valves do not prevent crankcase combustion, but only reduce the peak pressures, thereby minimizing damage.

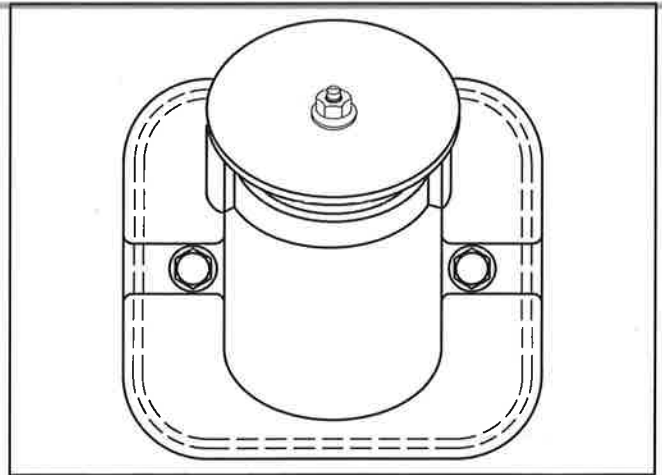


Figure 2.40-14. Crankcase Pressure Relief Valve

The valve incorporates an internal flame trap to retard the emission of flame while the valve is venting. The flame trap is of an oil-wetted wire gauze design. The cooling capacity of the gauze is doubled when oil-wetted, a condition effected by the oil mist that normally exists in the crankcase or by oil spray from the connecting rod bearings. The valve incorporates the flame trap as a single unit and the O-ring construction eliminates oil leakage.

### WARNING

The number of pressure relief valves used on the engine depends on the volume of the crankcase. Never operate the engine without all valves on the engine. The ability of the system to function is dependent upon the proper number of relief valves. Operation without the proper type and number of relief valves, or if the relief valves are not properly maintained, can result in severe personal injury or death.

# CRANKCASE BREATHER SYSTEM DESCRIPTION

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## SECTION 2.45

### PRELUBE AND STARTING SYSTEM DESCRIPTION

#### PRELUBE AND STARTING SYSTEM DESCRIPTION

- Prelube Pushbutton Valve
- Prelube Pump And Motor
- In-line Lubricator
- Start Pushbutton Valve
- Starter Motor(s) Air/Gas or Electric

#### **⚠ WARNING**

From the bulkhead, all gas vented from the system must be piped to a safe area in conformance with all applicable codes. Failure to comply could result in serious personal injury or death.

#### PRELUBE PUSHBUTTON VALVE

The PRELUBE pushbutton valve activates the prelube system (see Figure 2.45-1). The prelube system circulates oil through the the engine and turbocharger(s) to provide the engine adequate lubrication during startup.

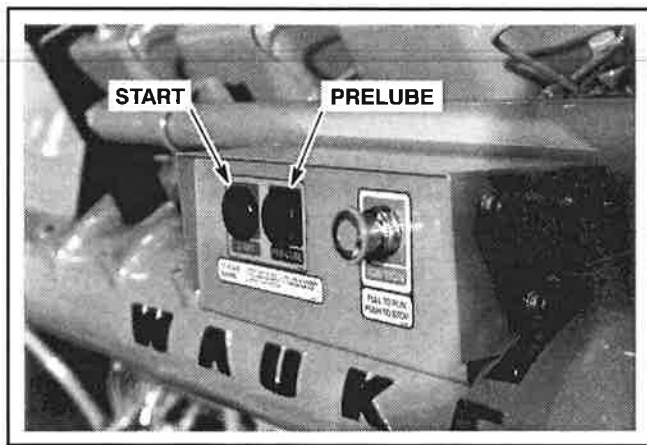


Figure 2.45-1. Start And Prelube Pushbutton Valves

#### PRELUBE PUMP AND MOTOR

The prelube pump and motor (see Figure 2.45-2) circulate the oil through the engine when the PRELUBE pushbutton is pressed.

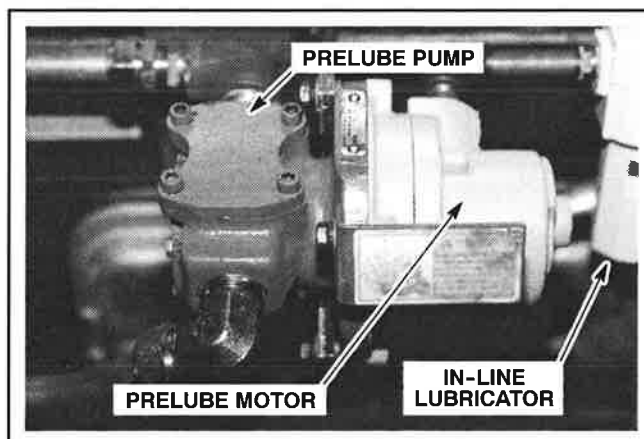


Figure 2.45-2. Prelube Pump and Motor

## PRELUBE AND STARTING SYSTEM DESCRIPTION

### IN-LINE LUBRICATOR

The in-line lubricator (see Figure 2.45-3) provides the prelude motor with lubrication during the starting sequence.

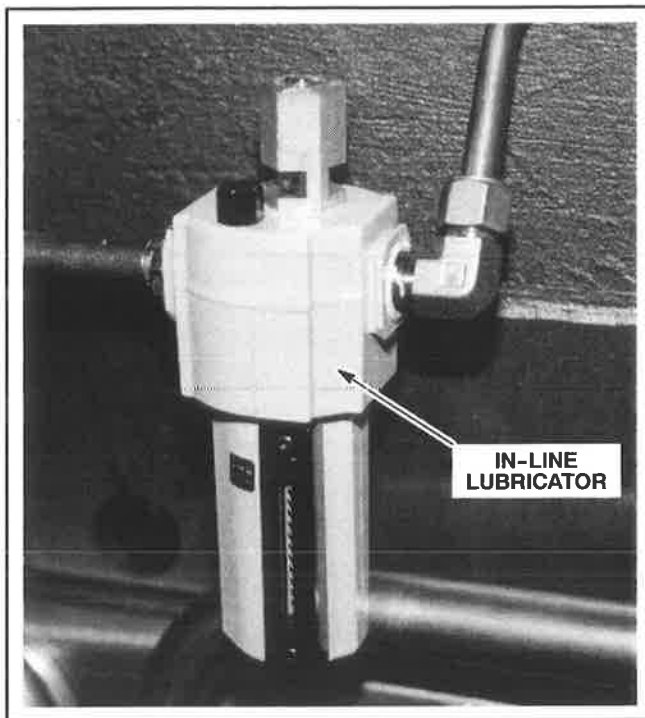


Figure 2.45-3. In-line Lubricator

### START PUSHBUTTON VALVE

The START pushbutton valve activates the starter motor system (see Figure 2.45-1). On air/gas starter systems the START pushbutton valve activates a series of valves that allow air/gas pressure to activate the air/gas starter motor. On electric start systems, an additional solenoid is added to the system to replace the signal normally provided by air/gas pressure.

### STARTER MOTOR - AIR/GAS

The air/gas pressure causes the starter pinion to shift into engagement with the flywheel ring gear and activates the starter motor (see Figure 2.45-4) to crank the engine. A lubrication reservoir provides lubrication to the air/gas starter during the starting sequence.

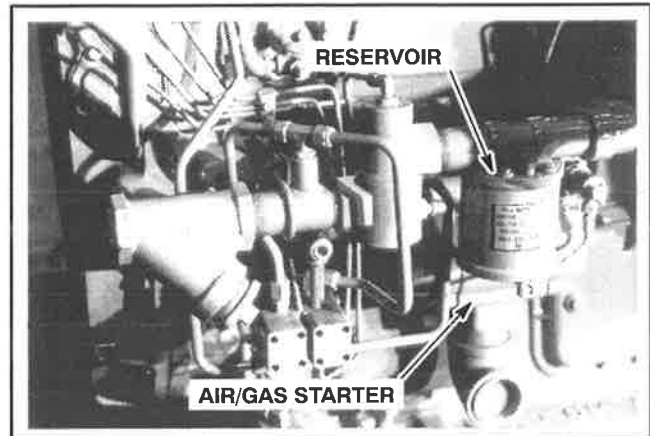


Figure 2.45-4. Air /Gas Starter

### STARTER MOTOR - ELECTRIC START

This system functions in much the same way as the air/gas starting system with the obvious difference being the use of electric starting motors (Figure 2.45-5). An additional solenoid is added to the system to replace the signal normally provided by air/gas pressure.

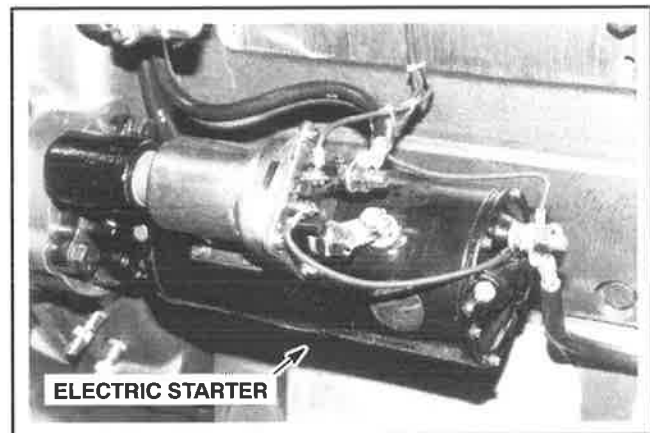


Figure 2.45-5. Electric Starter

## SECTION 2.50

### ENGINE PROTECTION SHUTDOWN SYSTEM DESCRIPTION

#### ENGINE PROTECTION SHUTDOWN SYSTEM DESCRIPTION OPTIONS

The control switches that make up the engine protection shutdown system must be supplied by the customer. Waukesha provides the following:

- Sensors and Thermocouples
- Thermocouple Junction Box
- Manual Shutdown Switches

#### **⚠ WARNING**

**Switches for alarms and automatic engine shutdown must be supplied by the customer. The sensors provided are for measuring and monitoring temperatures and WILL NOT shut the engine down if potentially harmful temperatures are reached. Waukesha will not be responsible for any property damage, personal injury or death, due to the failure to follow these instructions.**

**NOTE:** *The customer supplied control switches must be incorporated into the remote engine control panel logic.*

#### K-TYPE THERMOCOUPLES

Thermocouples are used to measure lube oil (see Figure 2.50-1), jacket water (see Figure 2.50-2), and intake manifold (left and right bank on Vee engines) air temperature (see Figure 2.50-4). These thermocouples are wired through the thermocouple junction box to a remote mounted instrument panel (customer supplied or as a Waukesha option). Additional thermocouples (see Figure 2.50-3 and Figure 2.50-5) are used to measure exhaust temperature and turbine inlet temperature.

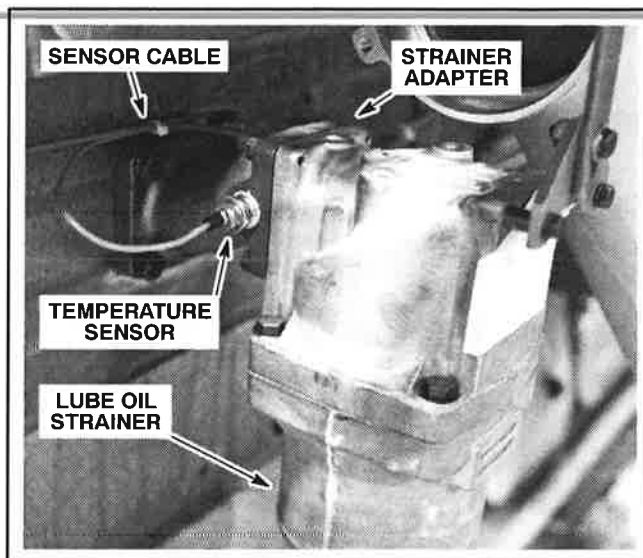


Figure 2.50-1. Lube Oil Inlet Temperature Sensor - 5115GL Engine Shown

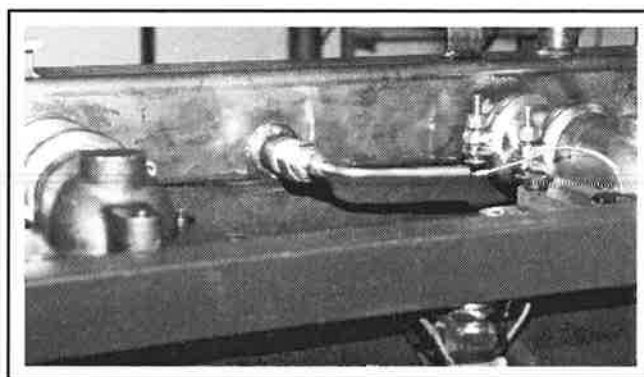


Figure 2.50-2. Jacket Water Temperature Sensor - 5115GL Engine Shown

# ENGINE PROTECTION SHUTDOWN SYSTEM DESCRIPTION

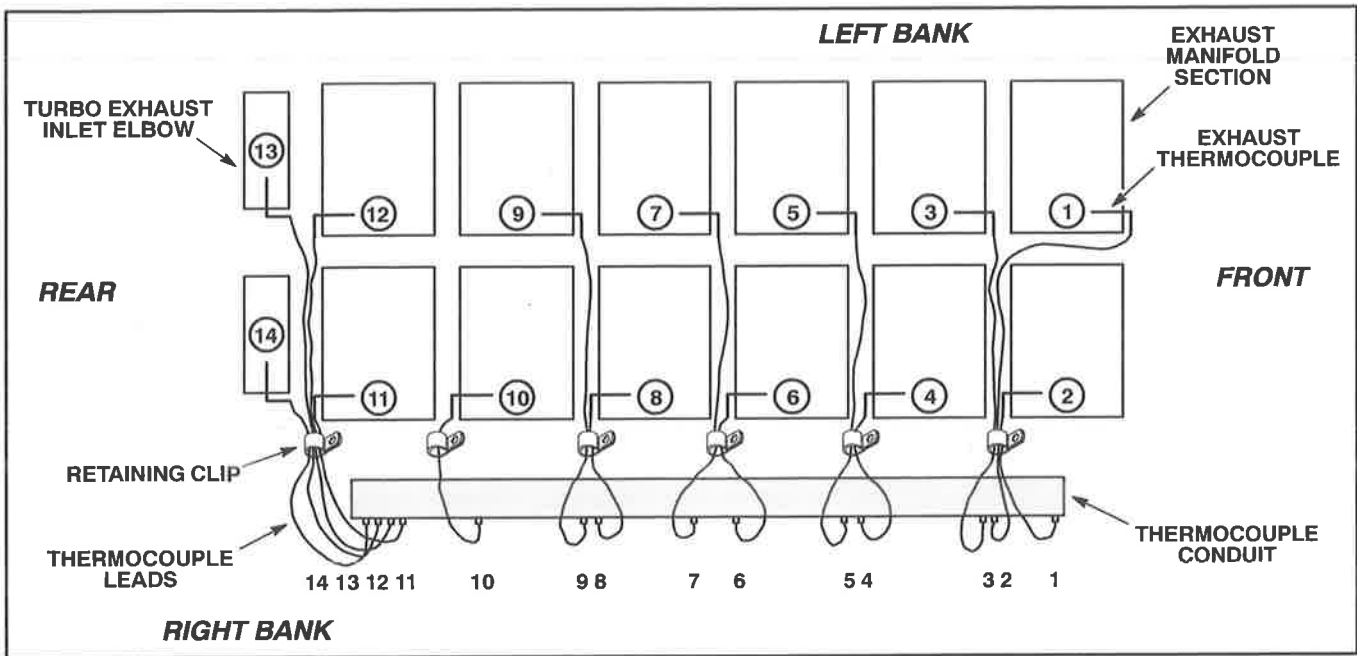


Figure 2.50-3. Exhaust Thermocouples Arrangement - 12 Cylinder Engine

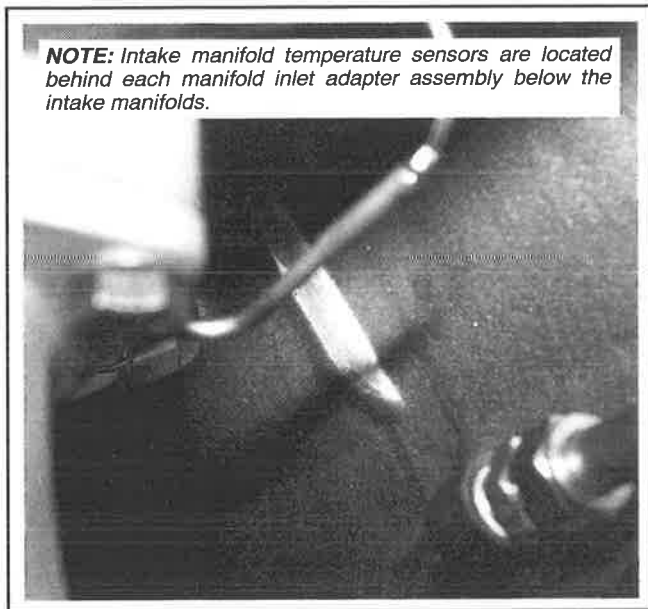


Figure 2.50-4. Intake Manifold Temperature Sensor - 5115GL Engine Shown

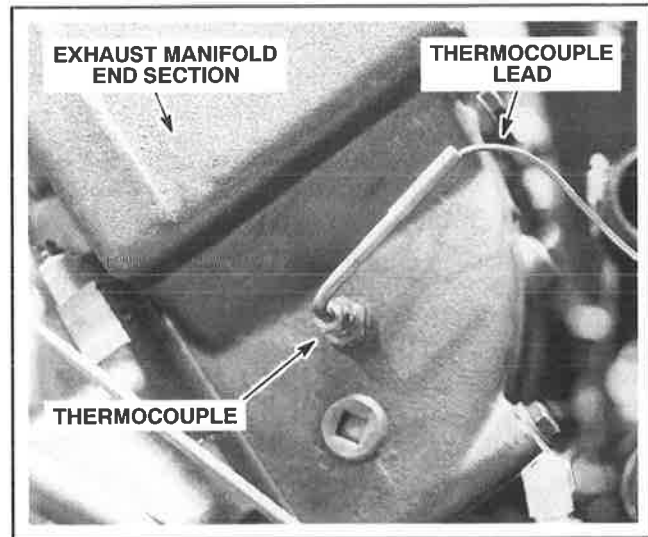


Figure 2.50-5. Exhaust Thermocouple - 12 Cylinder Engine Rear Left

## ENGINE PROTECTION SHUTDOWN SYSTEM DESCRIPTION

Additional K-Type thermocouples that may be found on the engine, are:

- Thermocouples used to monitor the main bearing temperatures (see Figure 2.50-6). All thermocouples end at the thermocouple junction box when shipped. It is the customer's responsibility to connect the wiring to the remote-mounted instrument panel. Main bearing sensor logic must be supplied by the customer.
- Thermocouple used to monitor oil sump temperature.
- Oxygen sensors mounted in the exhaust system.
- Detonation sensors (one for each cylinder) are used to detect detonation in the combustion chambers. Refer to Section 2.10, *Ignition Systems*, for information concerning the detonation sensors.
- Thermocouples for the compressor system.

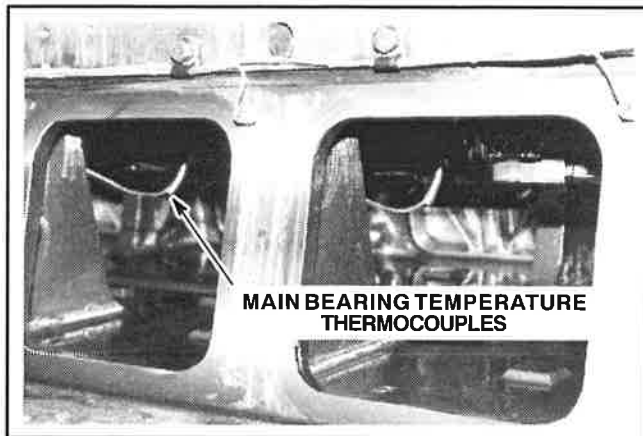


Figure 2.50-6. Main Bearing Temperature Thermocouples - 12 Cylinder Engine

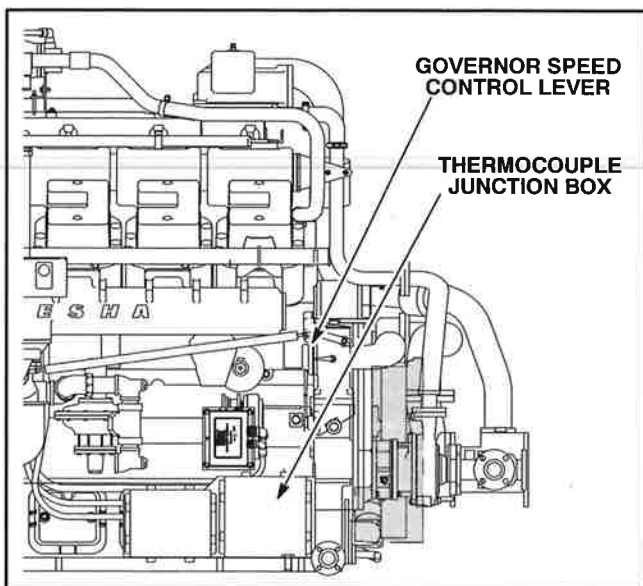


Figure 2.50-7. Thermocouple Junction Box And Governor Speed Control Lever - 5115GL Engine

### THERMOCOUPLE JUNCTION BOX

The function of the thermocouple junction box (see Figure 2.50-7) is to serve as the main junction point for the wiring of engine protection shutdowns.

### MANUAL SHUTDOWN LEVER AND GOVERNOR SPEED CONTROL LEVER

#### **⚠ WARNING**

**Always insure that the fuel gas valve(s) are closed after engine shutdown. Failure to close fuel gas valve(s) could cause severe personal injury or death.**

All engines have manual shutdown levers located on the right side carburetor (Figure 2.50-8) and may also have a governor speed control lever on the governor. These levers will return the engine to idle speed. Under some conditions, the engine may shutdown completely when using these levers. After the engine reaches idle speed, close the fuel gas valves to completely shutdown the engine. Always shutdown the fuel gas supply after the engine is shutdown.

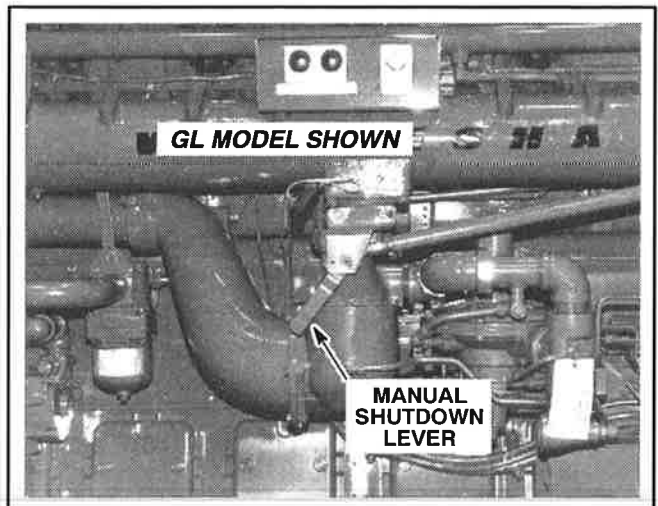


Figure 2.50-8. Manual Shutdown Lever - 12 Cylinder

## ENGINE PROTECTION SHUTDOWN SYSTEM DESCRIPTION

### IGNITION SWITCH/SWITCHES

#### **WARNING**

Always insure that the fuel gas valve(s) are closed after engine shutdown. Failure to close fuel gas valve(s) could cause severe personal injury or death.

On 6 and 12 cylinder engines, IGNITION (Emergency Stop) button(s), are located on the left and right sides of the engine on 12 cylinder engines, and the right side only on 6 cylinder engines (see Figure 2.50-9). Depressing either IGNITION (Emergency Stop) button(s) will stop the engine by de-energizing the ignition and electrical fuel supply solenoid valves. Always shut down the fuel gas supply after engine shutdown. To restart the engine after depressing either IGNITION (Emergency Stop) button(s), simply pull the depressed shutdown switch back out to its original position. The manual shutdown switches are wired to the main junction box.



Figure 2.50-9. Control Panel - Left Side

On 16 engines, the engine may be shut down by turning the IGNITION switch, located on the control panel to the OFF position (see Figure 2.50-10). Always shut down the fuel gas supply after engine shutdown.



Figure 2.50-10. 16 Cylinder Control Panel

### CUSTOMER SUPPLIED CONTROL SWITCHES

Control switches must be supplied by the customer. Control switches must include, but are not limited to; low oil pressure, high coolant temperature, high lube oil temperature, high intake manifold air temperature, and an overspeed switch. Switches should be wired to an alarm to warn of high temperatures and low pressure, as well as provide for automatic engine shutdown if potentially harmful temperatures, pressure, or over-speed conditions exist.

### PRESSURE AND TEMPERATURE SWITCH CALIBRATION

Calibrating and testing pressure and temperature switches, should be performed by qualified service technicians every 90 days.

### OPTIONAL INSTRUMENT PANEL

Waukesha Engine offers an optional instrument panel (see Figure 2.50-11). The instrument panel is shipped loose and requires 24VDC power.

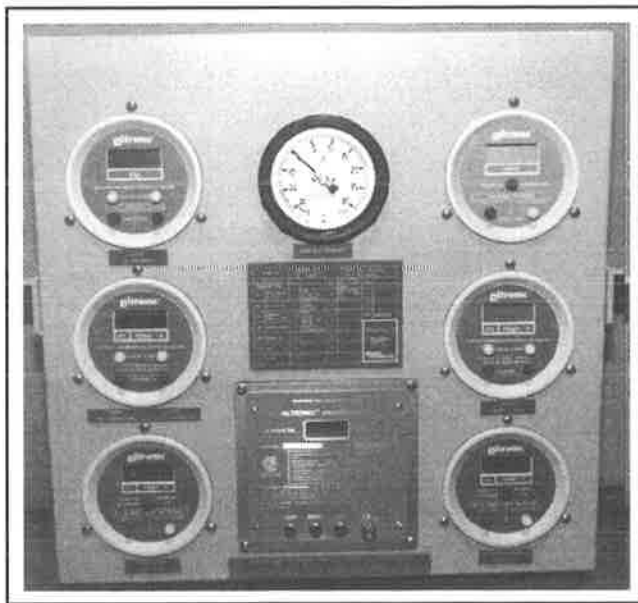


Figure 2.50-11. Optional Remote Instrument Panel

The instrument panel includes switch gauges for jacket water temperature, lube oil pressure, intake manifold temperature and overspeed. Gauges are included for individual exhaust thermocouples, pre and post turbine temperature, intake manifold pressure, tachometer and hourmeter. An annunciator will display the cause of the shutdown.

# ENGINE PROTECTION SHUTDOWN SYSTEM DESCRIPTION

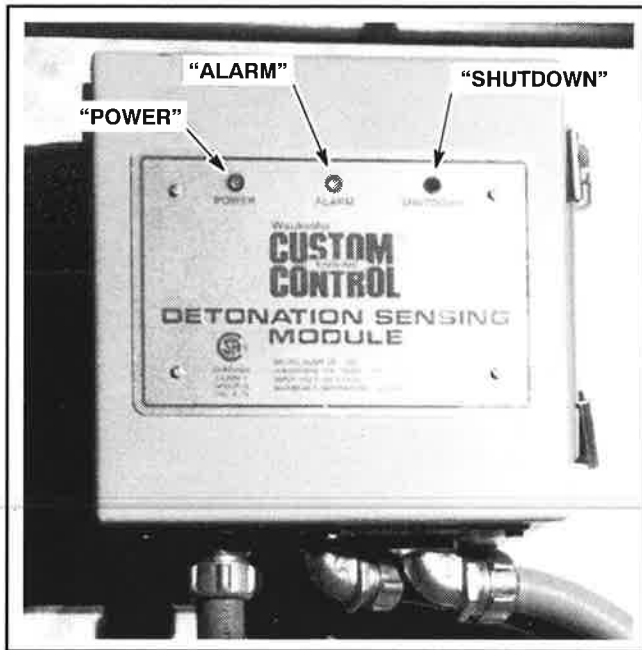
## DETONATION SENSING MODULE AND SENSORS

### **WARNING**

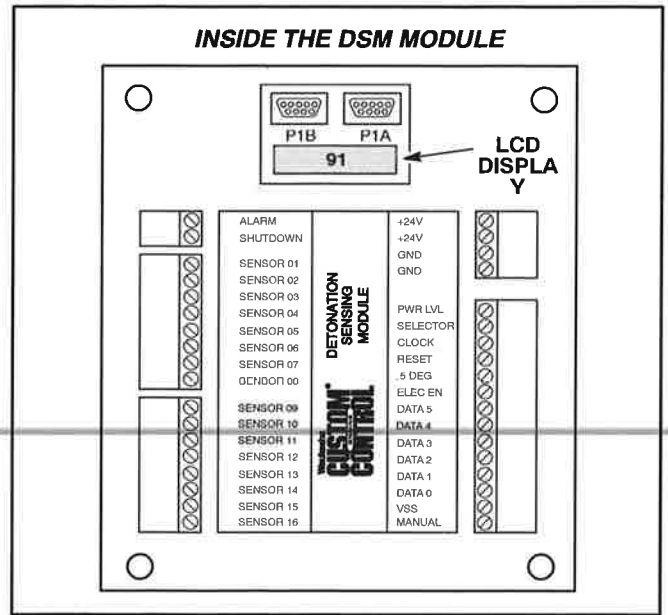
For maximum engine protection, the DSM system must be connected to a safety shutdown. The DSM system is considered a safety system and, as such, must be connected to shutdown the engine if the engine cannot be brought out of detonation. Disregarding this information could result in severe personal injury or death.

The DSM module is equipped with several features to inform site personnel of system status. These features include:

- “Power”, “Alarm”, and “Shutdown” lights (LED display) on the front panel of the DSM module (see Figure 2.50-12)
- A liquid crystal display (LCD) located inside the DSM module which continually shows the current status of the system through diagnostic codes (see Figure 2.50-13)
- The capability to drive remote alarms or lights

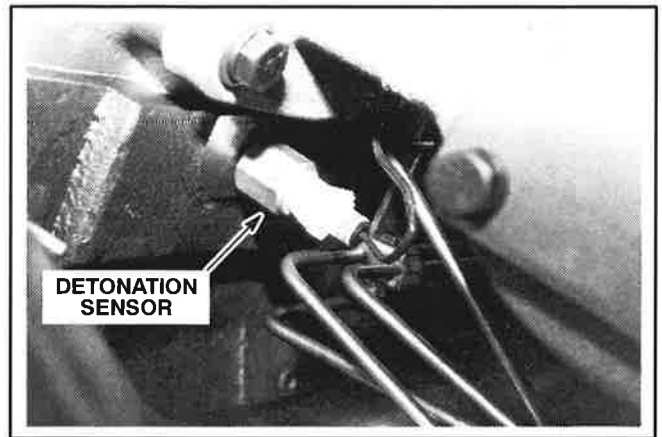


**Figure 2.50-12. Detonation Sensing Module Front Panel**



**Figure 2.50-13. Detonation Sensing Module LCD Display**

One DSM sensor per cylinder is installed just below the intake manifold (see Figure 2.50-14). These sensors send their signals back to the DSM module.



**Figure 2.50-14. Detonation Sensor (VHP Series)**

Refer to Form 6268, *DSM Custom Engine Control® Detonation Sensing Module Installation, Operation, And Maintenance Manual*, for further information.

# ENGINE PROTECTION SHUTDOWN SYSTEM DESCRIPTION

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# **CHAPTER 3 - ENGINE STARTUP AND SHUTDOWN**

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## **CONTENTS**

### **SECTION 3.00 - ENGINE STARTUP AND SHUTDOWN**

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## SECTION 3.00

### ENGINE STARTUP AND SHUTDOWN

#### PRESTART INSPECTION

#### WARNING

To avoid severe personal injury or death, be sure that the clutch, circuit breaker or other main power transmission device is disconnected.

1. Inspect the entire cooling system to verify that all control valves are properly opened and that all drain cocks are completely closed.

#### WARNING

Always wear protective clothing when checking or venting the cooling system on a heated engine. Slowly loosen the air bleed petcock to relieve any excess pressure. Use the vent on the pressure cap to allow pressure to escape. Escaping steam and/or hot water can result in severe burns or death.

2. Check the coolant level; add coolant when necessary. If coolant is needed, open the cooling system air vents to allow trapped air to escape.
3. Check for lube oil and/or coolant leaks.

4. Verify that all protective guards and shields on both the engine (see Figure 3.00-1) and the driven equipment are secure. Remove tools, rags, fittings or any other objects that may get caught by rotating parts.

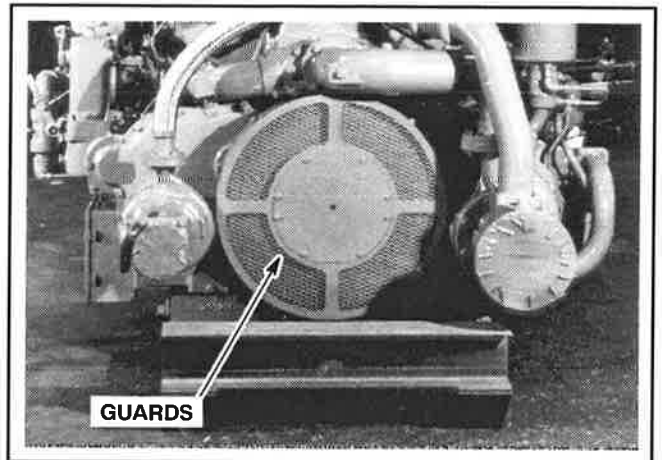


Figure 3.00-1. Engine Guards - 5115GL Engine Shown

## ENGINE STARTUP AND SHUTDOWN

5. On 6 and 12 cylinder engines, check air cleaner restriction indicator. If indicator shows red, clean pre-cleaner and/or air cleaner elements (see Figure 3.00-2). 16 cylinder engines have indicator gauges that are checked while the engine is running.

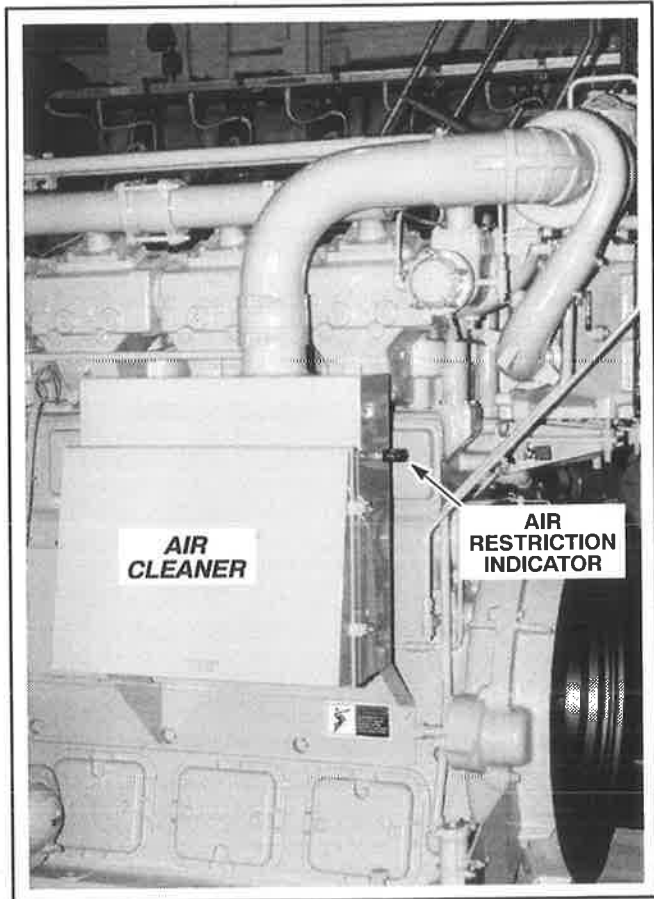


Figure 3.00-2. Air Restriction Indicator/Filter - 6 Cylinder Engine Shown

### **WARNING**

Make certain barring device is disengaged from flywheel prior to starting engine. Remove all wrenches from the barring device before engaging starter. Failure to follow proper procedures could cause severe personal injury or death.

6. Bar the engine over two revolutions in a counter-clockwise direction, to verify that nothing interferes with its rotation (see Figure 3.00-3).

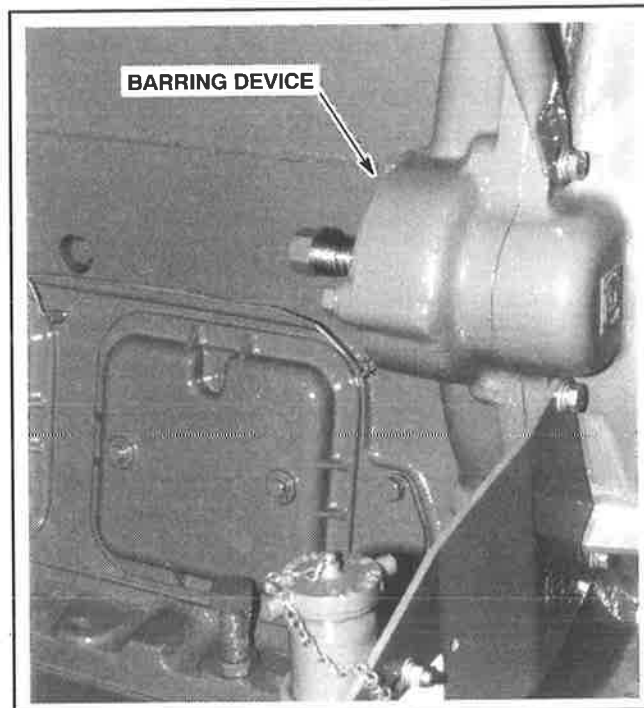


Figure 3.00-3. Engine Barring Device - 12 Cylinder Engine

7. Check the crankcase oil level daily before the engine is started. The blade of the dipstick is marked "low" and "full" (see Figure 3.00-4). Always maintain the oil level at the "full" mark. Both marks on the dipstick are "static lines." The dipstick does not indicate where the level of the oil should be when the engine is running.

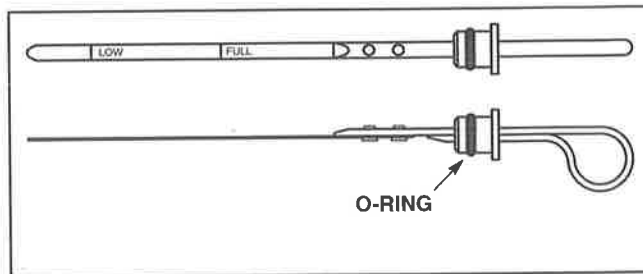


Figure 3.00-4. Dipstick

8. Check UG-8 governor oil level in sight glass (see Figure 3.00-5).

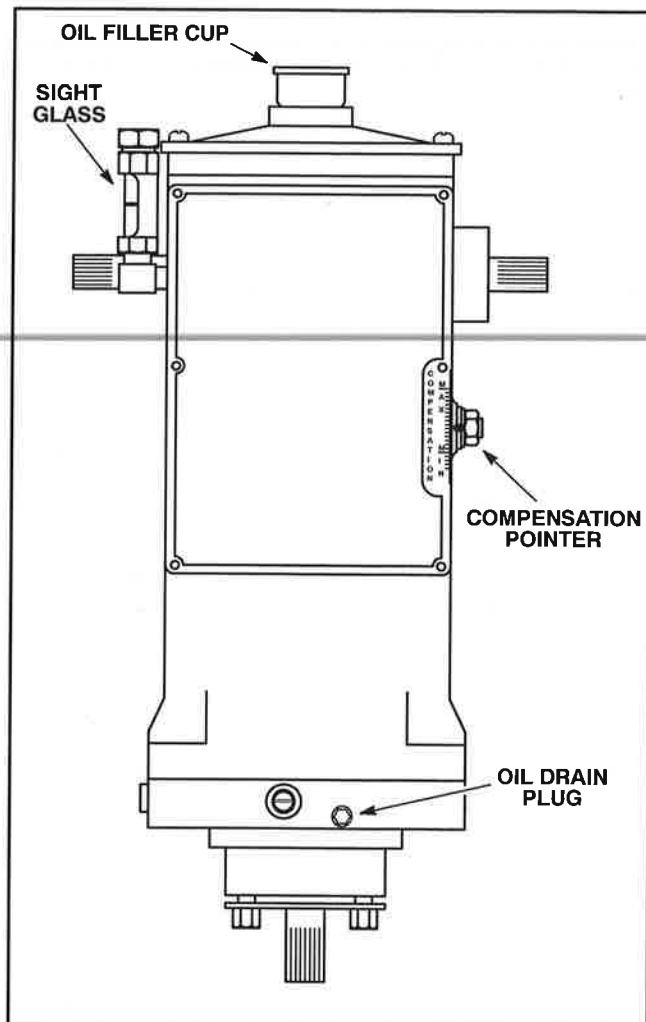


Figure 3.00-5. Woodward UG-8L Governor

9. Examine the engine foundation for condition of grout, tightness of hold down bolts and general alignment of driven equipment.

## ENGINE STARTUP PROCEDURES

1. Reset all engine protection switches and devices.
2. Press and hold down the PRELUBE button for 5 minutes to operate the prelube motor (see Figure 3.00-6 and Figure 3.00-7). Check the lube oil pressure gauge for a minimum of 5 psi (35 kPa).

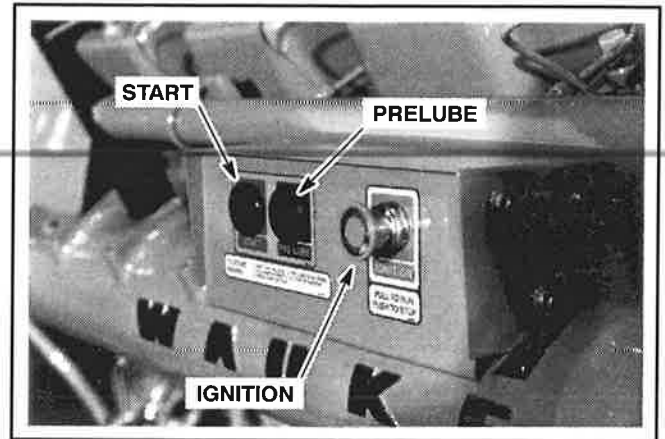


Figure 3.00-6. Control Panel - 12 Cylinder Engine

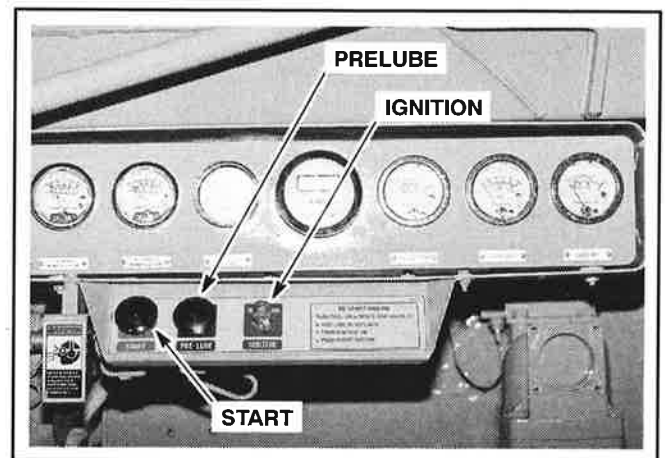
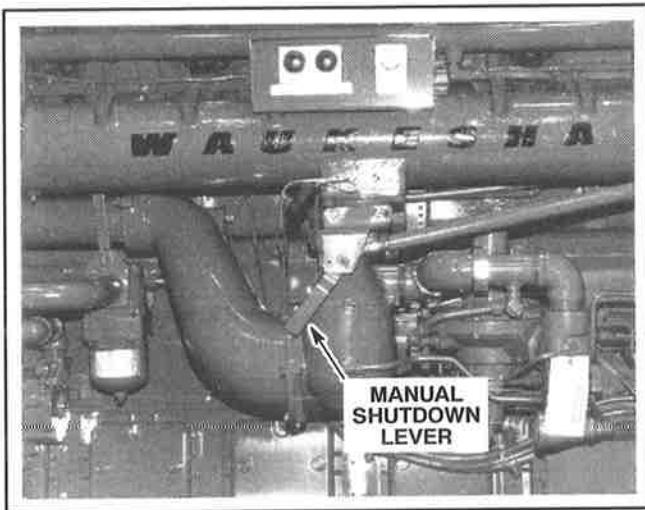


Figure 3.00-7. Control Panel - 16 Cylinder Engine

## ENGINE STARTUP AND SHUTDOWN

3. Place the manual shutdown lever in the open position (see Figure 3.00-8, Figure 3.00-9 and Figure 3.00-10).

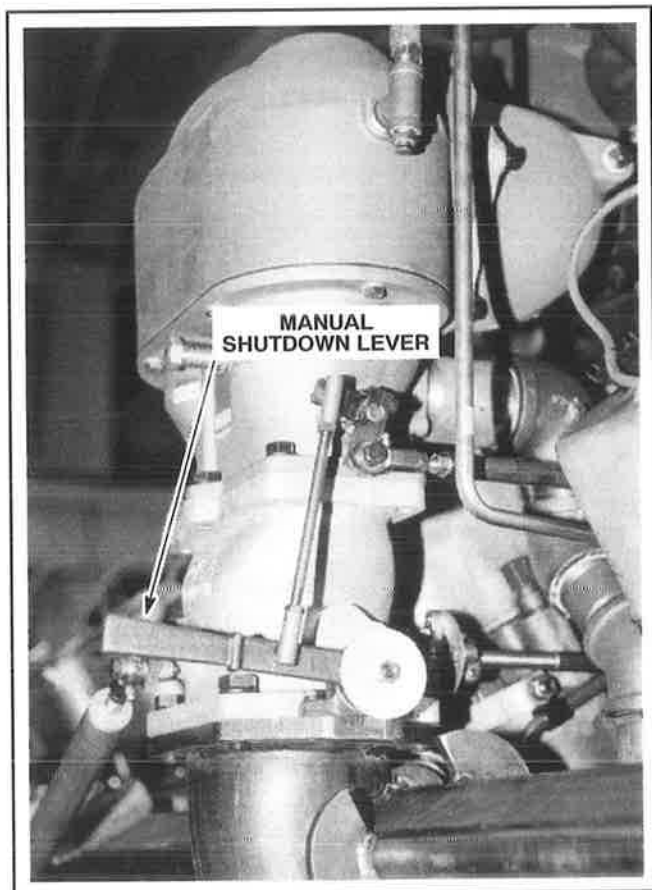


**Figure 3.00-8. Manual Shutdown Lever -  
12 Cylinder GL Engine**

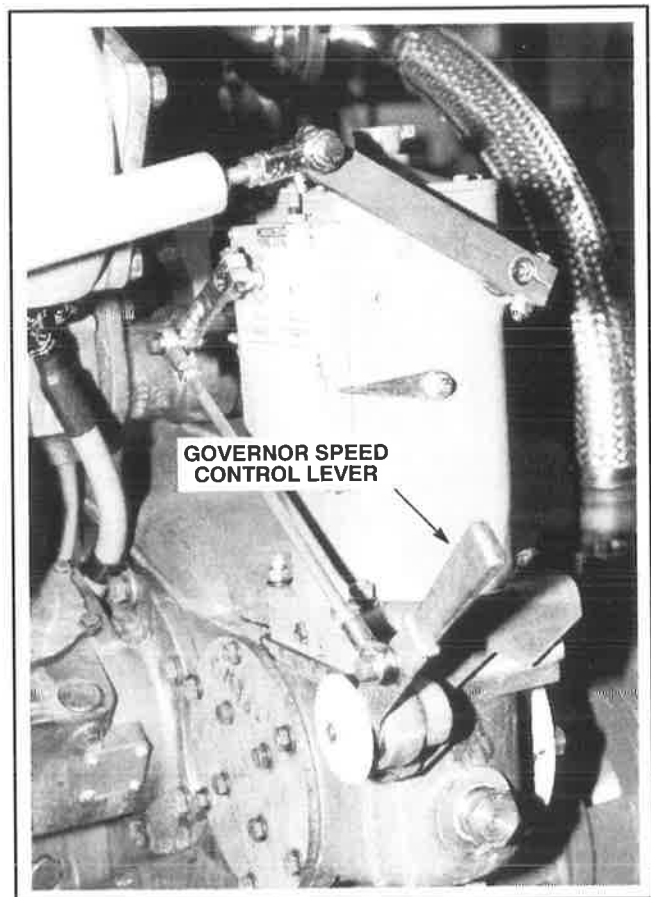


**Figure 3.00-10. Manual Shutdown Lever -  
6 Cylinder GSI Engine**

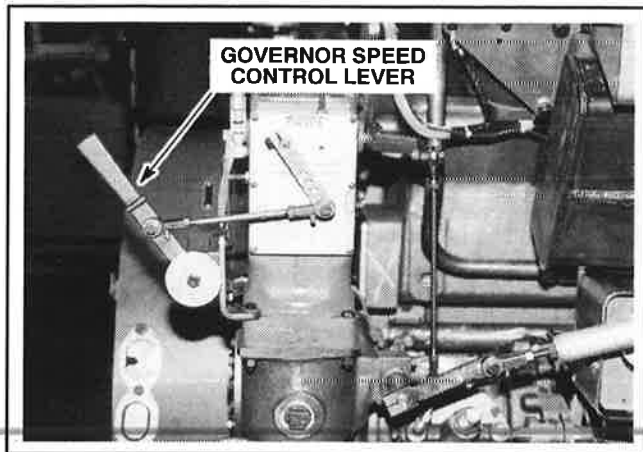
4. Place the governor speed control lever or dial to 1/3 open position (see Figure 3.00-11 and Figure 3.00-12).



**Figure 3.00-9. Manual Shutdown Lever -  
16 Cylinder GSI Engine**

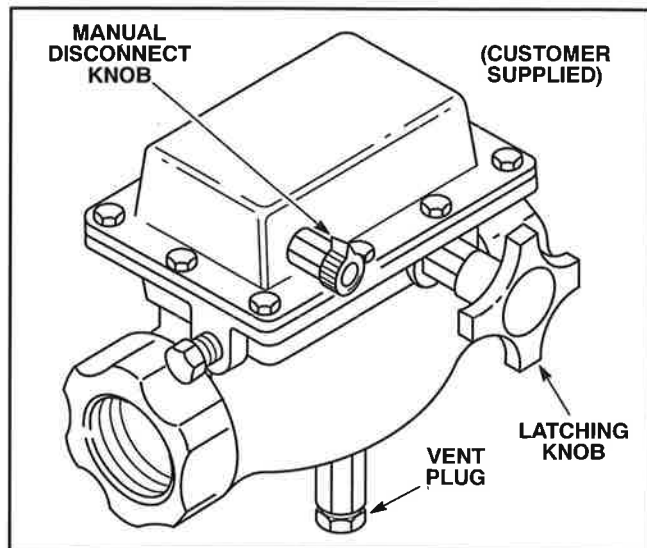


**Figure 3.00-11. Governor Speed Control Lever -  
12 Cylinder Engine**



**Figure 3.00-12. Governor Speed Control Lever - 16 Cylinder Engine**

5. Open the fuel shutoff valve(s) (Figure 3.00-13).



**Figure 3.00-13. Fuel Shutoff Valve - Customer Supplied**

6. On 6 and 12 cylinder engines, make sure that the IGNITION (Emergency Stop) buttons are pulled out (see Figure 3.00-6). On 16 cylinder engines turn the ignition switch to the ON position (see Figure 3.00-7).

7. Press the START button until engine starts (see Figure 3.00-6 and Figure 3.00-7).

8. Check for oil pressure as soon as the engine starts. Refer to Table 1.15-2, *VHP Specification* in Section 1.15 - *General Information*, for operating pressures.

**CAUTION** If the lube oil pressure gauge does not indicate sufficient oil pressure within 15 seconds, shut the engine down immediately. Never operate the engine without the proper oil pressure indication. Disregarding this information could result in product damage.

**CAUTION** Turbocharged engines should not be idled for extended periods. Accumulated carbon may damage turbocharger. Shut down and restart when needed.

9. Warm the engine by running with little or no load until the oil pressure is normal and the coolant temperature reaches 100° F (38° C). Refer to Table 1.15-2, *VHP Specifications* in Section 1.15 - *General Information*, for operating pressures and temperatures.

10. Gradually apply load, to avoid overloading the engine.

**NOTE:** Engines that are required to start at temperatures below 50° F (10° C) should be equipped with both an oil and coolant heater. These devices allow the engine to be started with the proper oil flow. If the heaters are manually controlled, allow the engine to become warm enough for normal starting.

## ENGINE STARTUP AND SHUTDOWN

### ENGINE DURING OPERATION CHECKS

**CAUTION** Stop the engine immediately if the oil pressure is low or fluctuating. Disregarding this information could result in product damage.

1. Observe and record the normal operating readings for oil pressure, oil temperature, and water temperature on the engine instrument panel (see Figure 3.00-7 and Figure 3.00-14) or optional remote instrument panel (see Figure 3.00-15). Refer to Table 1.15-2, *VHP Specifications* in Section 1.15 - *General Information*, for operating pressures and temperatures.

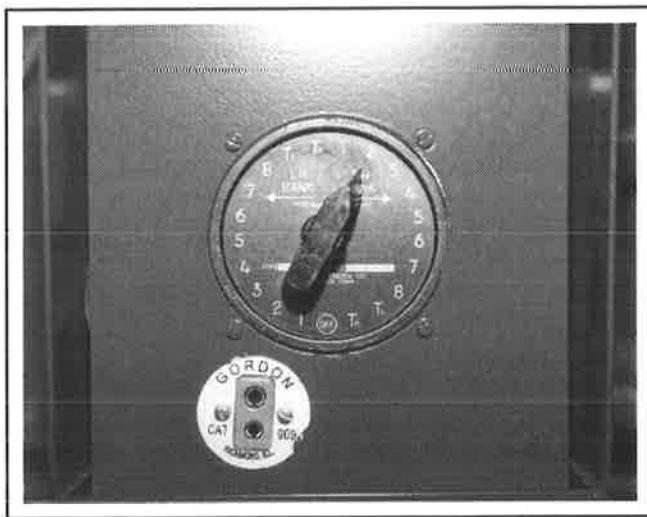


Figure 3.00-14. Thermocouple Selection Switch - 16 Cylinder

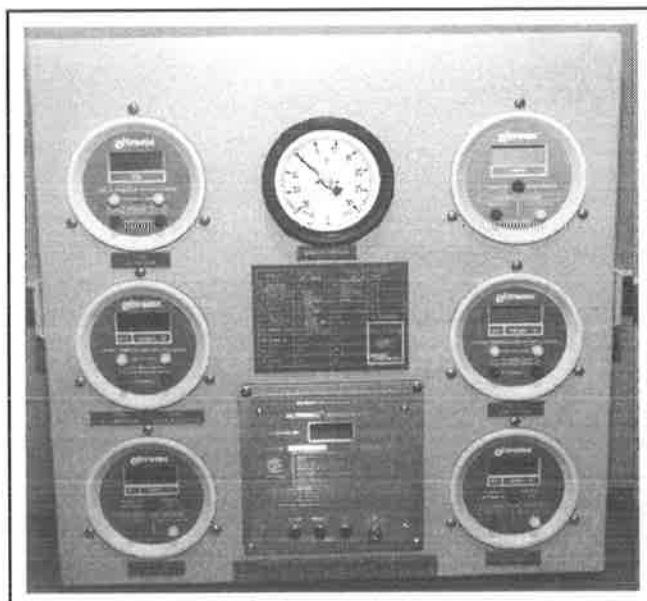


Figure 3.00-15. Optional Remote Instrument Panel

2. Check the air restriction indicator on the air cleaner while the engine is running. Refer to *Air Induction System*, and clean/replace precleaner and/or air cleaner elements if indicator shows red on 6 and 12 cylinder engines (see Figure 3.00-16). On 16 cylinder engines, check that the air restriction gauge is showing in the green for both the prefilter and final filter (see Figure 3.00-17). A toggle switch allows the operator to select the filter reading desired. The toggle switch should be left in the FINAL FILTER position during engine operation.

3. Listen to the engine. Certain problems, such as occasional misfiring, turbocharger bearing failure, or water pump problems, may first be noticeable in the engine sound.

4. Visually examine fuel, water, and lubrication lines for signs of leaks, damage, or corrosion.

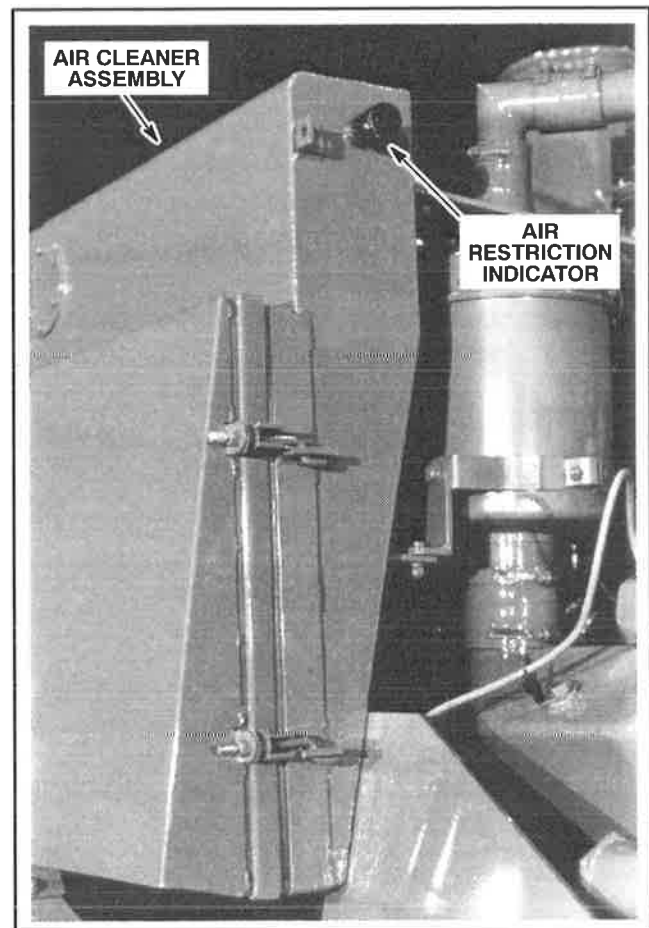


Figure 3.00-16. Air Restriction Indicator - 5115GL Engine



## ENGINE STARTUP AND SHUTDOWN

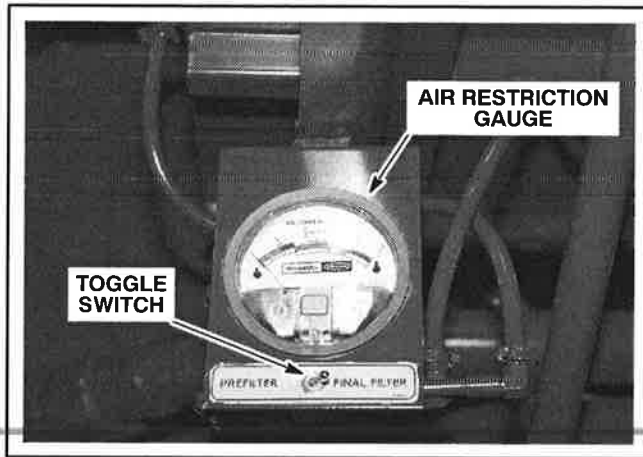


Figure 3.00-17. Air Restriction Indicator - 16 Cylinder Engine

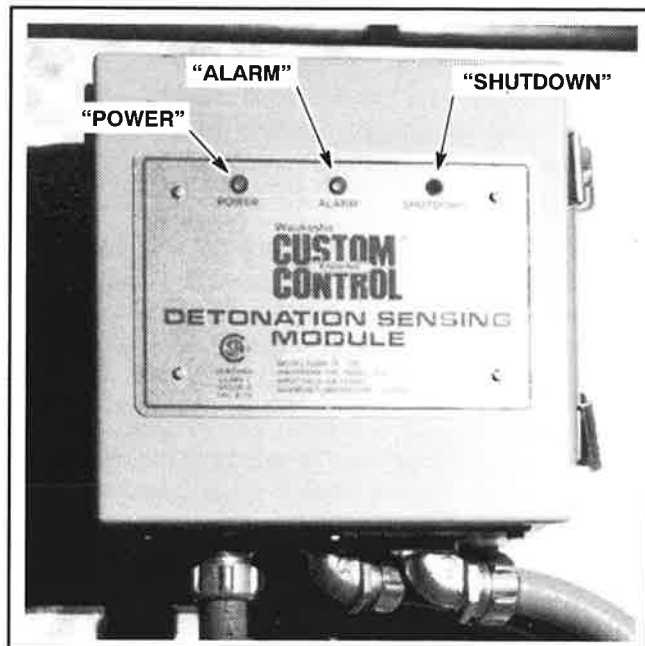


Figure 3.00-18. Detonation Sensing Module - Front Panel

5. Monitor the DSM module (see Figure 3.00-18) for system status. The DSM is equipped with several features to inform site personnel of system status. These features include:

- “Power”, “Alarm”, and “Shutdown” lights (LED display) on the front panel of the DSM module.
- A liquid crystal display (LCD) located inside the DSM module which continually shows the current status of the system through diagnostic codes.
- The capability to drive remote alarms or lights.

6. If red “Shutdown” light is illuminated, shut down the engine if automatic devices have not already done so. Call a Waukesha certified technician for assistance.

7. The yellow “Alarm” light illuminates to indicate that sensor output has been lost or disconnected. Call a Waukesha certified technician for assistance.

**NOTE:** Refer to Form 6268, *DSM Custom Engine Control® Detonation Sensing Module Installation, Operation, And Maintenance Manual*, for information concerning the DSM.

**NOTE:** Refer to Form 6253, (Previous Model) or Form 6272 (Current Model) *IM Custom Engine Control® Ignition Module Installation, Operation, And Maintenance Manual*, for further information concerning the IM.



Figure 3.00-19. IM Diagnostic LEDs

8. Monitor the three diagnostic LEDs on front of the IM housing: “Power,” “Pickup,” and “Application” (see Figure 3.00-19). These LEDs give operators visual confirmation on (1) incoming power, (2) Hall-effect pickup signal, and (3) proper application settings (see Figure 3.00-19).

- The green “Power” LED is lit any time power is applied to the IM. The power LED confirms to the operator that connection has been made to the IM from the VDC power supply.
- The red “Pickup” LED is lit when there is no Hall-effect pickup signal being detected by the IM due to a failed pickup, an incorrect air gap setting, and/or incorrect (bad) wiring. The pickup LED will also be lit when the engine is at rest.

## ENGINE STARTUP AND SHUTDOWN

- The red "Application" LED is lit whenever the IM detects a magnet pattern that does not match the application for which the IM Selector Switch is set (6 versus 8 cylinder) or when the incorrect IM model is installed (inline IM model versus vee engine IM model). Additionally, this LED will light when the Hall-effect pickup is lost (disconnected or failed), or if a magnet is lost or is very weak. The application LED will also light when the Selector Switch is in the "B" position (no application).

9. If green "Power" LED is not illuminated, shutdown the engine. Call a Waukesha certified technician for assistance.

10. If red "Pickup" LED is illuminated, shutdown engine. Call a Waukesha certified technician for assistance.

11. If red "Application" LED is illuminated, shutdown engine. Call a Waukesha certified technician for assistance.

### ENGINE SHUTDOWN PROCEDURES

#### ROUTINE SHUTDOWN

#### WARNING

**To avoid severe personal injury or death, allow the engine to cool for at least ten minutes after the engine is stopped. Do not restart an overheated engine or an engine that has been shutdown by the engine protection system until the reason for the shutdown has been determined and corrected.**

1. Gradually reduce engine load.
2. Place the governor speed control lever or dial in idle speed position, and allow the engine to idle for 5 minutes to cool down engine temperatures.

#### WARNING

**Always insure that the fuel gas valve(s) are closed after engine shutdown. Failure to close valve(s) could cause severe personal injury or death.**

3. Under normal operation, close the fuel valves to shut the engine down.
4. Press and hold the Prelube button for five minutes to post-lube the engine.

#### CAUTION

**If the engine is being shut down for an extended period of time, cap the exhaust pipe to prevent moisture or contaminants from entering the engine. Failure to follow these instructions could cause severe engine damage and/or personal injury.**

#### EMERGENCY SHUTDOWN

#### WARNING

**To avoid severe personal injury or death, allow the engine to cool for at least ten minutes after the engine is stopped. Do not restart an overheated engine or an engine that has been shutdown by the engine protection system until the reason for the shutdown has been determined and corrected.**

#### WARNING

**Always insure that the fuel gas valve(s) are closed after engine shutdown. Failure to close fuel gas valve(s) could cause severe personal injury or death.**

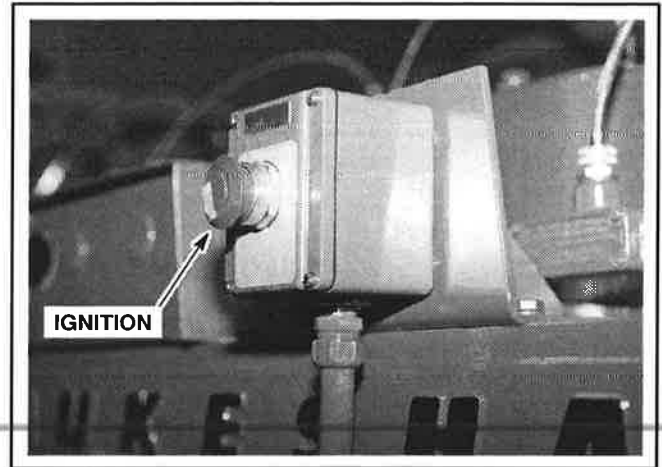
In the event of an emergency, the engine may be shutdown by using the IGNITION switch or buttons. The manual shutdown lever or governor speed lever/dial may be used to return the engine to idle speed. In all cases after engine shutdown, the fuel shutdown valve(s) must be closed.

*NOTE: Some governors may not have a speed control lever. The UG-8 dial governor is equipped with a dial speed control.*

**Engine Shutdown Using Ignition  
(Emergency Stop Button/Switch)  
6 & 12 Cylinder Engines**

**NOTE:** CSA equipped engines have a similar IGNITION (Emergency Stop button/switch) located on a separate sealed box (see Figure 3.00-21).

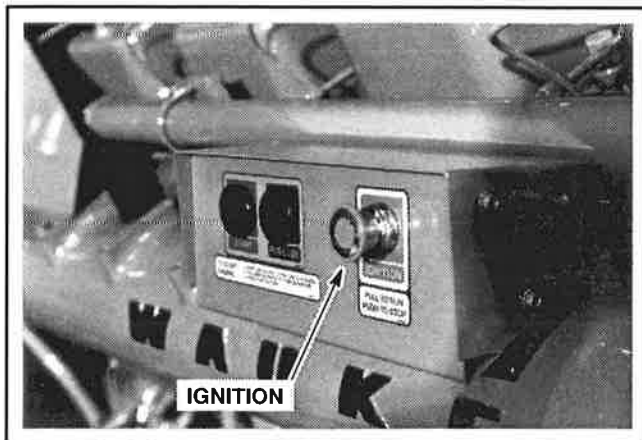
1. On 6 and 12 cylinder engines, shut down the engine by pushing in the IGNITION (Emergency Stop) button(s), located on the control panel(s) and simultaneously close the fuel shutdown valve(s). 12 cylinder engines have an ignition switch located on each side of the engine (see Figure 3.00-20 and Figure 3.00-21) while 6 cylinder engines have only one panel located on the right side of the engine (see Figure 3.00-22).



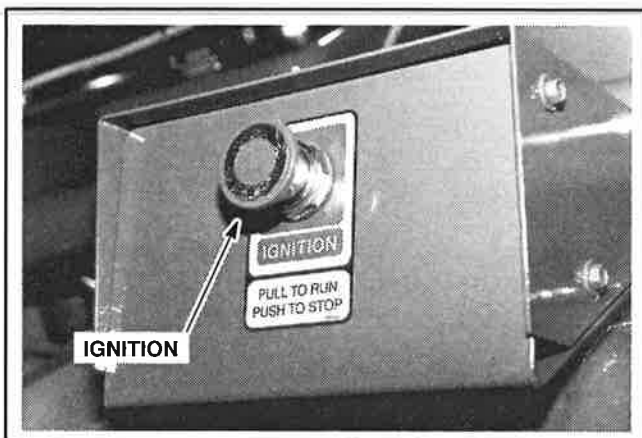
**Figure 3.00-22. CSA Control Panel -  
6 Cylinder Engine Right Side**

**⚠ WARNING**

Always insure that the fuel gas valve(s) are closed after engine shutdown. Failure to close fuel gas valve(s) could cause severe personal injury or death.



**Figure 3.00-20. Control Panel -  
12 Cylinder Engine Right Side**



**Figure 3.00-21. Control Panel -  
12 Cylinder Engine Left Side**

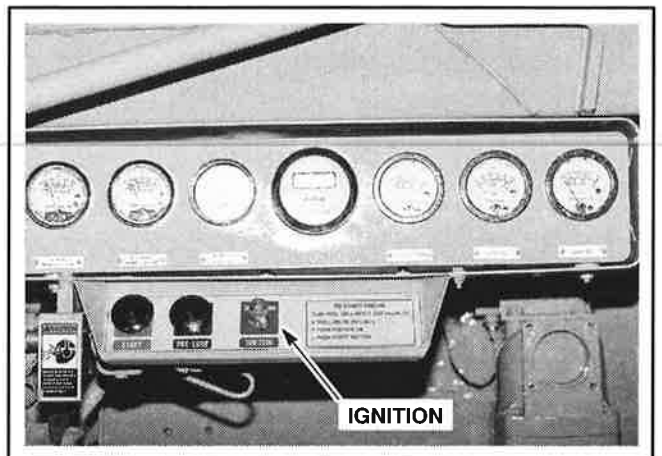
**Engine Shutdown Using Ignition Switch -  
16 Cylinder Engines**

To shut down the engine using the IGNITION switch, perform the following Steps.

1. On 16 cylinder engines, shut down the engine by turning the IGNITION switch, located on the control panel, to the OFF position, and simultaneously close the fuel shutdown valve(s) (see Figure 3.00-23).

**⚠ WARNING**

Always insure that the fuel gas valve(s) are closed after engine shutdown. Failure to close fuel gas valve(s) could cause severe personal injury or death.



**Figure 3.00-23. Control Panel -  
16 Cylinder Engine Right Side**

## ENGINE STARTUP AND SHUTDOWN

### Using Manual Shutdown Lever Or Governor Speed Control Lever To Return Engine To Idle Speed

**NOTE:** Some governors may not have a speed control lever. The UG-8 dial governor is equipped with a dial speed control.

1. The manual shutdown lever (located on the right side carburetor) (see Figure 3.00-24, Figure 3.00-25 and Figure 3.00-26) or the governor speed control lever/dial (mounted on the governor) (see Figure 3.00-27) may be used to return the engine to idle speed. Under some conditions, the engine may stop. In this case, close the fuel shutdown valve(s). If the engine does not stop, push in the IGNITION (Emergency Stop) button(s) on 6 and 12 cylinder engines, or turn the IGNITION switch to the OFF position, on 16 cylinder engines, and simultaneously close the fuel shutdown valve(s) to shutdown the engine.

### WARNING

Always insure that the fuel gas valve(s) are closed after engine shutdown. Failure to close fuel gas valve(s) could cause severe personal injury or death.



Figure 3.00-24. Manual Shutdown Lever - 6 Cylinder GSI Engine

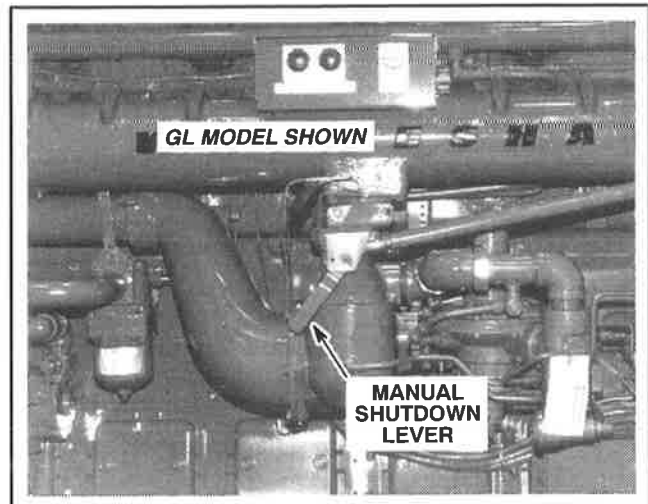


Figure 3.00-25. Manual Shutdown Lever - 12 Cylinder

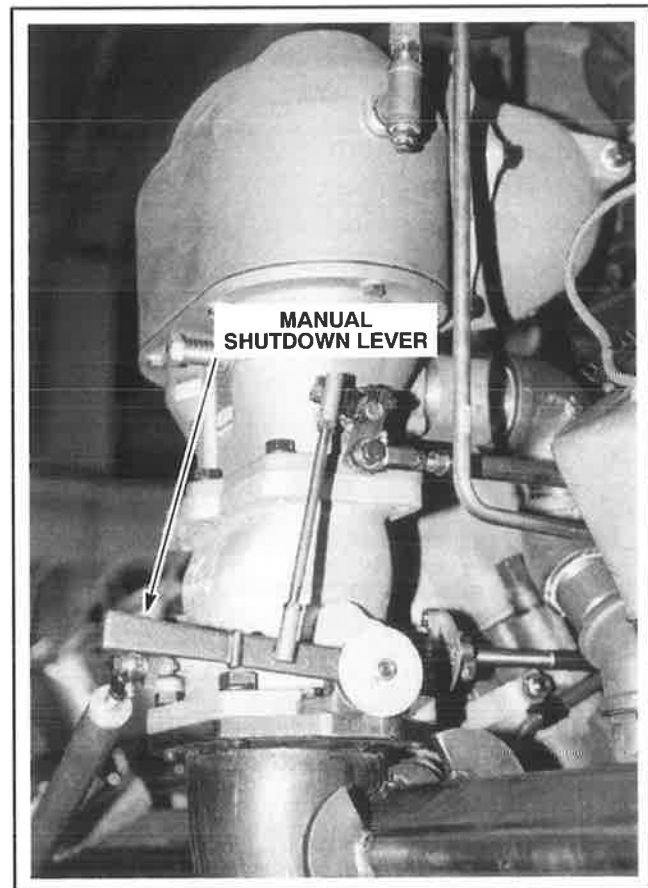


Figure 3.00-26. Manual Shutdown Lever - 16 Cylinder GSI Engine

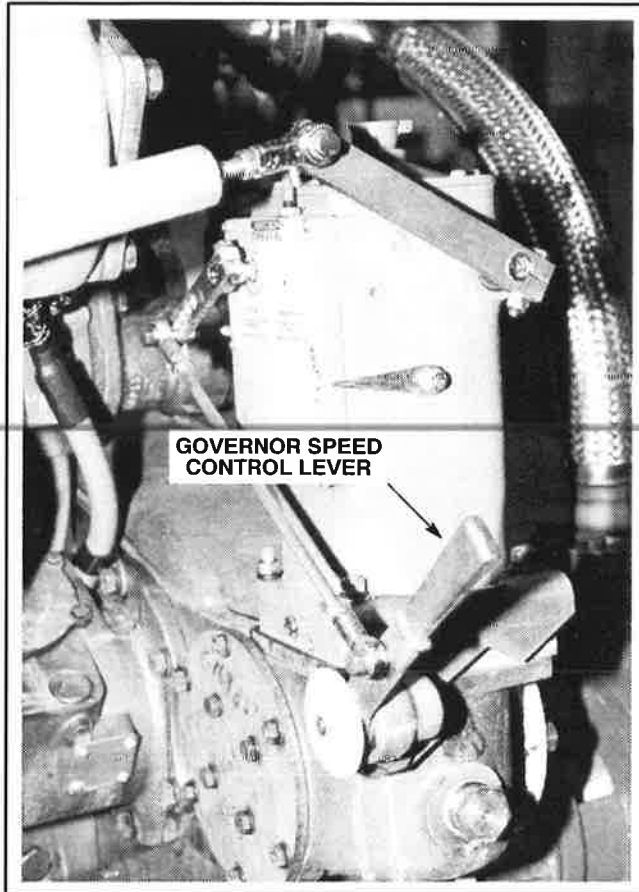


Figure 3.00-27. Governor Speed Control Lever -  
12 Cylinder Engine

or check starting circuitry and safety equipment with the starter disabled. Special attention must be taken to prevent internal corrosion, sticking and gumming of fuel controls, and deteriorated starting batteries. Arrangements should be made to run the engine and driven equipment under load at least every 90 days.

### ENGINE PERFORMANCE RECORD

Engine operating information, recorded during regular inspections, is necessary to apply proper Routine Maintenance schedules. Accurate records help control costs by avoiding unnecessary servicing, insuring needed servicing, and providing "trend" information on general engine condition. It is recommended to keep a record of the following information listed in Table 3.00-1.

### MAINTENANCE OF STANDBY UNITS

A generator set, or other standby unit, should be exercised once each week. A record should be maintained of performance and servicing, of both the engine and driven equipment.

**CAUTION** Turbocharged engines should not be idled for extended periods. Accumulated carbon may damage turbocharger. Shut down and restart when needed.

Always run the engine long enough to stabilize the oil and water temperatures at the normal operating level expected under load. Do not operate the engine under no-load conditions for other than very brief periods. Loads of at least one-third the normal rated capacity, are recommended. Ordinarily, an exercise run of one to two hours will be needed.

Some types of driven equipment cannot be operated without fairly extensive procedures "to put them on the line".

Weekly exercise may have to consist of periods long enough to check the engine's ability to crank and start,



**CONTENTS**

**SECTION 4.00 - SPEED GOVERNING SYSTEM MAINTENANCE**

**SECTION 4.05 - FUEL SYSTEM MAINTENANCE**

**SECTION 4.10 - IGNITION SYSTEM MAINTENANCE**

**SECTION 4.15 - AIR INTAKE SYSTEM MAINTENANCE**

**SECTION 4.20 - TURBOCHARGER SYSTEM MAINTENANCE**

**SECTION 4.25 - COOLING SYSTEM MAINTENANCE**

**SECTION 4.30 - LUBRICATION SYSTEM MAINTENANCE**

**SECTION 4.35 - EXHAUST SYSTEM MAINTENANCE**

**SECTION 4.40 - CRANKCASE BREATHER SYSTEM  
MAINTENANCE**

**SECTION 4.45 - PRELUBE AND STARTING SYSTEM  
MAINTENANCE**

**SECTION 4.50 - ENGINE PROTECTION SHUTDOWN SYSTEM  
MAINTENANCE**

**SECTION 4.55 - VALVE ADJUSTMENT**

**SECTION 4.60 - MAINTENANCE SCHEDULE**

**SECTION 4.65 - ENGINE STORAGE**

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## SECTION 4.00

### SPEED GOVERNING SYSTEM MAINTENANCE

#### SPEED GOVERNING SYSTEM MAINTENANCE

##### GOVERNOR MAINTENANCE

Check oil level in sight glass daily (see Figure 4.00-1).  
Change oil every 8000 hours. Use the same lubricating oil used in the engine crankcase.

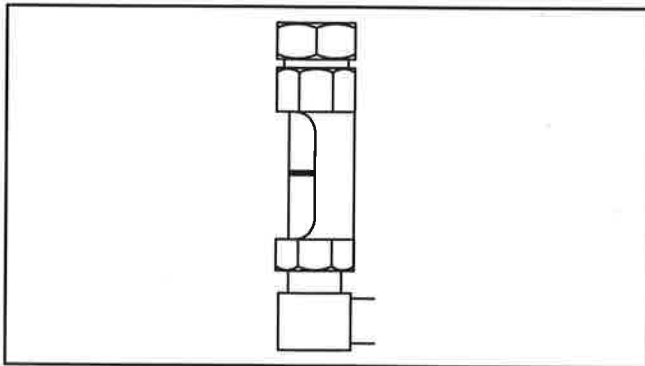


Figure 4.00-1. Governor Oil Level Sight Glass

##### Governor Oil Change And Fill (UG-8L Governor)

1. Place a small oil pan beneath the governor.
2. Remove oil drain plug from governor and allow oil to drain (see Figure 4.00-2).
3. Replace oil drain plug.
4. Lift up oil filler cap and slowly add oil until the oil appears at the line marked on the sight glass.

**NOTE:** Use the same oil as used in the engine crankcase.

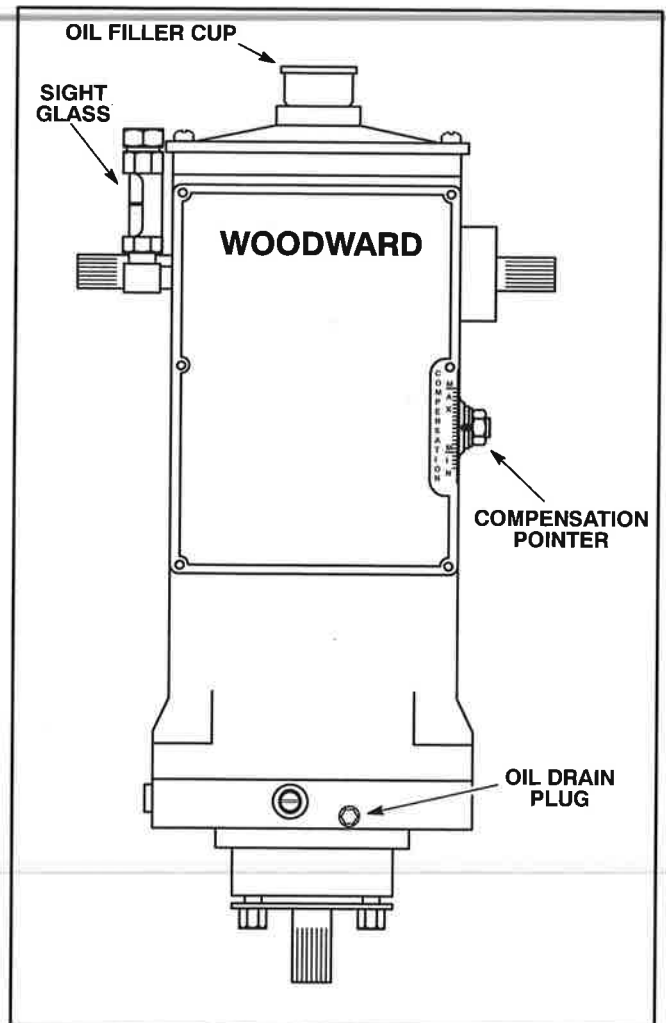


Figure 4.00-2. Woodward UG-8L Governor

# SPEED GOVERNING SYSTEM MAINTENANCE

## GOVERNOR ROD MAINTENANCE

### Governor Rod Inspection And Lubrication

1. Inspect that the jam nuts on both ends of the governor rod are secure (see Figure 4.00-3).
2. Inspect the governor rod for straightness and damage.
3. Lubricate the grease fittings on both ends of the governor rod at each oil change. Clean off any excess grease.

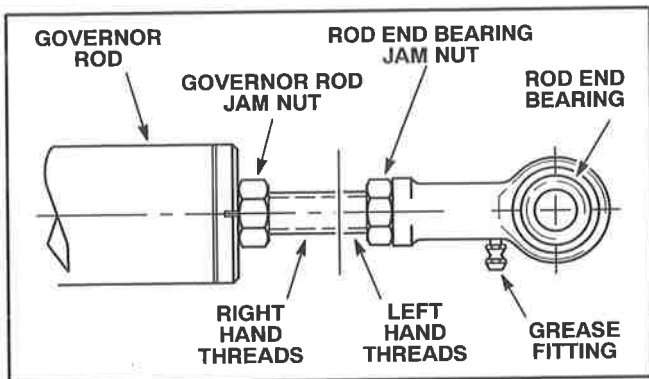


Figure 4.00-3. Governor Rod Assembly

## SECTION 4.05

### FUEL SYSTEM MAINTENANCE

#### FUEL SYSTEM MAINTENANCE

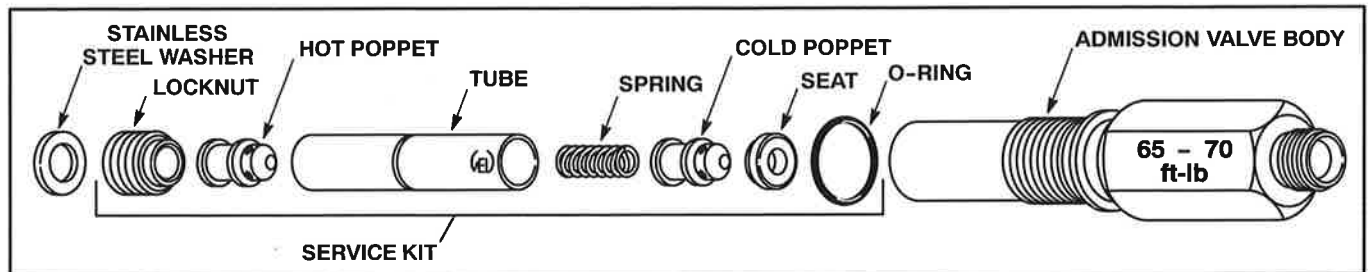


Figure 4.05-1. Admission Valve Assembly

#### ADMISSION VALVE MAINTENANCE

##### Admission Valve Removal - GL

### WARNING

Ensure that the fuel source is completely shut off prior to working on fuel system components. Clear the engine supply lines and piping of accumulated gas before performing any maintenance work on the fuel system or severe injury or death could result.

**NOTE:** This procedure applies only to the P/N 211587A admission valve. Refer to Service Bulletin 9-2574A or latest edition, for information on previous admission valves.

1. Disconnect the fuel supply tube from the admission valve body.
2. Remove the admission valve from the engine by turning counter-clockwise. Remove and discard the O-ring from the valve body (see Figure 4.05-1 and Figure 4.05-2).
3. Remove the stainless steel washer at the bottom of the admission valve bore using the seal remover (Tool P/N 494385) or an O-ring pick. Discard this washer.

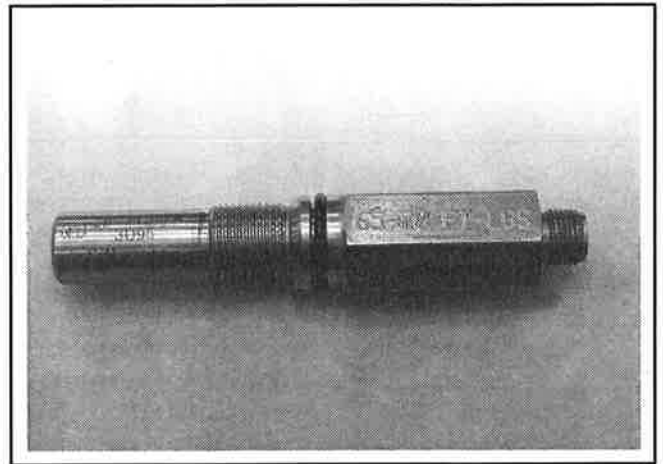



Figure 4.05-2. Admission Valve

##### Admission Valve Disassembly - GL

** CAUTION** Intermixing components with those of other valves is not permitted. Admission valves (and rebuild kits) are inspected as assemblies during manufacture. Disregarding this information could result in product damage and/or personal injury.

1. Remove the lock nut from the end of the admission valve body using a 1/4 inch Allen wrench.

## FUEL SYSTEM MAINTENANCE

**CAUTION** If a vise is needed to remove the lock nut, install a pair of brass jaw inserts to avoid damaging the assembly.

2. Remove the tube assembly. Remove the tube seat. Strike the admission valve body sharply against a piece of wood to free the tube and tube seat, if necessary.
3. Remove the contents of the tube. Remove the spring and cold poppet from one end. Remove the hot poppet from the other.
4. Remove and discard the O-ring from the admission valve body.

### Admission Valve Clean And Inspect - GL

1. Remove any loose carbon using a rag or soft nonmetallic bristle brush.
2. Boil all parts in a solution of one cup laundry detergent to one gallon of water for 30 - 45 minutes.
3. After boiling, rinse the parts in cold water and wipe dry.

### Admission Valve Assembly - GL

**CAUTION** The service kit parts may separate after the packaging is removed. There are internal differences between the hot and cold poppets, as well as the hot (flame trap) and cold (check valve) sides of the tube. The valve will not function properly if incorrectly assembled. Disregarding this information could result in product damage and/or personal injury.

**CAUTION** Do not mix parts from various admission valves, components are in matched sets. Disregarding this information could result in product damage and/or personal injury.

**NOTE:** Before assembling, all parts must be dry and oil free.

1. Look into both poppets. Note that the bore of the hot poppet is approximately 1/8 inch deeper than the cold poppet.

**NOTE:** The parts in the service kit are assembled in the proper order for installation in the valve body (see Figure 4.05-3). The service kit parts may separate after the packaging is removed. If the parts become separated, an easy way to identify the hot and cold poppets is to visually inspect the inside of the poppets (see Figure 4.05-3). Another way to identify the poppets is to install the spring. The spring will extend farther out of the cold poppet (see Figure 4.05-3). The cold poppet and spring are installed in the end of the tube that is marked with the WED label. Proper assembly is required.

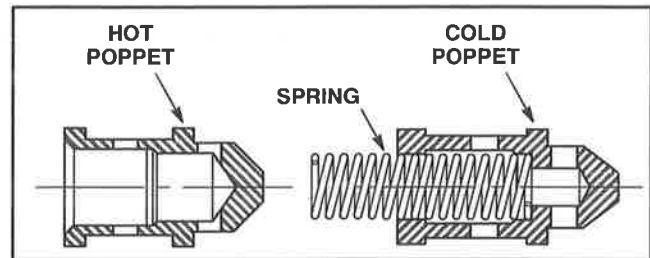


Figure 4.05-3. Spring Seats In Cold Poppets

2. Install the spring in the open end of the cold poppet. (see Figure 4.05-3).

3. Look into each end of the tube. Note that one end has a larger diameter counterbore (to fit the tip of the hot poppet), while the other end of the tube has a small opening encircled with a lip (spring seat).

4. Insert the cold poppet (spring end first) into the tube until the end of the spring contacts the spring seat. Verify that the tip of the poppet sticks out slightly.

**NOTE:** If the entire poppet fits within the tube, then the wrong (hot) end of the tube has been selected. Fit the cold poppet into the other end of the tube.

5. Install the hot poppet into the opposite end of the tube. The flat side of the poppet must face toward the open end of the tube, so that the tip of the poppet seats inside the counterbore.

6. Hold the tube assembly upright in one hand with the tip of the cold poppet pointing upward. Use a finger to keep the hot poppet in the other end of the tube.

7. Place the tube seat over the tip of the cold poppet, so that the lip on the seat fits within the tube ID.

8. With the long hex on top, slide the admission valve body over the cold poppet end of the tube until the entire assembly fits easily within the valve body.

9. Finger tighten the lock nut into the end of the admission valve body.

**CAUTION** Do not over-torque the lock nut or the tube may be permanently damaged. Disregarding this information could result in product damage.

**CAUTION** Do not over tighten the admission valve or the valve may become damaged.

10. Use an inch pound torque wrench and Allen socket to tighten the lock nut to 70 - 90 in-lb (8 - 10 N·m).
11. Install a new O-ring on the admission valve body. To prevent tears when the assembly is inserted into the cylinder head admission valve bore, lubricate the O-ring with Parker Super O-Lube®.

4. Tighten the valve to a torque of 65 - 70 ft-lb (88 - 95 N·m) dry.
5. Reattach both ends of the prechamber fuel inlet tube on the prechamber manifold and the admission valve assembly. Finger tighten the ferrule nuts. Use a wrench to tighten the ferrule nuts. Inspect for fuel leaks.

**Admission Valve Installation - GL**

1. Clean the washer seat at the bottom of the cylinder head admission valve bore.

**NOTE:** Previous production admission valves use a copper washer.

2. Install a new stainless steel washer at the bottom of the cylinder head admission valve bore (see Figure 4.05-4).

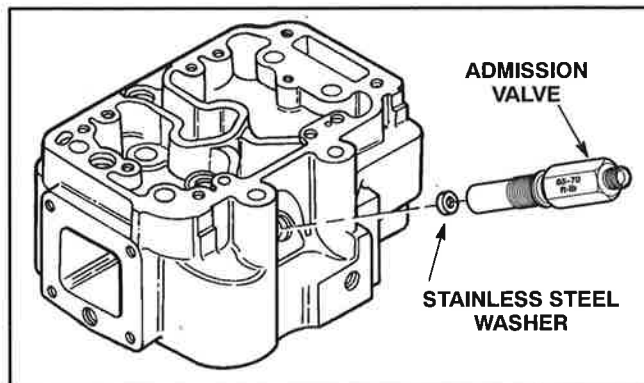


Figure 4.05-4. Install Stainless Steel Washer In Cylinder Head

**CAUTION** When installing the admission valve, make sure only a stainless steel washer is used and is seated flat against the seating surface in the cylinder head. If the stainless steel washer is damaged, fuel leaks will occur.

**CAUTION** Do not use copper washer P/N 16409 with P/N 211587A admission valve or with a P/N 211587 valve that has been upgraded by machining the lock nut. If the copper washer is used, the new assembly torque will drive the admission valve through the washer, causing damage.

3. Install the admission valve in the cylinder head bore.

# FUEL SYSTEM MAINTENANCE

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## SECTION 4.10

### IGNITION SYSTEM MAINTENANCE

#### IGNITION MAINTENANCE

##### SPARK PLUG MAINTENANCE - NON-CSA

##### Spark Plug Removal - NON-CSA

1. Detach the spark plug cable from the cable clip mounted on the rocker arm cover. Remove the rubber boot from the coil terminal connection (see Figure 4.10-1 and Figure 4.10-2). Remove the spark plug cable from the ignition coil.
2. Pull back the rubber recess cover from the spark plug well on G and GSI engines or the spark plug carrier bore on GL models.

**CAUTION**

Do not pull on the spark plug cables to remove the spark plug connectors. Pulling on the cable may loosen or detach the terminal connection within the Teflon tube. Disregarding this information could result in product damage and/or personal injury.

3. Holding onto the Teflon tube, remove the spark plug connector from the spark plug terminal nut.
4. Refer to Table 4.10-2 and select the proper spark plug tools. Remove the spark plug from the cylinder head or spark plug carrier bore.

**Table 4.10-1. Spark Plug Troubleshooting**

FIRING TIP APPEARANCE	CONDITION	REMEDY
Light casting of whitish ash, uniformly deposited	Normal with medium to high ash lube oils	No change; reflects a healthy operating cylinder
Excessive ash buildup	High oil consumption	Change engine lube oil type
	Wrong lube oil; ash content too high	Change engine lube oil type
Excessive ash buildup	Poor oil control around valve guides and piston rings	Inspect and replace worn parts as necessary
Black oil fouling deposits	Poor oil control around valve guides and piston rings	Replace worn parts as necessary
	Engine too lightly loaded	Adjust engine load
Gap bridging	Contaminated or "dirty" fuel gas	Add fuel filter
		Use more "open" electrode type plug
Carbon fouling	Spark plug firing tip temperature too low	Change plug heat range
	Engine too lightly loaded	Adjust engine load
	High oil consumption	Inspect and replace worn parts as necessary
Electrode burning	Spark plug firing tip temperature too high	Change plug heat range
Wear on side electrodes	Reverse polarity	Reverse ignition coil wiring
Aluminum contamination	Engine operated with severe detonation resulting in piston damage	Inspect piston crowns with borescope; replace worn parts as necessary
		Check ignition timing, fuel gas octane
		Reduce engine load
Bright blue or green deposits	Oxide of cobalt fouling from burning of Stellite® on valves and seats	Replace valves and seats

**NOTE:** 1. If any of the above conditions exist, be sure to correct the cause before installing new spark plugs.  
 2. "Stellite®" is a registered trademark of Stoddy Deloro Stellite, Inc."

# IGNITION SYSTEM MAINTENANCE

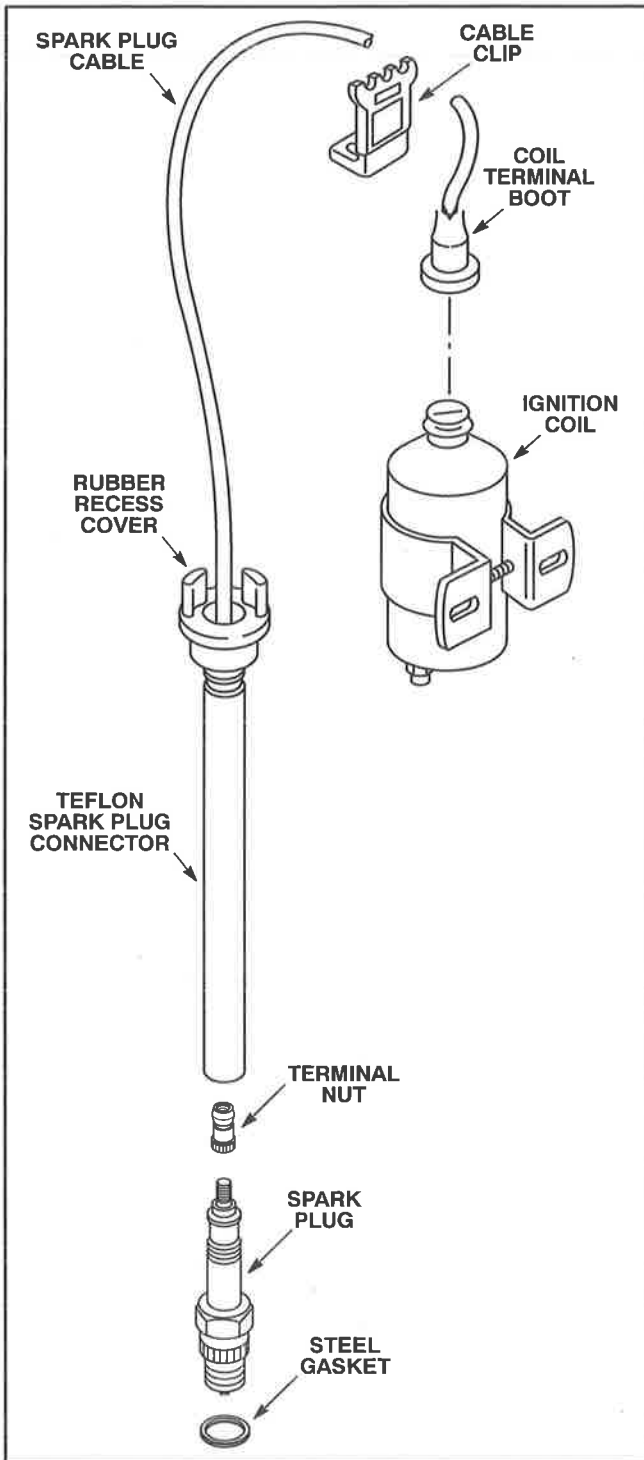


Figure 4.10-1. Install Spark Plug/Connections

## Spark Plug Inspection

Inspect the condition of the spark plugs, paying particular attention to the firing tip. Spark plugs often yield visual clues to abnormal conditions existing in the engine's power cylinders. Your observations also can be used as a guide in establishing the proper service interval. See Table 4.10-1.

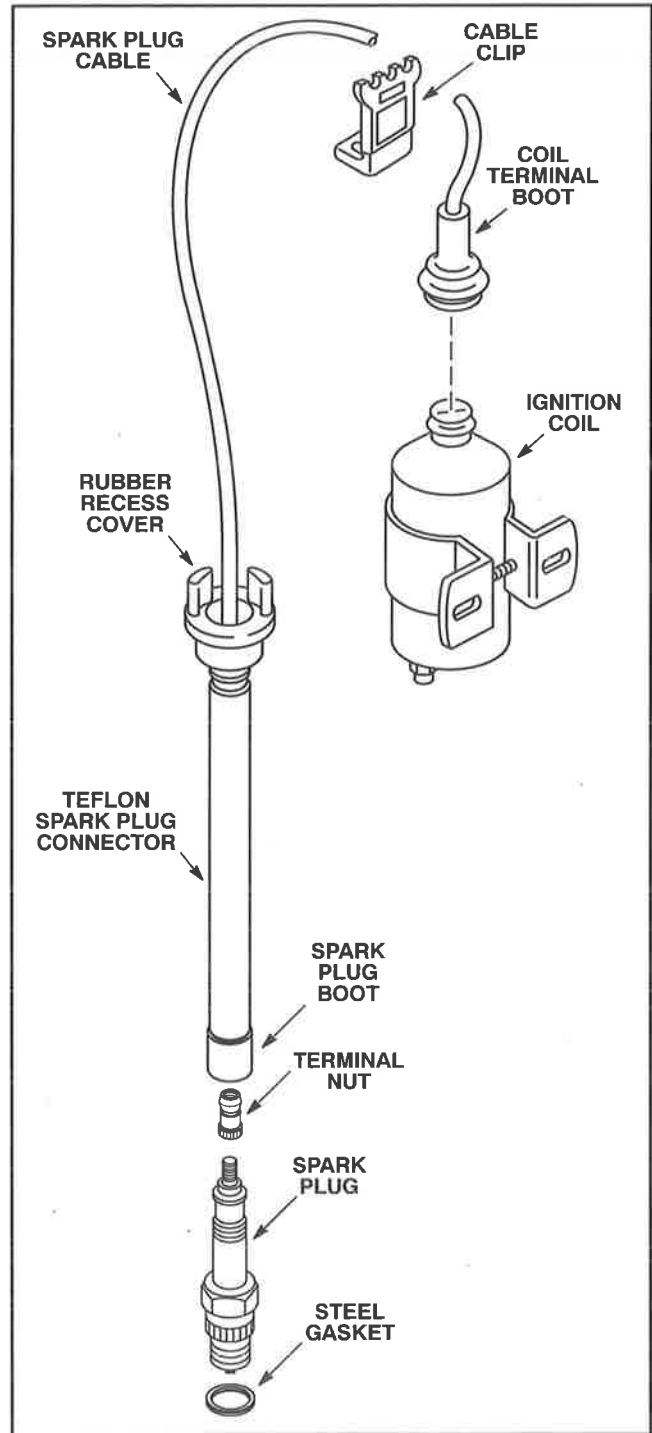


Figure 4.10-2. Install Spark Plug/Connections P/N 211357H Extension

Table 4.10-2. Spark Plug Tools

TOOL P/N	TOOL DESCRIPTION
167164D	Spark Plug Socket/Ext. (1 inch socket with 10 inch extension, for Shielded, CSA w/ F.M. coils)
475037	Spark Plug Socket (NEW) (7/8 inch Socket 15-1/2 inch long w/rubber O-ring insert)



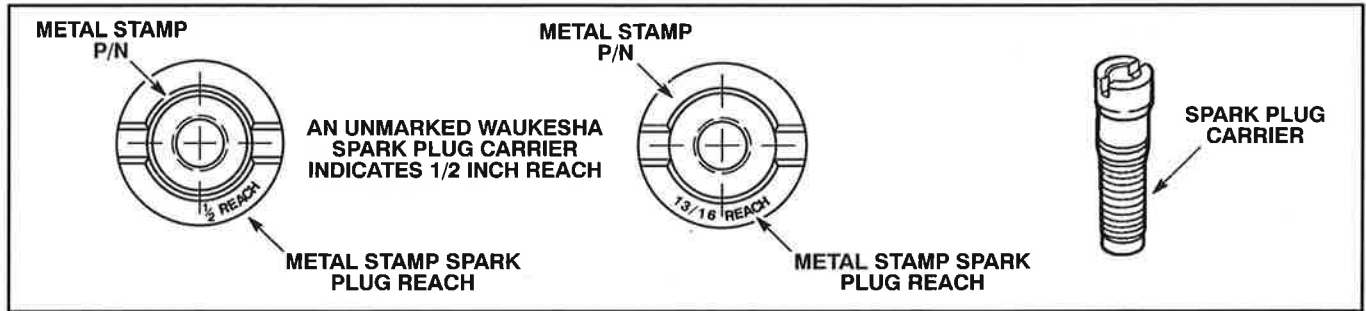


Figure 4.10-3. Spark Plug Carriers

**Spark Plug Installation - Non CSA**

**CAUTION** 13/16 inch reach spark plugs must be used with 13/16 inch reach carriers, and 1/2 inch reach spark plugs must be used with 1/2 inch reach carriers. Mixing carrier and spark plug components will cause damage to equipment and/or personal injury.

1. Obtain a set of new spark plugs (see Table 1.15-4 and Table 1.15-5). On GL models verify which size carrier is present and use the correct size spark plug, see **CAUTION** above and Figure 4.10-3. On G and GSI models select the 1/2 inch reach spark plug desired.

**CAUTION** The spark plug gasket must be properly seated to seal the combustion chamber and transfer heat from the plug. Disregarding this information could result in product damage and/or personal injury.

2. Install the steel gasket on the spark plug (see Figure 4.10-1). Use only new steel gaskets. Verify that the gasket is flat against the gasket seat.

3. Install the terminal nut.

4. Refer to Table 1.15-4 and Table 1.15-5 and set the spark plug gap.

**CAUTION** The presence of oil or grease on the ceramic insulator of the spark plug can cause flashover. Flashover, a condition where the spark falls to jump the gap because of an easier path to ground, results in misfire. Disregarding this information could result in product damage and/or personal injury.

**CAUTION** When using Actrel® 3338L for cleaning, always wear rubber gloves to prevent the cleaner from touching the hands as burning may occur.

**WARNING**

Always read and comply with safety labels on all containers. Do not remove or deface the container labels. Improper handling or misuse could result in severe personal injury or death.

5. Verify that the spark plug is clean. If necessary, use a dielectric solvent to remove any grease or oily fingerprints. Waukesha Engine Service Operations recommends the use of Actrel® 3338L dielectric solvent manufactured by Exxon Corp. and distributed by Safety-Kleen Corp., (800-669-5750), to clean the connectors.

6. Apply a light coat of KRYTOX® GPL-206 (P/N 489341) grease (or equivalent) on OD of the spark plug ceramic insulator on the portion of the ceramic insulator that will contact the spark plug extension assembly (see Figure 4.10-4).

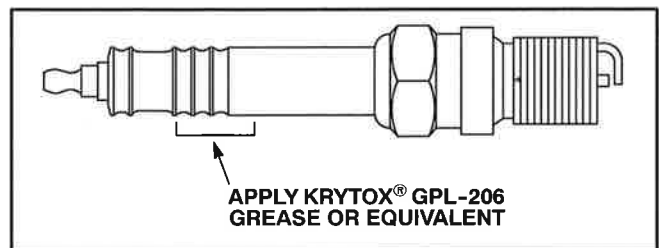


Figure 4.10-4. Apply KRYTOX® GPL-206 Grease

**CAUTION** Do not use oil or anti-seize compound on the spark plug threads. The spark plug may be overtorqued if oiled. distorts the spark plug and may crack the ceramic construction. Anti-seize compound may foul the firing tip, resulting in a plug shorted to ground. Disregarding this information could result in product damage and/or personal injury.

## IGNITION SYSTEM MAINTENANCE

**CAUTION** By missing the threaded hole in the spark plug carrier bore, the spark plug gap may be inadvertently closed or altered. Exercise caution to avoid bumping the electrodes into the spark plug carrier counterbore. Disregarding this information could result in product damage and/or personal injury

7. Torque the spark plug to 40 – 45 ft-lb (54 – 61 N·m) dry.

**NOTE:** The rubber recess cover keeps dirt and debris out of the spark plug well and functions as a rain shield for those engines that are outside. Any accumulation of rain water in the spark plug well can short out the spark plug, resulting in a misfire or a stalled engine. Before installing VHP spark plug recess covers, (see Figure 4.10-5), check to be sure that the rubber vent caps are opened. If the rubber vent caps are not opened, the spark plug recess covers and spark plug extensions, may pop off the spark plugs, due to pressure build up.

8. The rubber vent cap is pre-cut at the factory, but needs to be pulled back initially, to insure proper operation. About half of the rubber vent cap circumference is cut, the remaining half acts as a rubber hinge.

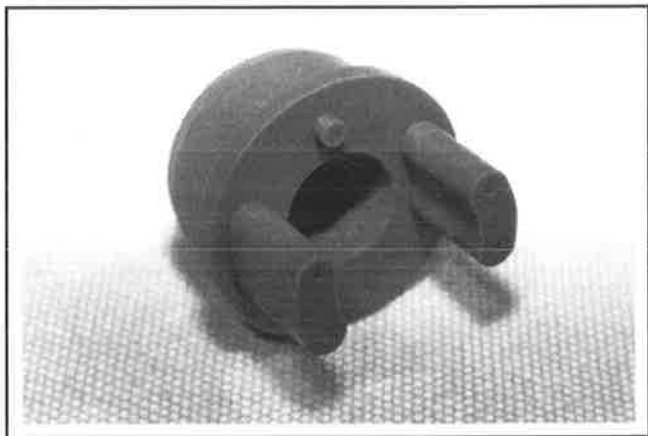


Figure 4.10-5. VHP Spark Plug Recess Cover

9. Using your thumb, gently pull the rubber vent cap towards the center hole of the spark plug recess cover until the vent hole is exposed (see Figure 4.10-6). Release the vent cap. The cap should close.

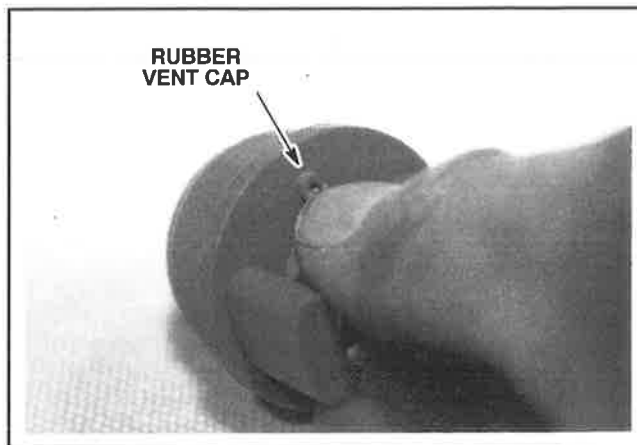


Figure 4.10-6. VHP Spark Plug Recess Cover Vent Cap

10. During normal operation, pressures generated in the spark plug recess will vent through the vent hole in the spark plug recess cover. During venting of pressure, the upper half of the rubber vent cap will pop up, and then return to the closed position

**NOTE:** If the rubber vent cap is torn off, the spark plug recess cover should be replaced, when it is to be used in outdoor environments.

11. Install the spark plug recess cover on the spark plug connector assembly.

**NOTE:** The rubber spark plug boots must be installed on the P/N 211357H spark plug extensions. These boots prevent flashover from the spark plug insulators.

**NOTE:** KRYTOX® GPL-206 (P/N 489341) is a higher temperature fluorinated grease.

12. On P/N 211357H connector assemblies, lightly coat the inside surface of the spark plug boot on the connector with a high performance fluorinated grease such as KRYTOX® GPL-206 (P/N 489341) or equivalent. Install the spark plug connector assembly to spark plug (see Figure 4.10-2).

13. Attach the spark plug cable to the ignition coil. Make sure that the cable terminal connection bottoms out in the coil contact well. Fit the rubber boot over the coil terminal connection. On P/N 211357H extensions, insure the rubber boot is fitted over the upper end of the spark plug extension. Secure the cable by snapping it into the cable clip mounted on the rocker arm cover.

## SPARK PLUG MAINTENANCE - CSA

### Spark Plug Removal - CSA (G, GSI)

1. Disconnect the spark plug cable from the coil (see Figure 4.10-7).

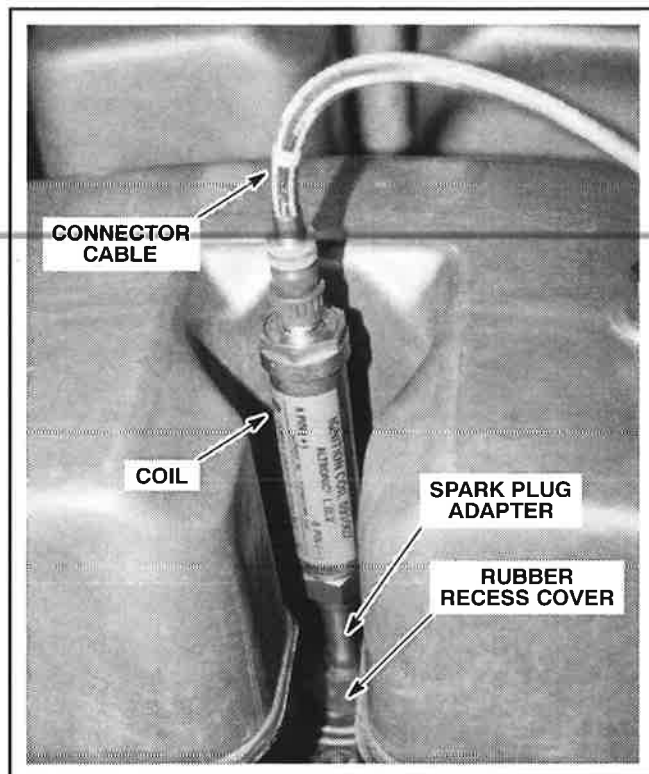


Figure 4.10-7. CSA Spark Adapter And Coil - G, GSI

2. Remove the rubber recess cover from the bottom of the spark plug recess. The recess cover is cut on one side to allow the recess cover to be removed from the spark plug adapter.
3. Remove the coil, spark plug adapter, and spark plug from the cylinder head (see Figure 4.10-8).

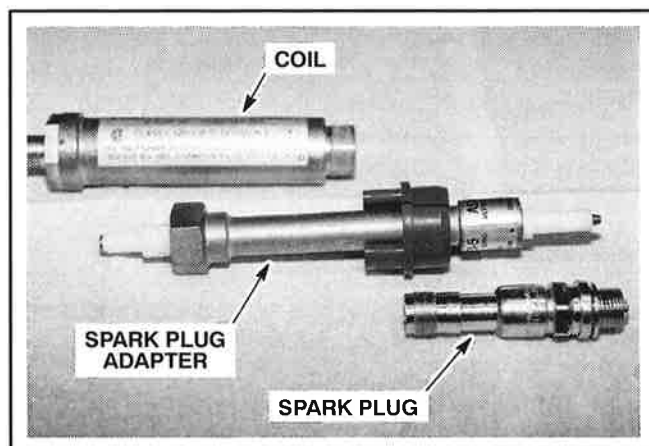


Figure 4.10-8. CSA Spark Adapter And Coil - G, GSI

### Spark Plug Installation - CSA (G, GSI)

**CAUTION** The spark plug gasket must be properly seated to seal the combustion chamber and transfer heat from the plug. Disregarding this information could result in product damage and/or personal injury.

1. Install the steel gasket on the spark plug (see Figure 4.10-1). Use only new steel gaskets. Verify that the gasket is flat against the gasket seat (see Figure 4.10-9).

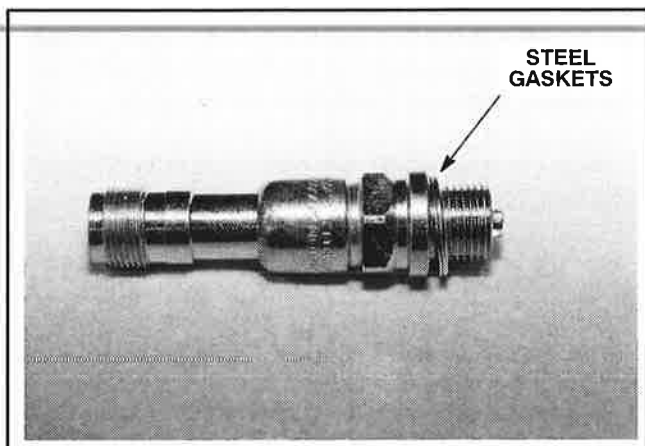


Figure 4.10-9. CSA Spark Plug - G, GSI

2. Refer to Table 1.15-4, *1/2 Inch Reach Spark Plugs* in Section 1.15, *General Information*, and set the spark plug gap.

**CAUTION** The presence of oil or grease on the ceramic insulator of the spark plug can cause flashover. Flashover, a condition where the spark fails to jump the gap because of an easier path to ground, results in misfire. Disregarding this information could result in product damage and/or personal injury

**CAUTION** When using Actrel® 3338L for cleaning, always wear rubber gloves to prevent the cleaner from touching the hands as burning may occur.

**WARNING**

Always read and comply with safety labels on all containers. Do not remove or deface the container labels. Improper handling or misuse could result in severe personal injury or death.

## IGNITION SYSTEM MAINTENANCE

3. Verify that the spark plug is clean. If necessary, use a dielectric solvent to remove any grease or oily fingerprints. Waukesha Engine Service Operations recommends the use of Actrel<sup>®</sup> 3338L dielectric solvent manufactured by Exxon Corp. and distributed by Safety-Kleen Corp., (800-669-5750), to clean the connectors.

**CAUTION** Do not use oil or anti-seize compound on the spark plug threads. The spark plug may be overtorqued if oiled, distorts the spark plug and may crack the ceramic construction. Anti-seize compound may foul the firing tip, resulting in a plug shorted to ground. Disregarding this information could result in product damage and/or personal injury

4. Install the spark plug in the spark plug bore. Torque the spark plug to 40 - 45 ft-lb (54 - 61 N·m) dry.

**CAUTION** By missing the threaded hole in the spark plug carrier bore, the spark plug gap may be inadvertently closed or altered. Exercise caution to avoid bumping the electrodes into the spark plug carrier counterbore. Disregarding this information could result in product damage and/or personal injury

5. Install the spark plug adapter, and coil on the spark plug and hand tighten components (see Figure 4.10-7).

6. Refer to *Spark Plug Installation - Non CSA* in this section (see Figure 4.10-5), and install the rubber recess cover around the spark plug adaptor and press it firmly into place in the cylinder head spark plug recess.

7. Connect the spark plug cable to the coil (see Figure 4.10-7).

### Spark Plug Removal - CSA (GL) (13/16 Inch Current Production)

**NOTE:** Previous production CSA GL models used a "long" coil P/N 69694D, mounted directly to a shielded 1/2 in. spark plug. This configuration is used with the previous 1/2 in. shorter spark plug carriers. See Table 1.15-4, 1/2 Inch Reach Spark Plugs in Section 1.15, General Information, for previous components. See Spark Plug Removal/Installation - CSA (G, GSI) in this section for similar procedures. Conversion Kits are available update to the new configuration shown in Figure 4.10-10.

**CAUTION** Do not pull on the spark plug cables to remove the spark plug connectors. Pulling on the cable may loosen or detach the terminal connection within the Teflon tube.

1. Disconnect the spark plug connector from the coil.
2. Remove three capscrews, lock washers and coil from the coil adapter.
3. Remove four capscrews, washers and coil adapter from the spark plug carrier.
4. Remove spark plug extension and the spark plug from the spark plug carrier (see Figure 4.10-10).

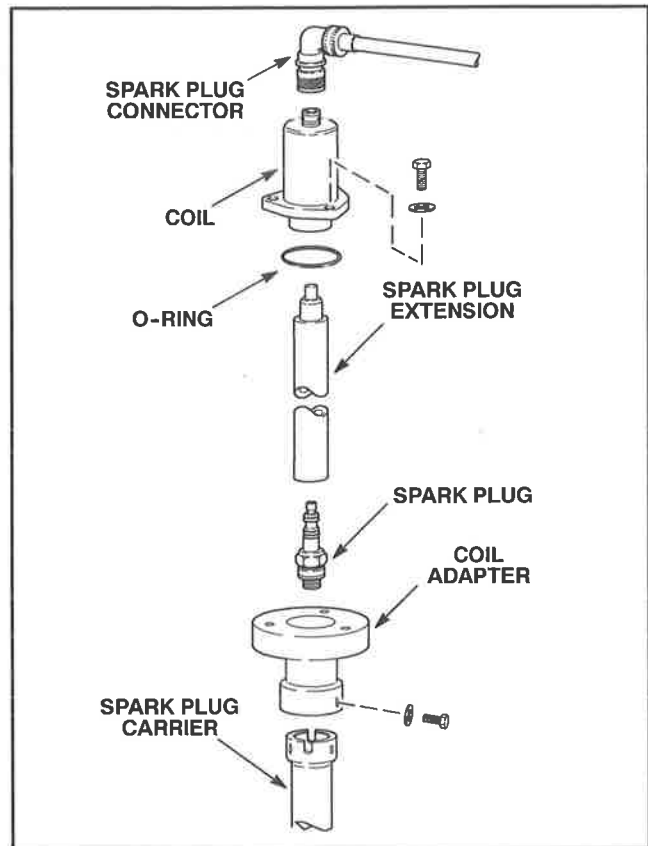


Figure 4.10-10. CSA GL Spark Plug Extension And Coil Assembly - Current Production

### Spark Plug Installation - CSA (GL) (13/16 Inch Current Production)

**CAUTION** 13/16 inch reach spark plugs must be used with 13/16 inch reach carriers, and 1/2 inch reach spark plugs must be used with 1/2 inch reach carriers. Mixing carrier and spark plug components will cause damage to equipment and/or personal injury.

1. Obtain a set of new spark plugs (see Table 1.15-5, 1/2 Inch Reach Spark Plugs in Section 1.15, General Information). Always use the correct size spark plug, see **CAUTION** above and Figure 4.10-3.

**CAUTION** The spark plug gasket must be properly seated to seal the combustion chamber and transfer heat from the plug. Disregarding this information could result in product damage and/or personal injury.

2. Install the steel gasket on the spark plug. Use only new steel gaskets. Verify that the gasket is flat against the gasket seat.
3. Install the terminal nut.
4. Refer to Table 1.15-5, *1/2 Inch Reach Spark Plugs* in Section 1.15, *General Information*, and set the spark plug gap.

**CAUTION** The presence of oil or grease on the ceramic insulator of the spark plug can cause flashover. Flashover, a condition where the spark fails to jump the gap because of an easier path to ground, results in misfire. Disregarding this information could result in product damage and/or personal injury

**CAUTION** When using Actrel® 3338L for cleaning, always wear rubber gloves to prevent the cleaner from touching the hands as burning may occur.

**WARNING**

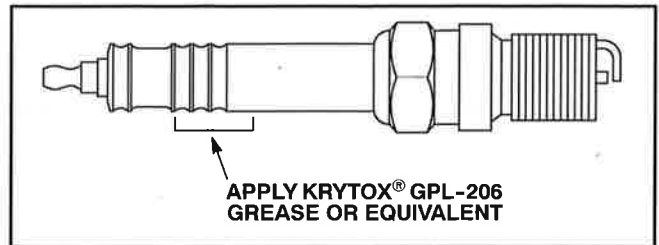
Always read and comply with safety labels on all containers. Do not remove or deface the container labels. Improper handling or misuse could result in severe personal injury or death.

5. Verify that the spark plug is clean. If necessary, use a dielectric solvent to remove any grease or oily fingerprints. Waukesha Engine Service Operations recommends the use of Actrel® 3338L dielectric solvent manufactured by Exxon Corp. and distributed by Safety-Kleen Corp., (800-669-5750), to clean the connectors.

**NOTE:** KRYTOX® GPL-206 (P/N 489341) is a higher temperature fluorinated grease.

6. Apply a light coat of KRYTOX® GPL-206 (P/N 489341) grease (or equivalent) on O.D. of the spark plug ceramic insulator on the portion of the

ceramic insulator that will contact the spark plug extension assembly (see Figure 4.10-11).

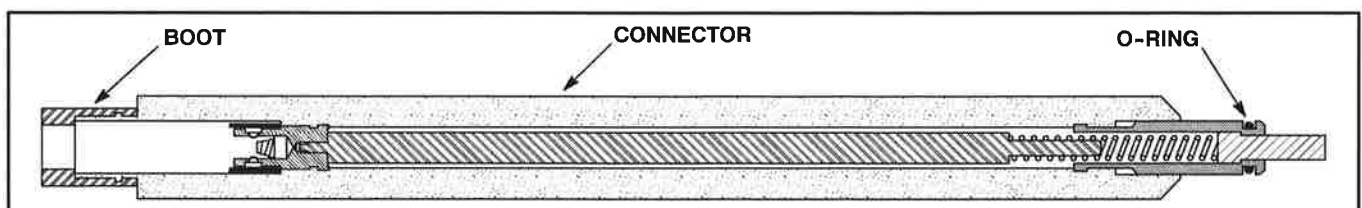


**Figure 4.10-11. Apply KRYTOX® GPL-206 Grease**

7. Install spark plug in the spark plug carrier with spark plug tool P/N 475037.

**CAUTION** By missing the threaded hole in the spark plug carrier bore, the spark plug gap may be inadvertently closed or altered. Exercise caution to avoid bumping the electrodes into the spark plug carrier counterbore.

8. Torque spark plug to 40 - 45 ft-lb (54 - 61 N·m) dry.
9. Lightly coat the inside surface of the spark plug boot on the connector with KRYTOX® GPL-206 (P/N 489341) (or equivalent) Install spark plug extension assembly to spark plug (see Figure 4.10-12).
10. Install the coil adapter on the spark plug carrier with four capscrews and washers. Torque capscrews to 6 - 7 ft-lb (8.1 - 9.5 N·m) oiled.
11. Apply a small amount of KRYTOX® GPL-206 (P/N 489341) (or equivalent) to the small silicone O-ring on the coil end of spark plug extension (see Figure 4.10-12).
12. Install the new O-ring P/N 292843, on the nose of the coil (see Figure 4.10-10).
13. Install the coil on the coil adapter with O-ring, three capscrews and lock washers. Torque capscrews to 11 - 13 ft-lb (14.9 - 17.6 N·m) oiled.
14. Connect the shielded primary cable to the coil (see Figure 4.10-10).



**Figure 4.10-12. Spark Plug Extension**

## IGNITION SYSTEM MAINTENANCE

### TIMING ADJUSTMENT - DYNAMIC (MAGNETO SYSTEM)

**CAUTION** Overly advanced ignition timing can result in detonation which may severely damage pistons and rings. Retarded timing will result in loss of power and poor fuel economy. Disregarding this information could result in product damage.

**CAUTION** Be sure all engine connections are completed properly before engine startup. Follow all startup procedures. Check that all engine openings are properly closed and that all tools are removed from the engine. Disregarding this information could result in product damage.

**CAUTION** Detonation is not allowed at any time, during engine operation, regardless of the specified timing. If detonation occurs at the specified timing, a timing adjustment must be made to retard the ignition timing until NO audible detonation exists. Engine damage may result if detonation occurs.

**NOTE:** This task applies to magnetos that have already been installed and static timed by a Waukesha Certified Technician. Call a Waukesha Certified Technician for the installation and static timing of magnetos.

1. Refer to the engine nameplate for the engine timing value (see Figure 1.15-2 and Figure 1.15-3).
2. Start the engine and run at rated speed (with or without load).
3. Connect a stroboscopic type timing light to the ignition cable of the #1R cylinder.
4. Turn up the timing pointer cover on the upper right side of the rear flywheel housing (see Figure 4.10-13).
5. Align the beam of the timing light with the timing pointer. The timing light will flash at the instant the spark occurs, making the tape on the rim of the flywheel visible (see Figure 4.10-15).

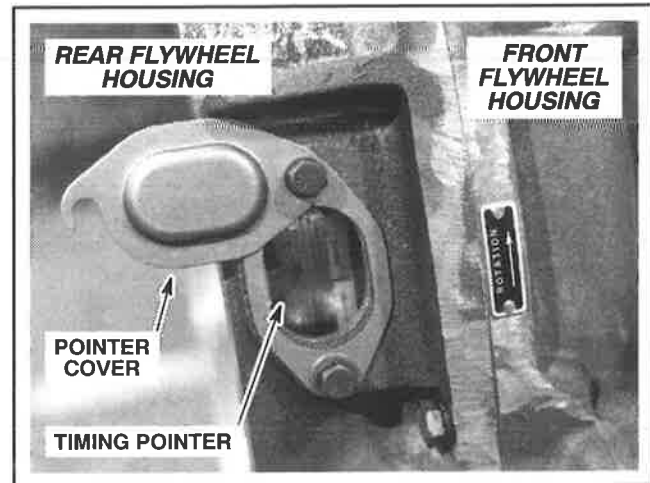


Figure 4.10-13. Timing Pointer - Rear Right

**NOTE:** The magneto flange has slots to allow the magneto to be rotated slightly once the capscrew hex nuts are loosened.

6. If required, readjust the timing by loosening the magneto's flange bolts just enough to allow the magneto to rotate (see Figure 4.10-14). Rotate the magneto slightly until the correct timing mark is aligned with the timing pointer.

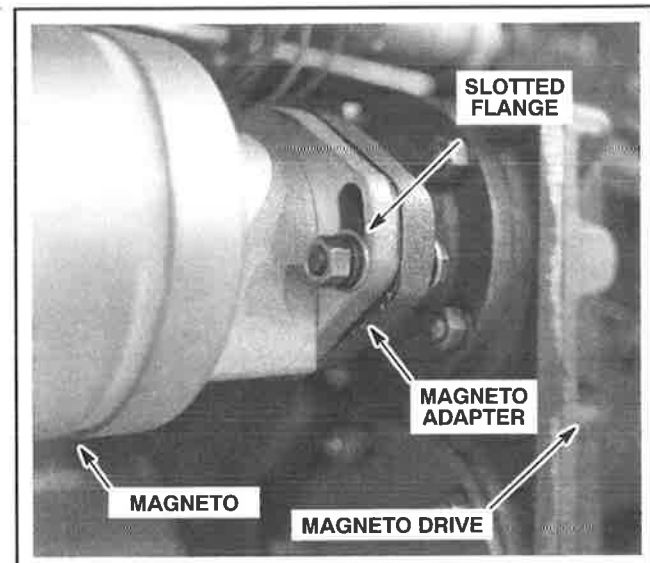


Figure 4.10-14. Magneto/Magneto Adapter Flange

7. Snug the flange capscrew hex nuts (see Figure 4.10-14).
8. Check the timing again with the timing light.
9. If the timing is not correct, repeat Steps 6 through 8.
10. Alternately wrench tighten the hex nuts on the two magneto/magneto adapter flange capscrews.

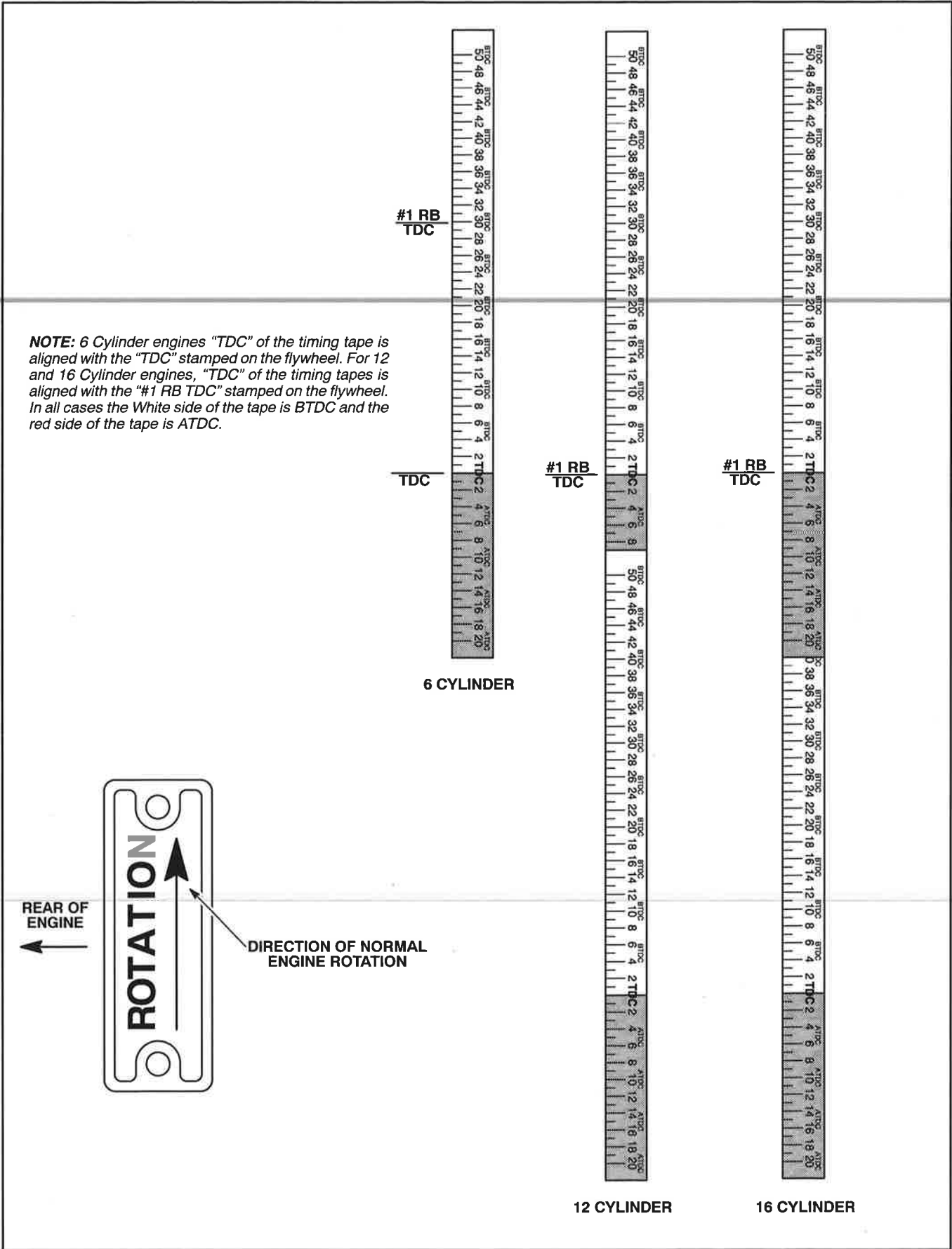


Figure 4.10-15. Timing Tapes



## IGNITION SYSTEM MAINTENANCE

### CEC IGNITION MODULE TIMING ADJUSTMENT - DYNAMIC

**NOTE:** This task applies to ignition modules that have already been installed and static timed by a Waukesha Certified Technician. For the initial installation and timing of a CEC ignition module, call a Waukesha Certified Technician. Refer to Form 6253 (Previous Model) or Form 6272 (Current Model) IM Custom Engine Control® Ignition Module Installation, Operation, And Maintenance Manual for further information concerning the IM.

The ignition module has two 16-position timing switches located under white plastic caps at one end of the box, one marked "A" and another marked "B" (see Figure 4.10-16). Grounding lead "D" in the 7-pin connector to the engine crankcase gives the timing selected by switch A. Open-circuiting lead "D" gives the timing selected by switch "B". This feature gives the engine operator the ability to switch between two different timing settings to accommodate automatic changeover between two fuels.

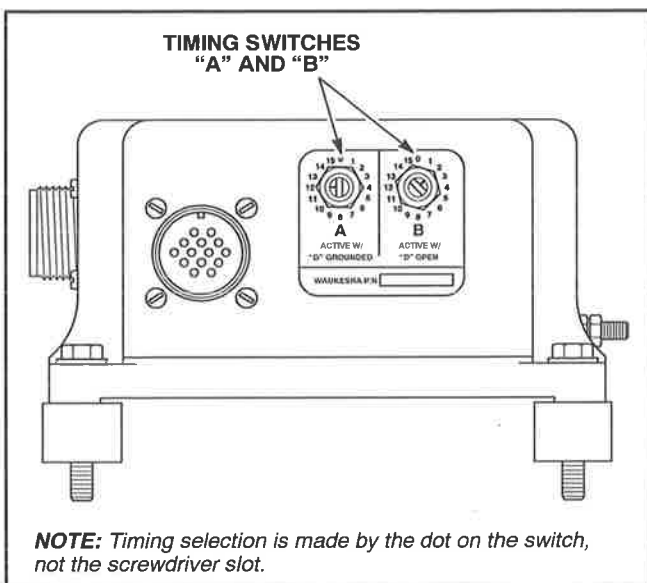


Figure 4.10-16. Timing Switches "A" And "B"

Each timing adjust switch has 16 switch positions (0 - 15) with a 1° timing variation per position. Switch position 15 gives the most advanced timing, while switch position 0 is full retard.

**CAUTION** Do not switch from position 15 to position 0, or from position 0 to 15 while the engine is running. The timing change is so large that it may damage the engine and/or cause it to shut down. Disregarding this information could result in product damage and/or personal injury.

**NOTE:** The outside temperature of ignition module casing should not exceed 150° F (65° C) in operation.

1. Check the engine's nameplate (see Figure 1.15-2 and Figure 1.15-3) to determine the exact timing (or most advanced) of the primary and secondary (if equipped) fuels.

2. Run the engine on primary fuel with the "D" lead (found in the 7-pin connector from box) **grounded** to the engine block and the detonation sensing module deactivated.

**NOTE:** VHP gas engines are to be run with no load on fuels other than natural gas fuel. With natural gas fuel, the engines may be run at any load.

3. Check engine timing at the flywheel using a timing light (see Figure 4.10-17).

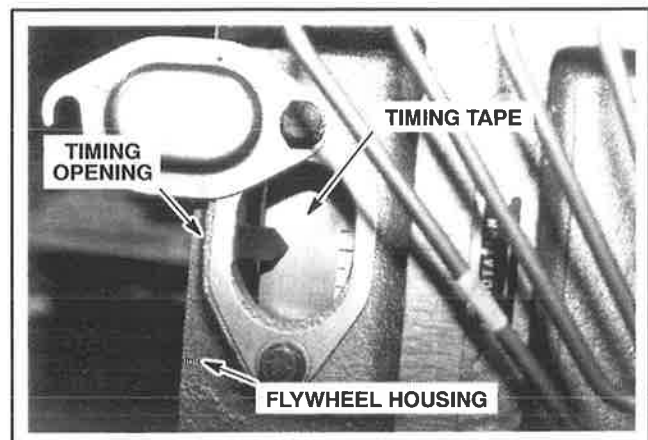


Figure 4.10-17. Flywheel Timing Opening

4. Adjust the "A" switch as required to achieve correct timing. Single fuel ignition adjustments are now complete.

**NOTE:** Increasing the timing switch position by one will advance the timing one degree. Decreasing the timing switch position by one will retard the timing one degree.

5. Run the engine on secondary fuel with the "D" lead (found in the 7-pin connector from box) **open** and the detonation sensing module deactivated.

**NOTE:** VHP gas engines are to be run with no load on fuels other than natural gas fuel. With natural gas fuel, the engines may be run at any load.

6. Check engine timing at the flywheel using a timing light (see Figure 4.10-17).



7. Adjust the "B" switch as required to achieve correct timing. Dual fuel ignition adjustments are now complete.

**NOTE:** Increasing the timing switch position by one will advance the timing one degree. Decreasing the timing switch position by one will retard the timing one degree.

**CAUTION** To prevent the timing from being altered, always replace the white caps over the timing switches once the desired setting has been selected. Disregarding this information could result in product damage.

### **WARNING**

If a gas engine has been cranked excessively without starting, shut off the gas fuel supply and ignition, and then crank the engine to purge the cylinders and exhaust system of accumulated unburned gas. If this is not done a spark could ignite the gas and cause an exhaust explosion. Failure to comply could cause severe personal injury or death.

### **WARNING**

If the ignition switch is left in the ON position when a CEC ignition module is disconnected, then the spark plugs may fire when the ignition system harness is reconnected, and could cause severe personal injury or death.

Before connecting the ignition harness (to the coils) to the CEC ignition module, discharge the storage capacitor to ground. Attach one end of a wire lead to the crankcase and then touch the other end to the harness connector pins on the CEC, one at a time. A snap is heard when a capacitor discharges.

### **WARNING**

As a safety measure, ground all the pins. Some breakerless ignition systems have more than one storage capacitor. Severe personal injury or death could result.

**NOTE:** If the ignition switch is in the OFF position, the capacitor is immediately grounded when the ignition harness is reconnected to the CEC ignition module.

## IGNITION SYSTEM GENERAL MAINTENANCE AND INSPECTION

### **WARNING**

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

1. Inspect cables and wires for broken or cracked insulation. Replace or repair as necessary.
2. Inspect ignition coils, ground wires, and brackets for loose hardware. Tighten as necessary.
3. Inspect spark plug and cable connectors for loose connections. Tighten as necessary.

# IGNITION SYSTEM MAINTENANCE

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## SECTION 4.15

### AIR INTAKE SYSTEM MAINTENANCE

#### AIR INTAKE SYSTEM MAINTENANCE

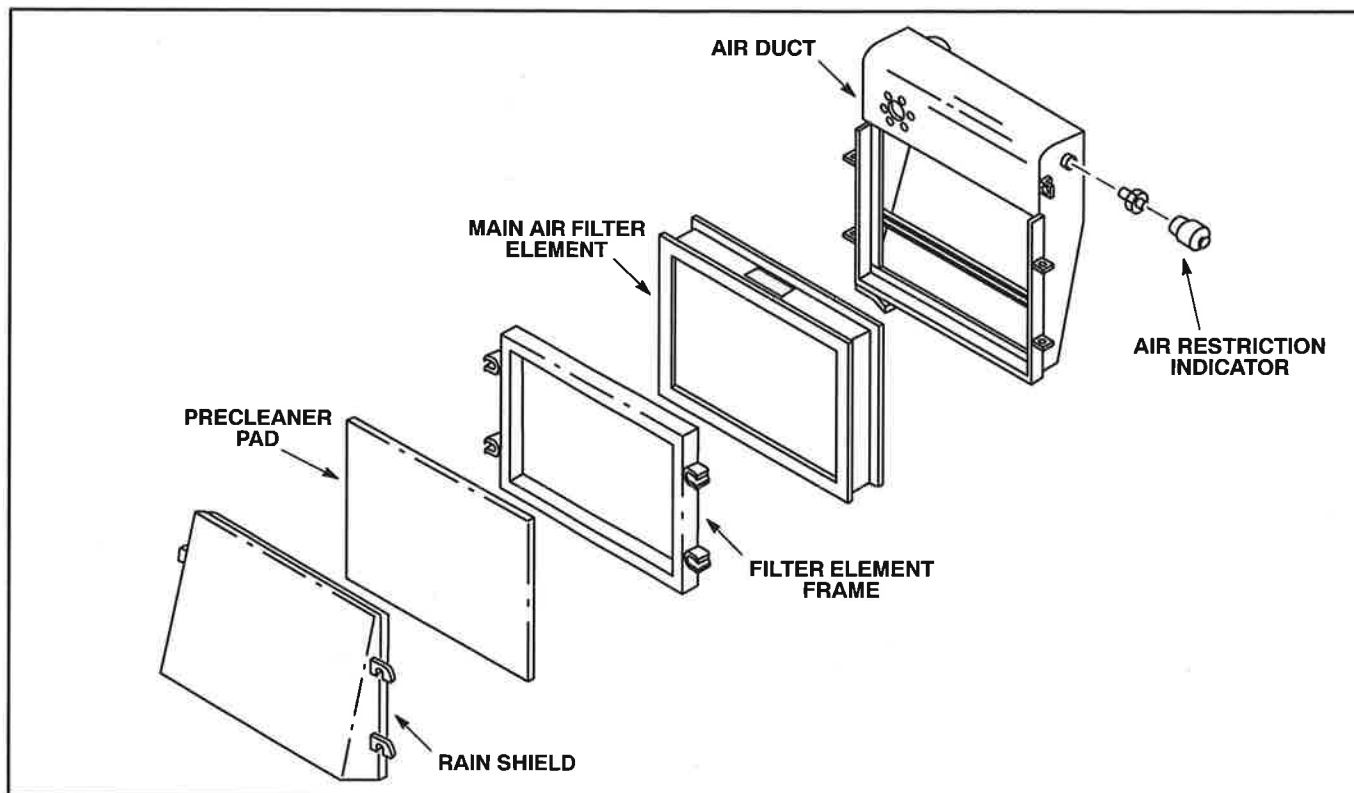


Figure 4.15-1. Air Cleaner Assembly - 6 And 12 Cylinder Engines

#### AIR FILTER MAINTENANCE

On 6 and 12 cylinder engines, the air restriction indicator (see Figure 4.15-1) will "pop red" if the air intake restriction is 15 in. (381 mm) of water. This indicates a clogged or dirty main air filter element and/or clogged or dirty precleaner element.

On 16 cylinder engines a gauge for each air filter indicates the condition of the precleaner filter and main air filter. Each gauge should register in the "green range". A switch allows the operator to monitor the pressure of the precleaner and main filter pressure independently.

#### Precleaner Pad Removal - 6 And 12 Cylinder

The precleaner is a foam rubber pad that increases the life of the main air filter element. Inspect and clean the precleaner pad daily or as required. This can be done while the engine is running. Replace the precleaner pad every 4000 running hours, or more often if necessary.

1. Locate the four threaded mounting studs on the air cleaner assembly and loosen the front lock nut (5/16 inch) on each (see Figure 4.15-2). (The rear locknut is loosened only for removal of the main air filter frame and element.)
2. Raise up and remove the rain shield.

## AIR INTAKE SYSTEM MAINTENANCE

3. Peel the precleaner pad off the main air filter element.

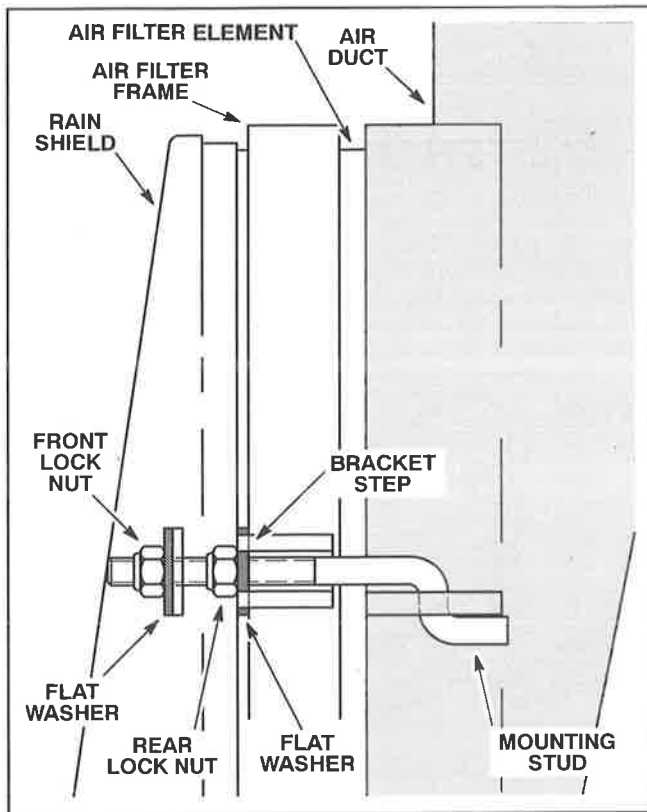


Figure 4.15-2. Air Cleaner Assembly -  
6 And 12 Cylinder Engines

### Precleaner Pad - Cleaning And Inspection - 6 and 12 Cylinder

1. Wash the precleaner pad with soap and water.

**CAUTION** Compressed air can easily damage the foam rubber pad.

2. Air dry the pad. Do not use compressed air.

### Precleaner Pad Installation - 6 And 12 Cylinder

**CAUTION** On new engines, a cardboard insert between the rainshield and precleaner pad must be removed before the engine is started. Disregarding this information could result in product damage.

1. Reinstall the precleaner pad between the rain shield and the main air filter element. If necessary, use a drop of adhesive on the corners to keep it from falling.

2. Do not clean and reuse the precleaner pad more than three times. Replace with a new precleaner pad.

**NOTE:** Use only Waukesha supplied precleaner pads.

3. Lower the rain shield on the four mounting studs of the air cleaner assembly. Alternately re-tighten the front lock nuts (5/16 inch).

4. Clean or replace the main air filter element if the air intake restriction indicator "pops" red after installation of a new or cleaned precleaner pad.

### Main Air Filter Element Removal - 6 And 12 Cylinder

Inspect and clean the main air filter element daily or as required. Replace main air filter element if the air restriction indicator "pops red" after the air cleaner is cleaned and the precleaner pad has been replaced or cleaned.

1. Locate the four threaded mounting studs on the air cleaner assembly and loosen the front lock nut (5/16 inch) on each (see Figure 4.15-2 and Figure 4.15-3).

2. Raise up and remove the rain shield.

3. Peel the precleaner pad off the main air filter element.

4. Loosen the rear lock nut (5/16 inch) on each mounting stud until the flat washer behind it can be brought forward far enough to clear the step in the welded bracket of the main air filter frame (see Figure 4.15-2).

5. Swing the four mounting studs to the outside in a horizontal motion. Remove the main air filter frame and element.

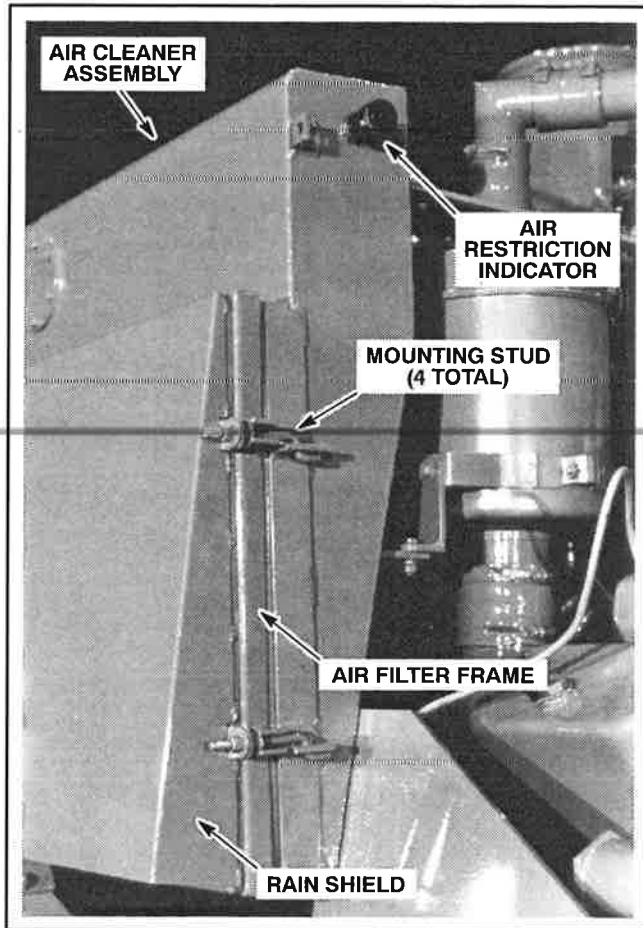


Figure 4.15-3. Air Cleaner Assembly - 6 Cylinder

### Main Air Filter Element - Cleaning And Inspection - 6 And 12 Cylinder

1. Clean the main air filter element using the following method.

- A. Gently tap the element on a flat surface with the dirty side of the element down.

### WARNING

Compressed air can pierce the skin and cause severe injury or death. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris.

- B. Using an OSHA approved safety nozzle, direct compressed air through the element opposite the direction of the air flow, as indicated by the orange arrow on the instruction label. The air pressure should be a maximum of 30 psi (207 kPa).

 **CAUTION** Compressed air can easily damage the pleated paper of the main air filter element.

C. Air dry the element. Do not use compressed air.

2. Carefully examine the element after cleaning. If damaged, replace.

**NOTE:** Use only Waukesha supplied air filter elements.

3. Do not clean and reuse the main air filter element more than three times. Replace with a new element.

4. Inspect the air duct for cracks. All of the combustion air must pass through the main air filter element, not through cracks or defects in the air cleaner assembly. If inspection of the duct work and intake manifold yields an accumulation of dust and grit, it is an indication that the main air filter element is not properly maintained or that air is getting into the system around or behind the element.

5. Inspect all air duct hoses. Replace any hose that is cracked or aged.

### Main Air Filter Element Installation - 6 And 12 Cylinder

**NOTE:** The orange flow arrow on the instruction label points toward the air outlet side. Always store the elements with the air outlet side down. Dirt and dust on the outlet side will pass into the engine when the element is installed.

1. Install the main air filter element with the instruction label facing up. Fit the deflection brace on the outlet side of the filter element over the horizontal bar running across the front of the air duct chamber.

2. Place the frame over the main air filter element.

3. Swing the four threaded mounting studs to the inside in a horizontal motion so that they fit within the welded brackets on the air filter frame. Move the flat washer behind the rear lock nut back into the step in the welded bracket.

4. Install the precleaner pad between the rain shield and the main air filter element. If necessary, use a drop of adhesive on the corners to keep it from falling.

5. Lower the rain shield on the four mounting studs.

6. Alternately tighten the rear lock nuts (5/16 inch).

7. Alternately tighten the front lock nuts (5/16 inch) on the four mounting studs.

## AIR INTAKE SYSTEM MAINTENANCE

8. Check the frame of the main air filter element to verify that its perimeter is sealed tightly. Damage to the frame may result in improper element sealing.

**NOTE:** After the restriction problem is corrected, reset the indicator by depressing the black button on the plastic housing.

### WARNING

The location of the air restriction indicator relative to the intake manifold causes it to be subjected to high pressure if the engine backfires. A restriction filter must be installed in the indicator air passage to dampen high pressure surges which would otherwise damage the indicator. Through the projection of broken material, damage to the indicator might pose a potential danger to persons standing nearby. The restriction filter also protects against the entrance of dust and dirt in the event that the restriction indicator is broken off or removed. Disregarding this information could result in severe personal injury or death.

Verify that the restriction filter is in place between the clean air tap and indicator.

### WARNING

Do not grasp the indicator housing; the plastic may crack or break resulting in a hand injury.

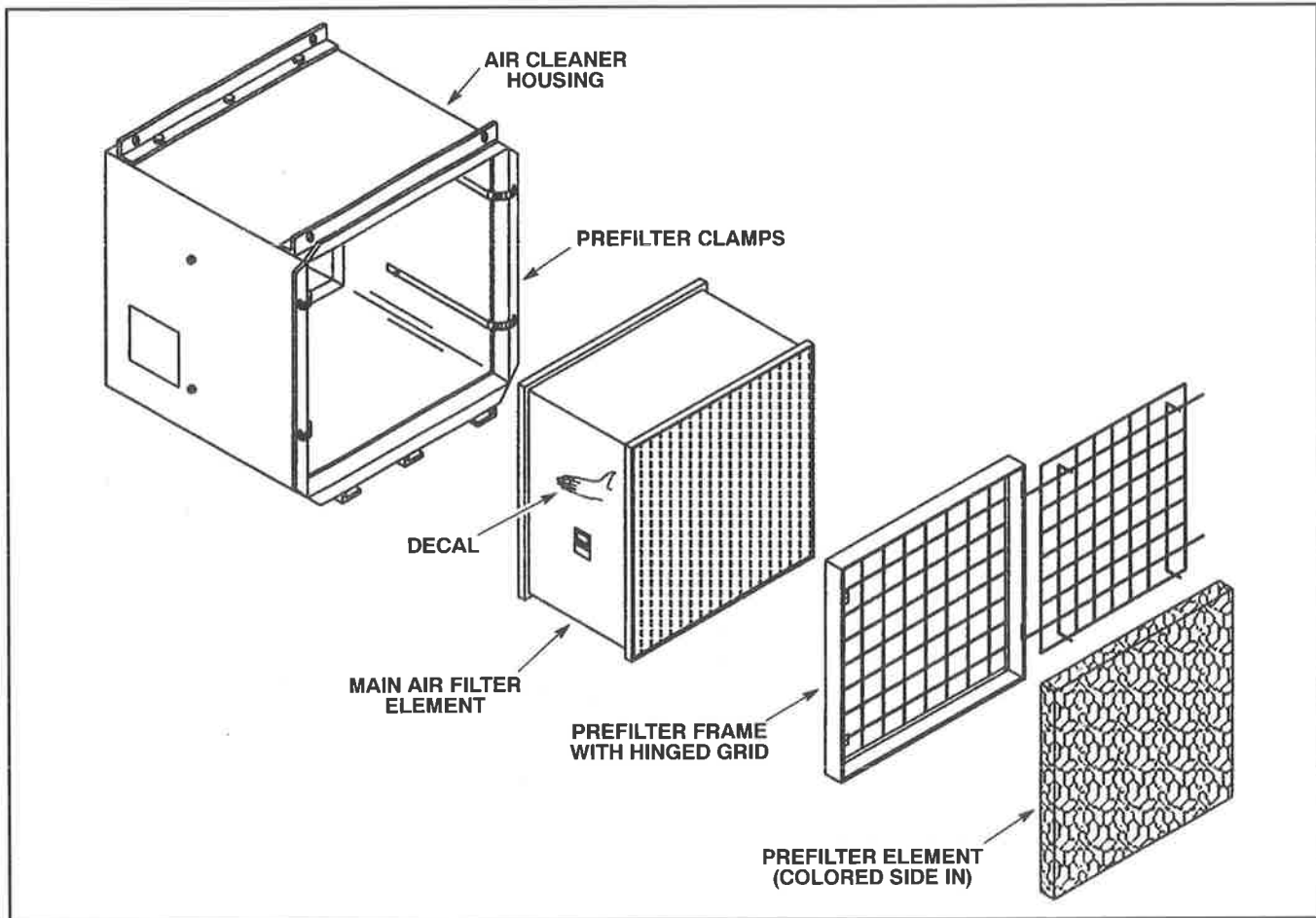


Figure 4.15-4. Air Cleaner Assembly - 16 Cylinder Engines

### Prefilter Pad Removal - 16 Cylinder

The prefilter is a filament pad that increases the life of the main air filter element (see Figure 4.15-4 and Figure 4.15-5). Inspect and clean the prefilter pad daily or as required. This can be done while the engine is running. Replace the prefilter pad every 4000 running hours, or more often if necessary.

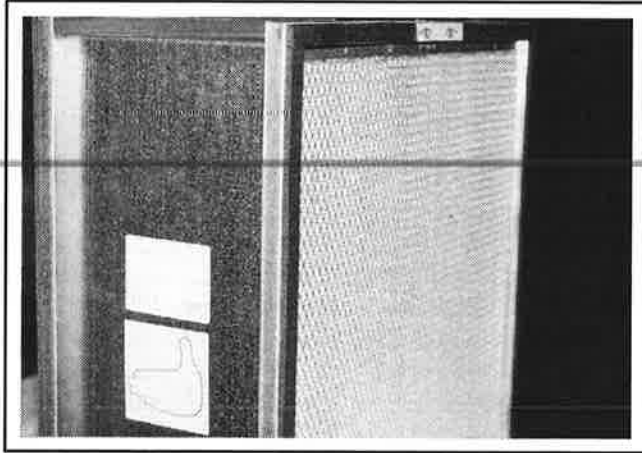


Figure 4.15-5. Air Cleaner Assembly - 16 Cylinder

1. Raise up and remove the rain shields.
2. Open the front grate to remove the prefilter pads from the prefilter frame (see Figure 4.15-6).

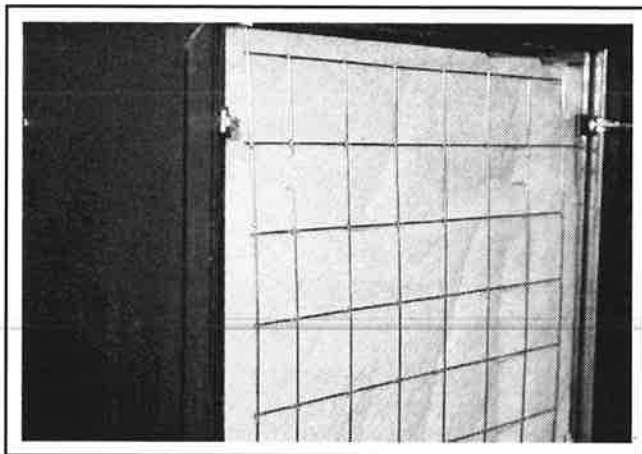


Figure 4.15-6. Prefilter Pad - 16 Cylinder

3. Discard the prefilter pads.

### Prefilter Pad Installation - 16 Cylinder

**CAUTION** The dark blue sides of the prefilter pads must face the main air cleaner elements or damage to equipment could result.

1. Install the new prefilter pads in the grates so that the dark blue sides of the prefilter pads will face towards the main air filter elements when the prefilter pads are installed.
2. Close the front grate door and secure by inserting the ends of the grate in the slots in the prefilter frame (see Figure 4.15-6).
3. Install the rain shields.

### Main Air Filter Element Removal - 16 Cylinder

Inspect and clean the main air filter element daily or as required. Replace main air filter element if the air restriction indicator "indicates red" after the air cleaner is cleaned and the prefilter pad has been replaced.

1. Raise up and remove the rain shield.
2. Locate the four mounting clamps on the front of the air cleaner assemblies and loosen the clamps to remove the prefilter frame and prefilter pads (see Figure 4.15-6).
3. Discard the prefilter pads.
4. Pull out the main air filter elements.

## AIR INTAKE SYSTEM MAINTENANCE

### Main Air Filter Element - Cleaning And Inspection - 16 Cylinder

1. Clean the main air filter element using the following method.

- A. Gently tap the element on a flat surface with the dirty side of the element down.

#### WARNING

Compressed air can pierce the skin and cause severe injury or death. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris.

- B. Using an OSHA approved safety nozzle, direct compressed air through the element opposite the direction of the air flow, as indicated by the hand on the side of the filter element. The air pressure should be a maximum of 30 psi (207 kPa).

 CAUTION Compressed air can easily damage the pleated paper of the main air filter element.

- C. Air dry the element. Do not use compressed air.

2. Carefully examine the element after cleaning. If damaged, replace.

**NOTE:** Use only Waukesha supplied air filter elements.

3. Do not clean and reuse the main air filter element more than three times. Replace with a new element.

4. Inspect the air duct for cracks. All of the combustion air must pass through the main air filter element, not through cracks or defects in the air cleaner assembly. If inspection of the duct work and intake manifold yields an accumulation of dust and grit, it is an indication that the main air filter element is not properly maintained or that air is getting into the system around or behind the element.

5. Inspect all air duct hoses. Replace any hose that is cracked or aged.

### Main Air Filter Element Installation - 16 Cylinder

 CAUTION On new engines, a cardboard insert between the rainshield and prefilter pad must be removed before the engine is started. Disregarding this information could result in product damage.

 CAUTION The pleats of the main air filter must be positioned vertically in the air filter housing or damage to equipment could result.

**NOTE:** The hand on the side of the filter element points toward the air outlet side of the air filter housing. Also a label with a pair of eyes printed on it is positioned on the air inlet side of the filter element. These eyes should be visible from the air filter housing inlet opening and at the top of the air cleaner, if the filter is properly installed. If both labels are missing, one side of the air filter element has a metal brace horizontally across the back. This side should be positioned, towards the air outlet side. Always store the elements with the air outlet side down. Dirt and dust on the outlet side will pass into the engine when the element is installed.

1. Install the main air filter elements with the hand on the side of the filter elements pointing toward the air outlet side of the filter housings. Insure that the pleats of the elements are positioned vertically.

 CAUTION The dark blue sides of the prefilter pads must face the main air cleaner elements or damage to equipment could result.

2. Install the new prefilter pads in the grates so that the dark blue sides of the prefilter pads will face towards the main air filter elements when the prefilter pads are installed.

3. Position the front grate and prefilter pad assemblies on the air filter housings and secure using the four clamps (see Figure 4.15-6).

4. Install the rain shields.



## SECTION 4.20

### TURBOCHARGER SYSTEM MAINTENANCE

#### TURBOCHARGER SYSTEM MAINTENANCE

##### TURBOCHARGER INSPECTION

### **⚠ WARNING**

Turbocharger components are extremely hot. Always allow the turbocharger to cool prior to conducting an inspection. Failure to comply with these instructions could result in severe burns.

**⚠ CAUTION** Inspection and repair of turbochargers must be performed by a factory qualified service agent. Failure to follow these instructions could cause engine damage and/or personal injury.

1. Inspect the engine air cleaner, service if required.
2. Inspect the turbocharger mounting and connections for lube oil and air leaks (see Figure 4.20-1 and Figure 4.20-2).

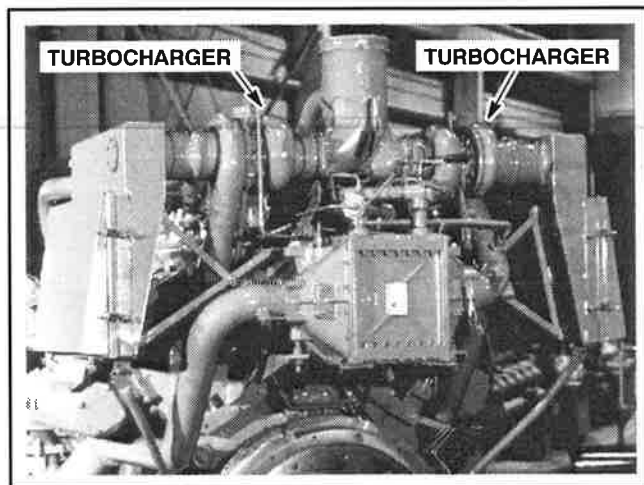


Figure 4.20-1. 5115GL - Rear View

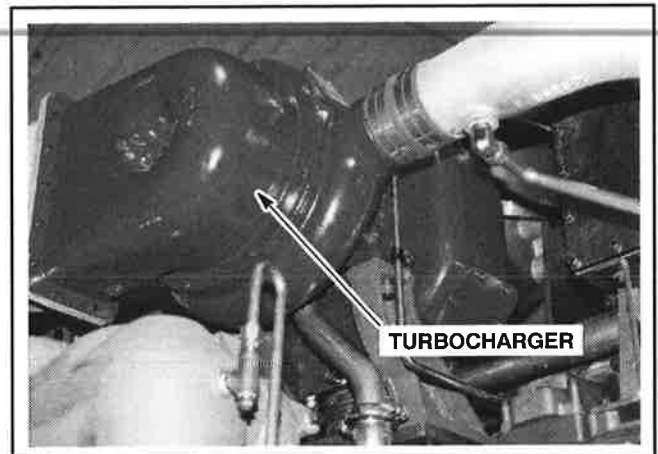


Figure 4.20-2. Turbochargers - 16 Cylinder GSI Side View

**⚠ CAUTION** Do not run the engine if the air cleaner is not operating efficiently or if leaks exist in the ducting. Dust leaking into the air ducting can damage the engine and the turbochargers and/or cause personal injury.

3. With the engine shutdown, inspect all air ducting for loose clamps or connections. Check the manifold connections to the turbine inlet and at the engine exhaust manifold gaskets.
4. Visually repeat the inspection while the engine is running.
5. Monitor the turbochargers for unusual vibrations or noise. If excessive vibration is evident, shutdown the the engine and call your Waukesha authorized service agent.
6. Establish a schedule with your Waukesha authorized service agent to inspect the interior of the compressor for accumulations of dirt. Dirt can cause the compressor wheel to become unbalanced, which reduces efficiency and causes bearing failure.

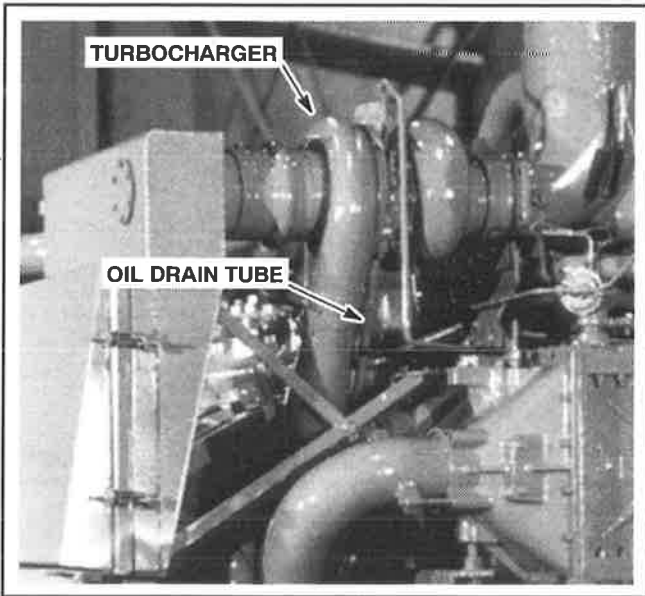
## TURBOCHARGER SYSTEM MAINTENANCE

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### TURBOCHARGER LUBRICATION CHECK

**⚠ CAUTION** Before operating a new or rebuilt turbocharger (or starting a new engine for the first time), check to ensure that the turbocharger is receiving proper lubrication. Failure to follow these instructions could cause engine damage and/or personal injury.

1. Remove the oil drain tube (see Figure 4.20-3) from the turbocharger(s).



**Figure 4.20-3. Turbocharger Oil Drain Tubes -  
12 Cylinder**

2. Activate the prelube system and visually check for oil flow at the turbocharger oil drain area.
3. Reconnect the oil drain tube only after oil is observed at the oil drain area.
4. Start the engine at reduced speeds until the coolant temperature gauge indicates a temperature of 100° F (38° C).
5. Run the engine at rated output and listen for unusual sounds at the turbocharger, especially those of metal contacting metal. If any noise of this type is apparent, contact your Waukesha authorized service agent.

## SECTION 4.25

### COOLING SYSTEM MAINTENANCE

#### COOLING SYSTEM MAINTENANCE

##### COOLING SYSTEM ADDITIVES

Standard closed heat exchanger or radiator cooled cooling systems operating up to 250° F (121° C) must be treated with industrial grade inhibited antifreeze or with some other effective commercial cooling water treatment product. These products usually provide corrosion protection by forming a film on the surfaces of the cooling system and also act as a scale suppressant by modifying or conditioning the dissolved scale forming minerals. To work effectively, all antifreeze and water treatment products require a clean system, free of dirt, oil, scale and rust.

##### Ethylene Glycol

The most common cooling water additive is ethylene glycol. The required proportion normally depends on the lowest ambient temperature levels from which the system must be protected. A fifty-fifty mix of water and ethylene glycol will produce the best results for freezing and boiling protection, but cooling water efficiency is reduced by as much as 15%. Since the radiator cooling system effectiveness drops by approximately 2 - 3% for each 10% of glycol concentration, the radiator sizing for the specified heat rejection value must be taken into account to accommodate this relationship.

A minimum of 30% ethylene glycol is generally recommended for adequate antifreeze and corrosion protection. The amount should not exceed 67% to avoid impairing the heat transfer processes. A concentration beyond this percentage does not tend to lower the freezing point any further and may result in engine damage.

Since it effectively raises the boiling point of the water, the use of ethylene glycol is also beneficial in hot temperatures. Therefore, ethylene glycol treated water is still recommended in those climates where antifreeze is not normally required (see Table 4.25-1).

Table 4.25-1. Water Versus Glycol Concentration

PERCENT WATER/GLYCOL	COMMENTS
70/30	Minimum Glycol for Adequate Anti-freeze/Corrosion Protection
50/50	Best for Corrosion, Freezing and Boiling Protection

With heat exchanger cooling systems, it should be remembered that the circulation of ethylene glycol solution only protects the closed system coolant. Therefore, the heat exchanger water supply, as well as the auxiliary cooling water circuit, must also be protected.

##### Propylene Glycol

Propylene glycol has similar cooling properties when compared to ethylene glycol. Ethylene glycol has the advantage of lower viscosity than propylene glycol at temperatures less than 0° F (-17° C). Propylene glycol has a low toxicity, and it may be less stringently regulated than ethylene glycol. Propylene glycol also has been proven to alleviate cavitation erosion that may be experienced when using ethylene glycol solutions.

## COOLING SYSTEM MAINTENANCE

Other treatments the engine operator should consider are (see Table 4.25-2):

**Table 4.25-2. Other Cooling System Treatments**

TREATMENT	COMMENTS
Deionized, Distilled or Softened Water	Although a maximum hardness of 200 ppm is acceptable for initial fill and make-up, use only softened water, where the insolubles may be as low as 0.5 ppm.
Sodium Nitrate	Iron and steel corrosion inhibitor.
Molybdate	Slows the growth of bacteria.
Tolyltriazole	Copper corrosion inhibitor.
Synthetic Polymer	Prevents hard scale build up.
Borax Buffer	Corrects the water pH to 8.5.
Silicates	General corrosion inhibitor; over 0.1% concentration is not recommended for industrial engines. A concentration that is too high can cause the cooling water in the radiator to gel, resulting in solid deposits. High silicate inhibitor concentration is used primarily for high speed aluminum engines.

**NOTE:** Refer to Service Bulletin 4-2429C or latest revision, for more detailed coolant treatment information.

### COOLING SYSTEM SPECIFICATIONS AND RECOMMENDATIONS

#### Cooling System Specifications

Ensure that the temperature of the cooling water leaving the engine (as indicated by the temperature gauge) does not exceed 220° F (104° C).

Refer to Table 1.15-2 for the jacket water outlet temperature alarm and safety shutdown setpoints.

**NOTE:** Customer supplied fuel shutoff type safety equipment must be provided to prevent engine damage and possible personal injury.

Engine overheating, as evidenced by high jacket water temperatures, may be caused by one or more of the following conditions:

- restricted air flow through the radiator
- defective thermostats
- worn jacket water pump
- excessive jacket water pump suction
- blown head gasket
- faulty temperature gauge
- low coolant level
- overloaded engine
- air bound system

- insufficient air circulation
- exhaust recirculation

#### Cooling System Recommendations

1. Ensure that the rise in coolant temperature does not exceed 10° F (5.6° C).

2. Maintain the drop in system pressure at 8 - 15 psi (55 - 103 kPa). While pressure that is too low promotes cavitation erosion, pressure that is too high may cause the water pump seals to leak.

3. Analyze the raw water chemistry to verify that it does not contain contaminants and that it is not too hard. Use only soft water, where the insolubles are as low as 0.5 ppm. Hard water accelerates the formation of scale deposits.

4. Analyze the cooling water chemistry every month to verify that it contains the proper inhibitor and additive concentrations.

5. Measure antifreeze content according to the lowest anticipated temperature and refill as needed with the same brand.

6. Maintain cooling water pH between 8.5 and 10.5; an acidic coolant with a pH of less than 7 will speed the corrosion of cast iron, aluminum and steel, while a pH of 11 or higher will accelerate the corrosion of aluminum and solder.

7. Check the cooling system level each day or consider the installation of a coolant low level shutdown switch. Even if a high coolant temperature switch is provided, it will not shut the engine down if the system runs low on cooling water.

8. Check the cooling system for rust, sludge or other foreign matter. Clean and flush the entire cooling system once each year, unless evidence of corrosion or sediment build up demonstrates the need for more frequent changes. Use only clean, soft water.

9. To eliminate the recirculation of particles and contaminants in the cooling water circuit, install a cleanable filter (sized at approximately 10 microns) in the coolant flow. Inspect and clean the filter on a regular basis.

10. Frequently inspect hoses and all cooling system connections for cracks and leaks. Do this when the engine is operating at normal pressure.

11. On a radiator, check for damaged fan blades, a poorly fitting shroud, sticking shutters or dirt in the radiator core. Repair or clean as needed.

12. Check the radiator cap gasket for proper seal.

13. If a heat exchanger is used, inspect it for scale or corrosion, and when necessary, clean the inside of the tubes with a round, soft-wire brush. Flush with cleaning solvent.

14. Periodically remove the intercooler and rod-out the tubes with a soft-wire brush or circulate a suitable cleaning solution.

15. Consider the installation of the following cooling system safety accessories:

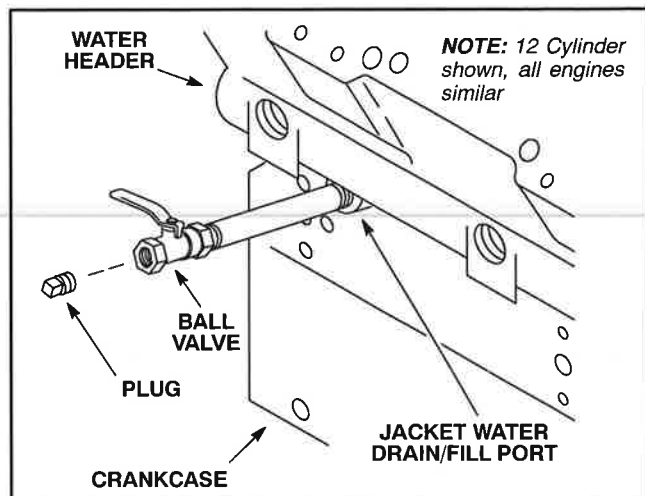
- A high water temperature shutdown device
- A low water level shutdown device
- A coolant level sight glass

To avoid scored pistons and other serious problems, a high water temperature shutdown device will stop the engine if the coolant gets too hot. A low water level device will shut down the engine if the coolant level drops excessively, preventing cracked or warped cylinder heads, exhaust manifolds and water manifolds. A sight glass is a quick and easy method of visually checking the coolant level.

### JACKET COOLING WATER CIRCUIT - INITIAL FILL

**NOTE:** The following description is not applicable to permanent vent systems.

1. Remove the 3/4 inch NPT countersunk headless pipe plugs from the drain hole just below the level of the jacket water header (see Figure 4.25-1).



**Figure 4.25-1. Customer Supplied Ball Valve - 12 Cylinder**

**NOTE:** To facilitate draining and flushing of the engine jacket water, replace one of the 3/4 inch NPT countersunk headless pipe plugs with a customer-supplied ball valve (see Figure 4.25-1). The ball valve must be threaded to accept both a hose connection and pipe plug.

2. Open the air bleed petcock(s) on top of the cluster thermostat housing on 6 and 12 cylinder engines and on top of the water manifold on 16 cylinder engines.

3. Attach the makeup line to the ball valve and add treated cooling water to the crankcase (see *Water Treatment* in this section).

**NOTE:** Always fill the engine from the bottom up to minimize the formation of damaging air pockets. As the engine fills, air is pushed up and out.

### ⚠ WARNING

**Antifreeze solution is toxic and poisonous. Always wear protective clothing when working with antifreeze solution. Follow the safety instructions provided on the container provided by the manufacturer. Failure to follow proper procedures could cause severe personal injury or death.**

4. Add coolant to the engine until the level causes it to escape from the petcock(s) on top of the cluster thermostat housing on 6 and 12 cylinder engines. On 16 cylinder engines, petcock(s) are located on top of the water manifold. See Table 1.15-2 for jacket water capacities.

5. Close the cluster thermostat housing petcock(s) and continue filling the system until the level of the coolant reaches the top of the surge tank or radiator.

6. Close the ball valve and unthread the hose connection.

### ⚠ WARNING

**Always install a pipe plug in the ball valve when the hose connection is removed. If the lever of the ball valve is inadvertently bumped open, the absence of a plug will cause the coolant to drain. During operation, loss of any coolant may result in catastrophic engine damage. Escaping steam and/or hot water can cause severe burns or severe personal injury or death.**

7. Apply Perma Lok® Heavy Duty Pipe Sealant with Teflon® to the threads of the pipe plug. Install the plug in the ball valve.

## COOLING SYSTEM MAINTENANCE

 **CAUTION** Air in the cooling system speeds up the formation of rust, increases corrosion and produces hot spots within the engine.

8. Bleed trapped air (see *Cooling Water System Air Bleed*).

9. Top off the surge tank or radiator.

### AUXILIARY COOLING WATER CIRCUIT - INITIAL FILL

**NOTE:** The following description is not applicable to permanent vent systems.

1. Open the air bleed petcocks in the intercooler cooling water inlet/outlet bonnets.

2. Open the air bleed petcocks on the intercooler water inlet and outlet tubes located behind the venturi extractor.

3. Open the air bleed petcocks in the inlet side of the wastegate water return tubes.

4. From the top of the surge tank or radiator, add treated cooling water (see *Water Treatment* in this section) to the auxiliary cooling water circuit.

5. Continue filling the circuit until the level causes it to escape from the air bleed petcock(s) in the intercooler cooling water inlet/outlet bonnet(s). Close the petcock(s) when water begins to flow out in a solid steady stream.

6. Continue filling the auxiliary cooling water circuit until the level causes it to escape from the petcocks in the intercooler cooling water supply and the inlet side of the wastegate water return tubes. Close the petcocks when water begins to flow out in a solid steady stream. See Table 1.15-2 for the capacities of the various auxiliary water system components.

**NOTE:** Customer supplied items and connections not included. Waukesha supplied items include the auxiliary water pump, intercooler, oil cooler and the engine mounted intercooler water supply and return piping.

7. Continue filling the auxiliary cooling water circuit until the level of the coolant reaches the top of the surge tank or radiator.

 **CAUTION** Air in the cooling system speeds up the formation of rust, increases corrosion and produces hot spots within the engine.

8. Bleed trapped air (see *Cooling Water System Air Bleed*).

9. Top off the surge tank or radiator.

### COOLING WATER SYSTEM - AIR BLEED

Air bleed the jacket water and auxiliary cooling water circuits at least once each day. Open and close the air bleed petcocks in the order that they are listed below, starting at the lowest petcock in the system and ending at the highest. Bleed one petcock at a time. The number of air bleed petcocks and their locations are listed in Table 4.25-3.


1. **Initial Bleed:** open each air bleed petcock prior to engine startup. A hissing sound often accompanies the escape of trapped air. Close the petcock when the hissing stops and water begins to flow out in a solid steady stream.

### WARNING

**Always wear protective clothing when bleeding the cooling system on a heated engine. Slowly loosen the air bleed petcock to relieve any excess pressure. Escaping steam and/or hot water can result in severe burns.**

2. **Check Bleed:** start the engine and reopen each petcock. Close the petcock when the hissing stops and water begins to flow out in a solid steady stream.

3. **Final Bleed:** once the temperature of the jacket water circuit has stabilized (as indicated by the panel mounted temperature gauge), reopen each petcock. Close the petcock when the water begins to flow out in a solid steady stream.

 **CAUTION** Air can be drawn into the engine through small leaks in the jacket water system. The problem is compounded when the void created by the loss of coolant is filled by more air. If aeration causes the coolant to foam, the probability of engine damage due to overheating is greatly increased.

4. Carefully inspect the jacket water system for coolant leaks while the engine is running.

**Table 4.25-3. Air Bleed Petcocks**

COOLING WATER CIRCUIT	NUMBER OF PETCOCKS	LOCATION
<b>6 Cylinder Engine</b>		
Jacket Water	1	Jacket water pump housing (front center); needle valve in lieu of petcock in outlet port to jacket water header
	1	Cluster thermostat housing (above bypass outlet port at front)
Auxiliary	1	Intercooler water inlet/outlet bonnet (upper rear)
	2	Intercooler cooling water inlet/outlet elbows (upper rear)
	1	Wastegate water tube (rear)
<b>5115GL Engine</b>		
Jacket Water	2	Cluster thermostat housing (above bypass outlet ports at front)
Auxiliary	2	Intercooler water inlet/outlet bonnets (upper rear)
	2	Intercooler water inlet/outlet tubes (behind venturi extractor)
	2	Wastegate water return tube (rear right and left bank)
<b>12 Cylinder Engine</b>		
Jacket Water	1	Jacket water pump housing (front center); outlet port to left bank jacket water header
	2	Cluster thermostat housing (above bypass outlet ports at front)
Auxiliary	2	Intercooler water inlet/outlet bonnets (upper rear)
	2	Wastegate water return tube (rear right and left bank)
<b>16 Cylinder Engine</b>		
Jacket Water	1	Top of jacket water pump
	1	Top of water manifold
Auxiliary	4	Intercooler cross pipes (2 per intercooler)
	4	Intercooler top center (2 per intercooler)

**COOLING WATER CIRCUITS - DRAIN AND FLUSH**

Unless evidence of corrosion or sediment buildup demonstrates the need for more frequent maintenance, clean and flush both the jacket water and auxiliary cooling water circuits at least once each year.

1. Start the engine. Let the engine run about 10 minutes to stir up any rust or sediment.



**WARNING**

**Always wear protective clothing when draining the cooling systems on a heated engine. Slowly loosen the air bleed petcocks to relieve any excess pressure. Escaping steam and/or hot water can result in severe burns or death.**

2. Shut down the engine. Open the air bleed petcocks at the highest point in both the jacket water and auxiliary cooling water circuits, whether it be on top of the surge tank, radiator or other heat transfer device.

**NOTE:** To facilitate draining and flushing of the engine jacket water, replace one of the 3/4 inch NPT counter-sunk headless pipe plugs (just below the level of the jacket water header) with a customer-supplied ball valve. The ball valve must be threaded to accept both a hose connection and pipe plug.

3. Verify that the customer-supplied ball valve is in the closed position. Remove the pipe plug and attach the drainage line.

4. Drain the coolant from the jacket water and auxiliary cooling water circuits. Avoid delay, so that the water is drained before the rust and sediment has a chance to settle.

## COOLING SYSTEM MAINTENANCE

5. Open all air bleed petcocks (see Table 4.25-4).

**Table 4.25-4. Water Drain Petcocks**

COOLING WATER CIRCUIT	NUMBER OF PETCOCKS	LOCATION
<b>6 Cylinder Engines</b>		
Jacket Water	2 (plugs)	Jacket water header (front and rear)
	2 (plugs)	Water manifold (front and rear)
	1	Jacket water pump housing (see exit hole in side panel of safety guard assembly)
	1	Oil cooler (bottom rear)
Auxiliary	2	Intercooler (rear, left and right)
	1	Auxiliary water pump (bottom)
	1	Wastegate water pipe (also used for air bleed)
<b>5115GL Engine</b>		
Jacket Water	4 (plugs)	Jacket water headers (front and rear)
	2	Water manifold (front and rear)
	1	Jacket water pump housing
Auxiliary	1	Auxiliary water pump
	4	Intercooler (lower)
<b>12 Cylinder Engines</b>		
Jacket Water	4 (plugs)	Jacket water headers (front and rear)
	2	Water manifold (front and rear)
	2	Water Elbows front left and right)
Auxiliary	8	Intercooler (rear, left and right)
	1	Auxiliary water pump (bottom)
	1	Water return pipe (pipe end at crankcase Vee, engine front)
<b>16 Cylinder Engines</b>		
Jacket Water	4 (plugs)	Jacket water headers (front and rear)
	2	Water manifold (front and rear)
	1	Jacket water pump housing (see exit hole in side panel of safety guard assembly)
Auxiliary	2	Intercooler (4 each intercooler)
	1	Auxiliary water pump (bottom)
	1	Wastegate (1 per wastegate)

6. Open all water drain petcocks. Remove all drain plugs. Place a small catch pan beneath each petcock before opening.

7. Close all water drain petcocks. Apply Perma Lok® Heavy Duty Pipe Sealant with Teflon® to the threads, and install all drain plugs.

8. Select and inspect an internal surface that is suitable for gauging the effectiveness of the cleaning and descaling solution. If necessary, insert a piece of drill

welding rod into the water passage opening to feel for an accumulation of lime and mineral scale deposits.

9. Attach the makeup line to the ball valve and add clean, soft water to the crankcase. Always fill the engine from the bottom up to minimize the formation of air pockets. As the engine fills, air is pushed up and out.

10. Successively close each air bleed petcock when water begins to flow out in a solid steady stream. Begin at the lowest petcock and finish at the highest.

11. Close the cluster thermostat housing petcock(s) and continue filling the jacket water system until the level reaches the top of the surge tank or radiator.

12. Bleed trapped air. Begin at the lowest petcock and finish at the highest. Bleed one petcock at a time. Close the petcock when the hissing stops and water begins to flow out in a solid steady stream.

13. Attach the makeup line and add clean, soft water to the surge tank or radiator of the auxiliary cooling water circuit.

14. Top off the surge tank or radiator of the jacket water circuit.

15. Successively close each air bleed petcock when water begins to flow out in a solid steady stream.

16. Continue filling the auxiliary cooling water circuit until the level reaches the top of the surge tank or radiator.

17. Bleed trapped air. Begin at the lowest petcock and finish at the highest. Bleed one petcock at a time. Close the petcock when the hissing stops and water begins to flow out in a solid steady stream.

18. Top off the surge tank or radiator of the auxiliary cooling water circuit.

### **WARNING**

**Always wear protective clothing when venting the cooling system on a heated engine. Slowly loosen the air bleed petcock to relieve any excess pressure. Escaping steam and/or hot water can result in severe burns or death.**

19. Start the engine and slowly reopen each air bleed petcock. Close the petcock when the hissing stops and water begins to flow out in a solid steady stream.



20. Slowly reopen each air bleed petcock when the engine jacket water temperature has stabilized (as indicated by the panel mounted temperature gauge). Close the petcock when the water begins to flow out in a solid steady stream.

21. Let the engine run about 10 minutes to stir up any rust or sediment in the cooling water system.

### WARNING

**Always wear protective clothing when draining the cooling systems on a heated engine. Slowly loosen the drain petcocks to relieve any excess pressure. Escaping steam and/or hot water can result in severe burns or death.**

**NOTE:** *Contaminants left in the cooling water systems will reduce or deplete the effectiveness of the cleaning solution.*

22. Stop the engine. Drain the crankcase and all cooling system accessories. Drain the auxiliary cooling water circuit. Avoid delay, so that the water is completely drained while the rust and sediment are still in suspension.

23. Attach the makeup line and fill the jacket water and auxiliary cooling water circuits with a suitable cleaning solution. Use a non-acidic, non-corrosive, biodegradable compound that prevents the loss of metal in the engine and avoids damage to internal gaskets and seals.

**NOTE:** *Follow the manufacturer's recommendations for the proper concentration of cleaning solution and length of cleaning time.*

24. Bleed trapped air.


25. Top off the surge tank or radiator of the jacket water and auxiliary cooling water circuits.

26. Start the engine. Let it run for at least 10 minutes or until the cleaning solution is depleted.

27. To ensure that the contaminants remain in suspension, drain the cooling systems as quickly as possible.

28. Inspect internal surfaces. If the results are not satisfactory, refill the engine with cleaning solution. Repeat Steps 23 thru 27 as necessary.

29. To flush the systems of cleaning solution and any residual contaminants, fill the jacket water and auxiliary cooling water circuits with clean, soft water. Drain immediately.


 **CAUTION** All antifreeze and water treatment products require a clean system in order to work effectively. If contaminants, such as dirt, rust, scale, lime, grease, oil and/or cleaning agents, are not completely flushed out, they can destroy the corrosion inhibitors and scale suppressants intended to keep freshly filled cooling systems clean.

30. Inspect the drain water for cleanliness. Fill and flush the systems again, if necessary. The best results are obtained when the drain water runs clear.

31. Fill the jacket water and auxiliary cooling water circuits with coolant. Be sure that the coolant has the proper inhibitor and additive concentrations (see *Water Treatment*). Bleed the system of trapped air.

### WARNING

**Always install a pipe plug in the ball valve when the hose connection is removed from the jacket water header. If the lever of the ball valve is inadvertently bumped open, the absence of a plug will cause the coolant to drain. During operation, loss of any coolant may result in catastrophic engine damage. Escaping steam and/or hot water can cause severe burns or death.**

 **CAUTION** Air can be drawn into the system through small leaks in the cooling water circuit. The problem is compounded when the void created by any loss of coolant is filled by more air. Air in the cooling system speeds up the formation of rust, increases corrosion and produces hot spots within the engine. If aeration causes the coolant to foam, the probability of engine damage due to overheating is greatly increased.

32. Carefully inspect the jacket water and auxiliary cooling water circuits for leaks.

## COOLING SYSTEM MAINTENANCE

### IDLER PULLEY BEARING LUBRICATION

All engines with the exception of 5115GL engines require greasing the ball bearing in the jacket water pump idler pulley bracket every 720 running hours.

1. Locate the idler pulley bracket grease fitting mounted above the drain cock in the panel of the safety guard assembly (right bank side) (see Figure 4.25-2 and Figure 4.25-3).

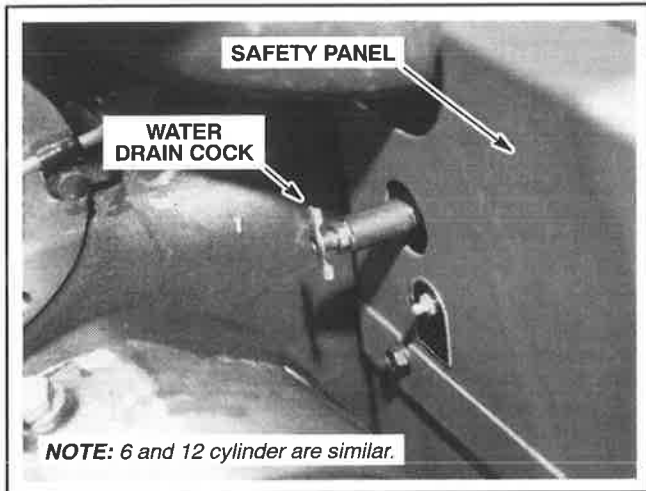


Figure 4.25-2. Idler Pulley Bearing Lube - 12 Cylinder Shown



Figure 4.25-3. Idler Pulley Bearing Lube - 16 Cylinder

**CAUTION** Do not over grease the idler pulley bearing. Over greasing causes high bearing temperatures that shorten bearing service life. Disregarding this information could result in product damage and/or personal injury.

2. Using a hand held grease gun, apply one stroke of Lithoplex® Grease No. 2 (Multipurpose Lithium Complex Formula Containing Molybdenum Disulfide) to the grease fitting.

### AUXILIARY WATER PUMP BEARINGS LUBRICATION

All engines with the exception of 5115GL engines require greasing the ball bearing(s) in the auxiliary water pump every 720 running hours. The pump is mounted to a bracket at the front left or right corner of the oil pan. Depending on the model of the auxiliary water pump used, the pump may have one or two grease fittings. Safety guards on some engines may cover access to grease fittings. In this case an access hole is provided to allow the fitting to be greased.

1. Locate the grease fitting(s) on the auxiliary water pump (see Figure 4.25-4, Figure 4.25-5 and Figure 4.25-6).

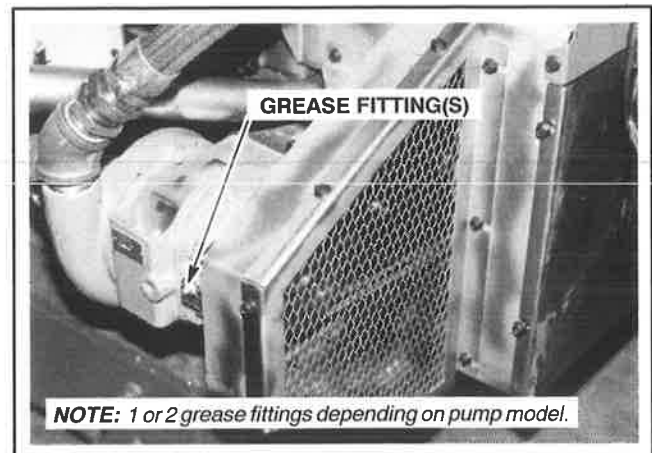
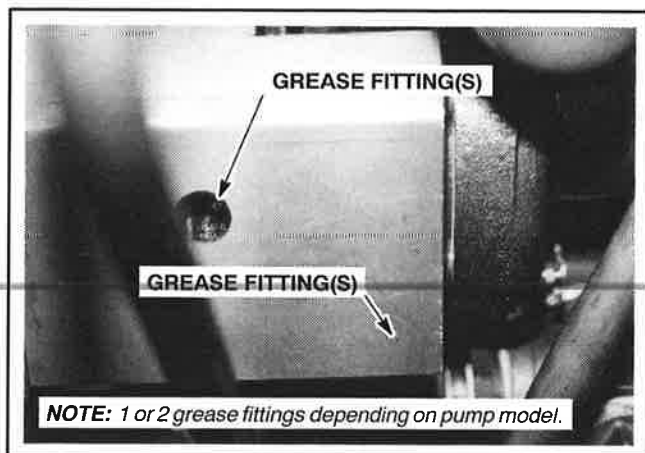


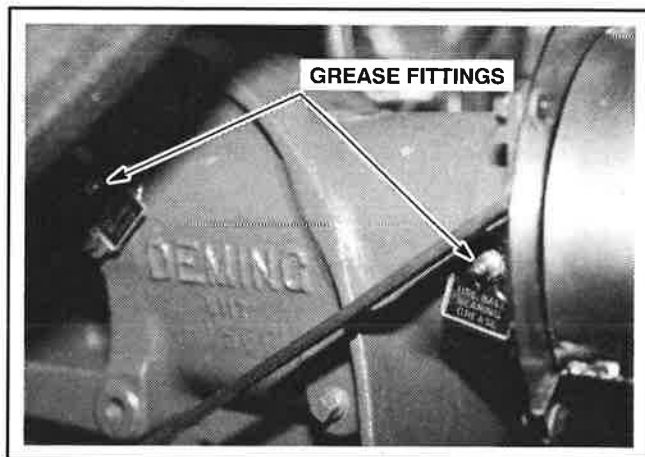
Figure 4.25-4. Auxiliary Water Pump Lube - 6 Cylinder

**CAUTION** Do not over grease the water pump bearings. Over greasing causes high bearing temperatures that shorten bearing service life. Disregarding this information could result in product damage and/or personal injury.

2. Using a hand held grease gun, apply two or three strokes of Lithoplex® Grease No. 2 (Multipurpose Lithium Complex Formula Containing Molybdenum Disulfide) to the grease fitting(s).



**Figure 4.25-5. Auxiliary Water Pump Lube -  
12 Cylinder**



**Figure 4.25-6. Auxiliary Water Pump Lube -  
16 Cylinder**

### GREASE RECOMMENDATIONS

A Lithium complex type grease is now recommended over the Lithium soap base grease because of its ability to resist water. Lithium complex type grease also provides superior rust protection qualities (especially steel surfaces), as well as its thermal and mechanical stability at high operating temperatures. The Lithium complex grease has a continuous operating temperature of approximately 350° F (177° C), whereas the Lithium soap base grease has an upper operating temperature limit of approximately 225° F (107° C).

### JACKET WATER PUMP DRIVE BELTS REPLACEMENT

#### **⚠ WARNING**

Always install the safety guards after completing any service operation. Never operate the engine with the safety guards removed. Disregarding this information could result in product damage, severe personal injury or death.

**NOTE:** 5115GL engines are not equipped with belts.

1. Remove front safety guard.

**⚠ CAUTION** An accumulation of dirt in the sheave grooves impairs traction and accelerates belt wear. Disregarding this information could result in product damage and/or personal injury.

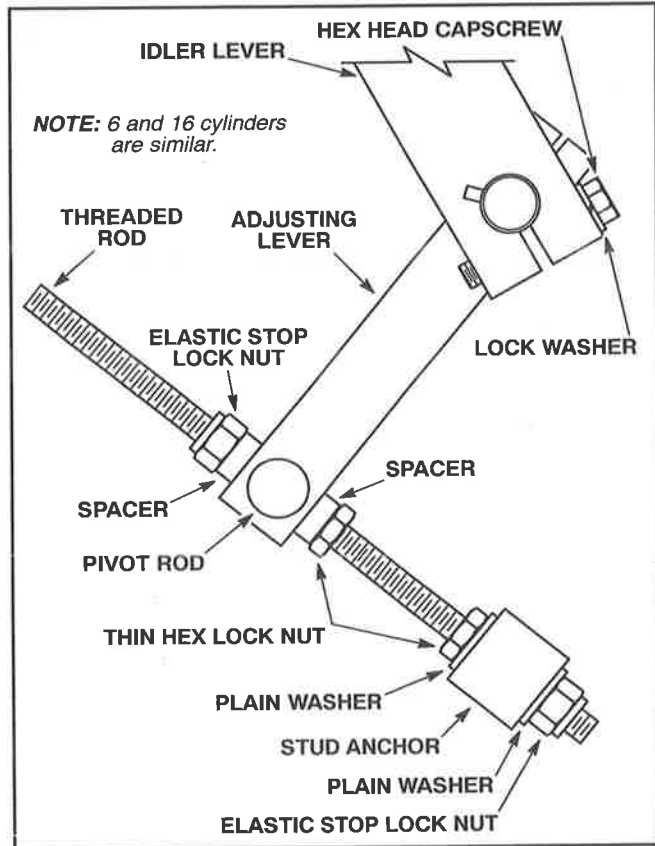
2. Verify that the pulley sheaves are clean and completely free of grease, oil, dirt and grit.

3. Inspect the drive belts for fraying, cracks or wear. Belts must not be glazed, split, peeled or greasy. Replace as necessary.

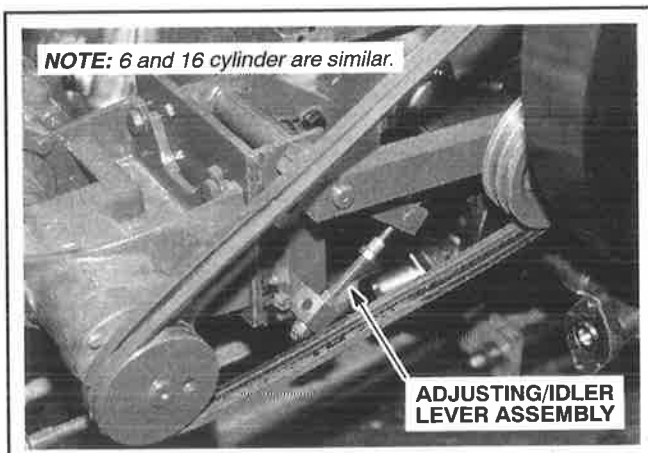
**⚠ CAUTION** Belts are matched and tied in sets. Always replace the drive belts in sets. Never replace just one drive belt even if only one belt is worn. Since the older belts are stretched during hours of engine operation, the circumference of new belts is slightly smaller. A difference in belt size will cause the new belt to carry the full load, resulting in rapid belt failure and possible damage to driven equipment. Disregarding this information could result in product damage and/or personal injury.

## COOLING SYSTEM MAINTENANCE

4. Remove the auxiliary water pump drive belts. Back the upper thin hex lock nut on the threaded rod away from the adjusting lever (see Figure 4.25-7 and Figure 4.25-8). The movement of the idler pulley releases the drive belt tension. Slip the drive belts off the auxiliary water pump and idler pulleys.

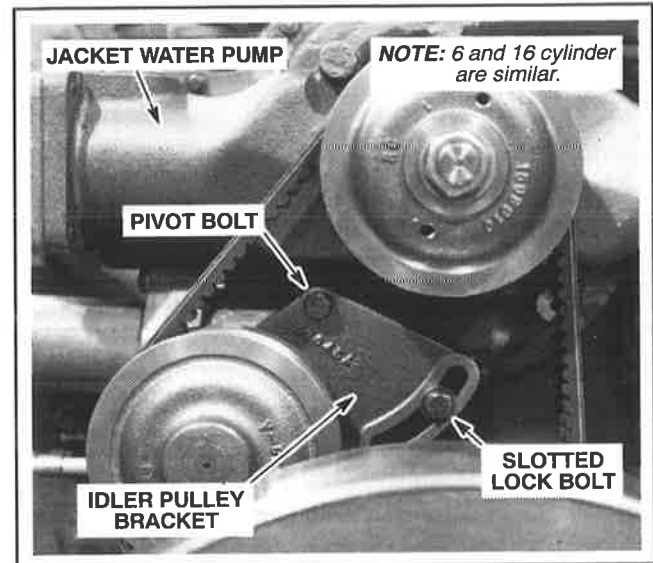


**Figure 4.25-7. Adjusting/Idler Lever Assembly - 12 Cylinder Shown**



**Figure 4.25-8. Adjusting/Idler Lever Assembly - 6 Cylinder Shown**

5. Loosen the pivot bolt on which the idler pulley bracket turns (see Figure 4.25-9). Loosen the slotted lock bolt to unlock the position of the bracket. The belt tension is released as the idler pulley bracket rotates.



**Figure 4.25-9. Tighten Idler Pulley Bracket Bolts - 12 Cylinder Shown**

6. Slip the old drive belts off the jacket water pump and idler pulleys. Remove the belts from the rear crankshaft pulley and discard.

7. Place a new drive belt in the rear groove of the rear crankshaft pulley. The rear groove is the one closest to the gear cover. Slip the belt into the rear groove of the jacket water pump pulley.

8. Place a new drive belt into the second last groove of the rear crankshaft and jacket water pump pulleys.

9. Rotate the idler pulley bracket clockwise to seat the jacket water pump drive belts in the two pulley grooves.

10. Refer to *Jacket Water Pump Drive Belt Tension Adjustment* to adjust the belts.

### **⚠ WARNING**

**Always install the safety guards after completing any service operation. Never operate the engine with the safety guards removed. Disregarding this information could result in product damage, severe personal injury or death.**

11. Install the safety guards.

### JACKET WATER PUMP DRIVE BELT TENSION ADJUSTMENT

Check the tension and condition of the two jacket water pump drive belts weekly. Replace the drive belts every 8000 running hours or as necessary.

**WARNING**

**Always install the safety guards after completing any service operation. Never operate the engine with the safety guards removed. Disregarding this information could result in product damage, severe personal injury or death.**

*NOTE: 5115GL engines and ebullient cooled engines, are not equipped with belts.*

1. Remove the safety guard.

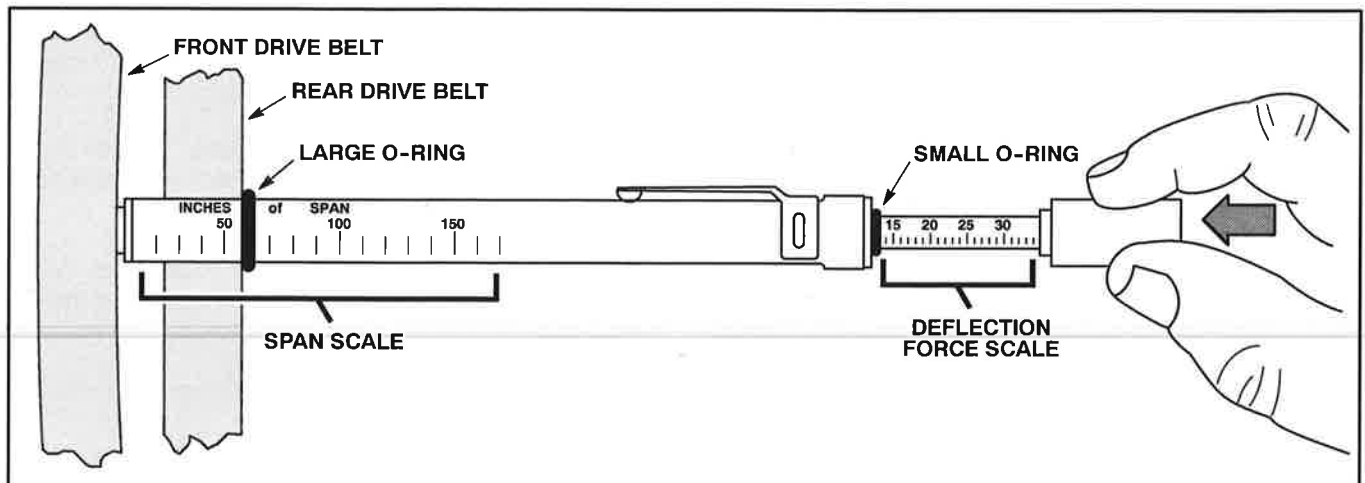
**CAUTION**

**Be sure that the belts are cool when the tension is checked or adjusted. The thermal expansion of warm belts will result in a false tension reading. Disregarding this information could result in product damage and/or personal injury.**

2. Using V-Belt Tension Tester (Tool P/N 474016), check the drive belt tension.

- A. Measure the distance between the center lines of the crankshaft and jacket water pump pulleys. Align the bottom of the large O-ring on the "Inches of Span" scale to the measured distance.
- B. Align the bottom of the small O-ring on the "Deflection Force" scale with the zero mark.
- C. Place the tension tester squarely on the front drive belt at the center of the longest unsupported span (between the jacket water pump pulley and the crankshaft pulley). Apply inward force on the plunger perpendicular to the belt span until the bottom of the large O-ring is even with the top of the rear drive belt (see Figure 4.25-10).
- D. Remove the tension tester and read the force applied from the bottom of the small O-ring on the deflection force scale. The tension of the belts must be between 11.9 - 17.5 lb. (53 - 77 N-m).
- E. Check the rear belt tension in the same manner.

*NOTE: If the tension tester is not available, moderate hand pressure should deflect the long part of the belt approximately 0.25 - 0.50 in. (6 to 13 mm) or as a general rule, 0.01562 in. (0.4 mm) per 1 in. (25.4 mm) of belt span measured from pulley center to pulley center. Belt span should be measured each time.*



**Figure 4.25-10. Drive Belt Tension Tester**

## COOLING SYSTEM MAINTENANCE

3. If belt tension adjustment is necessary, loosen the pivot bolt on which the idler pulley bracket turns (see Figure 4.25-11). Loosen the slotted bolt to unlock the position of the bracket. The belt tension is released as the idler pulley bracket rotates upward in a counter-clockwise direction.

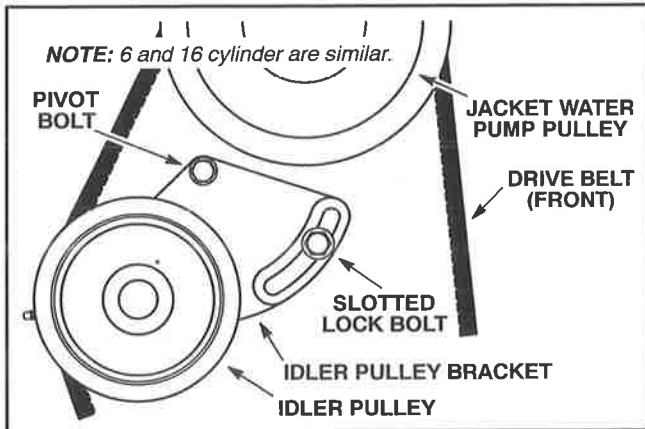


Figure 4.25-11. Jacket Water Pump Drive Belt Tensioning - 12 Cylinder Shown

**CAUTION** Belts that are too tight result in excessive stretching and overheating. Too much tension may also damage drive components, such as sheaves and shafts, and lead to premature failure of the idler pulley and/or water pump bearings. Disregarding this information could result in product damage and/or personal injury.

**CAUTION** Belts that are too loose result in belt slippage. Slippage causes burn spots, overheating, rapid wear and breakage. The vibration created by loose belts may also be sufficient to cause unnecessary wear of the pulley grooves. Disregarding this information could result in product damage and/or personal injury.

4. To reset the belt tension, insert a pry bar between the upper edge of the idler pulley bracket and the untapped boss on the left bank side of the water pump housing (see Figure 4.25-12). To tighten the drive belts, use the pad above the untapped boss for leverage and push up on the pry bar to move the idler pulley bracket downward (CW).

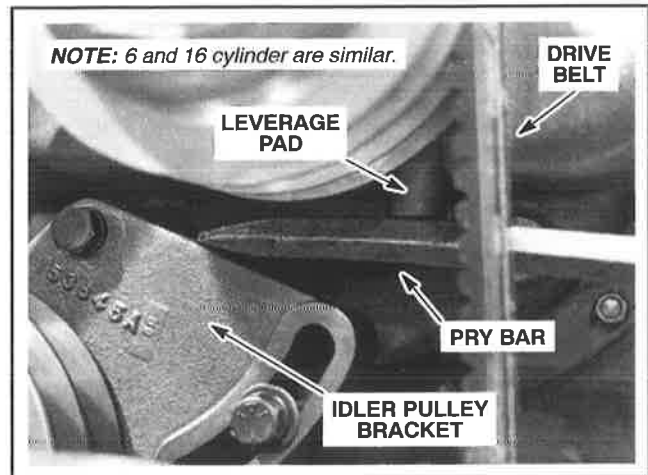


Figure 4.25-12. Jacket Water Pump Drive Belt Tension - 12 Cylinder Shown

5. Holding the pry bar in position, use the tension tester to apply inward pressure to the center of the longest unsupported span on the front drive belt (between the jacket water pump pulley and the crankshaft pulley).

6. Tension used belts between 11.9 and 17.5 lb.

**NOTE:** If the tension tester is not available, moderate hand pressure should deflect the long part of the belt approximately 0.25 - 0.50 in. (6 to 13 mm) or as a general rule, 0.01562 in. (0.4 mm) per 1 in. (25.4 mm) of belt span measured from pulley center to pulley center.

7. Tighten the slotted lock bolt on the idler pulley bracket when the proper belt tension is obtained (see Figure 4.25-11). Tighten the pivot bolt.

8. Inspect the belts for proper seating. V-belts should ride on the sides of the pulley sheaves, not on the bottom of the groove.

9. Verify that the tension of the front drive belt is between 11.9 and 17.5 lb. Verify the tension of the rear drive belt.

10. See *Auxiliary Water Pump Drive Belts Tension Adjustment*.

### **WARNING**

Always install the safety guards after completing any service operation. Never operate the engine with the safety guards removed. Disregarding this information could result in product damage, severe personal injury or death.

11. Install the safety guards.

## AUXILIARY WATER PUMP DRIVE BELT REPLACEMENT

### **⚠ WARNING**

Always install the safety guards after completing any service operation. Never operate the engine with the safety guards removed. Disregarding this information could result in product damage, severe personal injury or death.

**NOTE:** 5115GL engines are not equipped with belts.

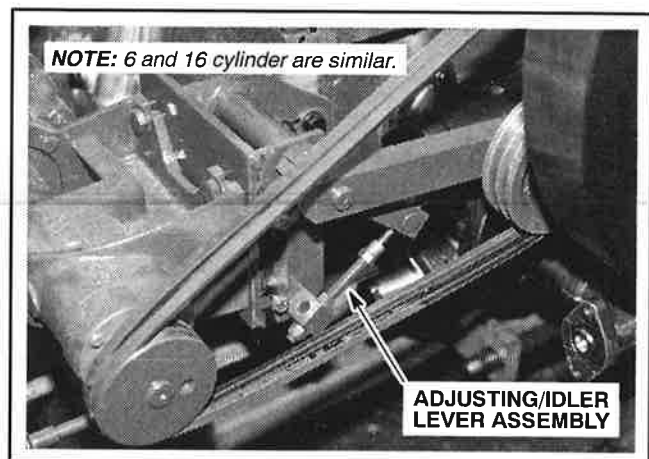
1. Remove the safety guard.

**⚠ CAUTION** An accumulation of dirt in the sheave grooves impairs traction and accelerates belt wear. Disregarding this information could result in product damage and/or personal injury.

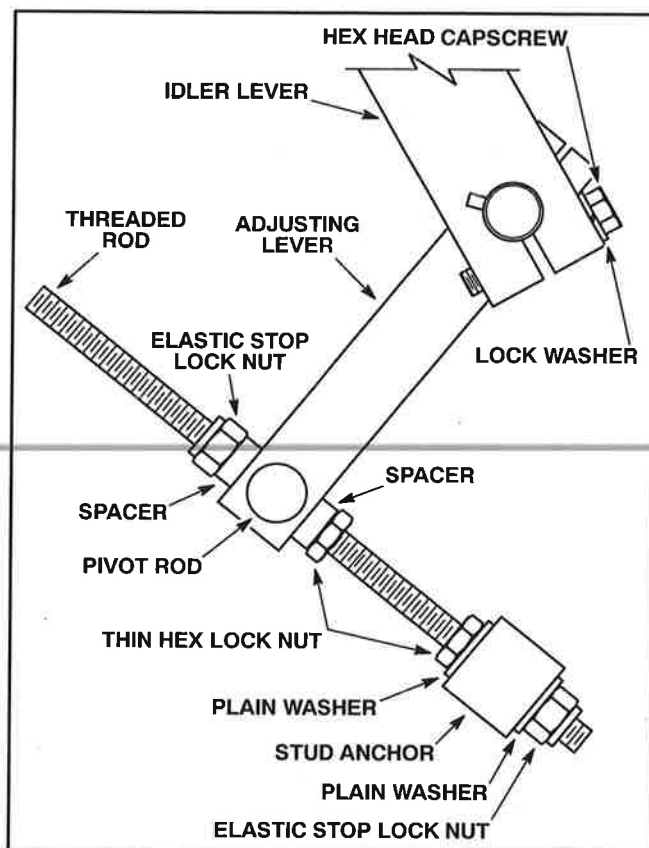
2. Verify that the pulley sheaves are clean and completely free of grease, oil, dirt and grit.

3. Inspect the drive belts for fraying, cracks or wear. Belts must not be glazed, split, peeled or greasy. Replace as necessary.

4. If replacement is necessary, back the upper thin hex lock nut on the threaded rod away from the adjusting lever (see Figure 4.25-13 and Figure 4.25-14). The pivot point of the idler lever follows the adjusting lever. The movement of the idler pulley releases the drive belt tension.

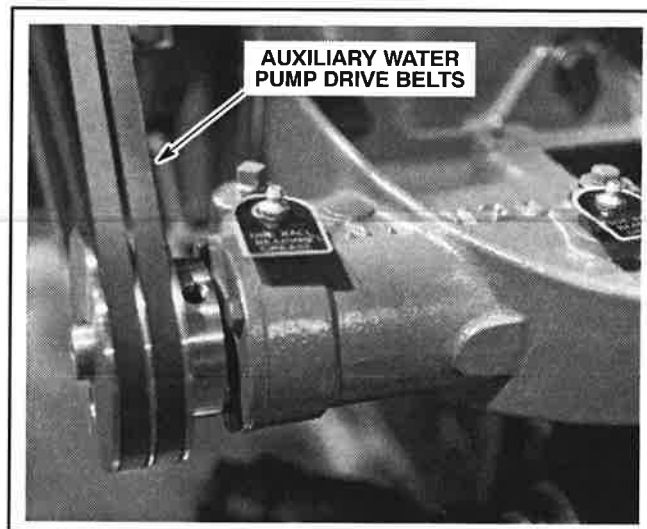


**Figure 4.25-13. Adjusting/Idler Lever Assembly - 6 Cylinder Shown**



**Figure 4.25-14. Adjusting/Idler Lever Assembly - 12 Cylinder**

5. Remove the drive belts from the auxiliary water pump and idler pulleys (see Figure 4.25-13 and Figure 4.25-15). Remove the belts from the rear crankshaft pulley and discard.



**Figure 4.25-15. Auxiliary Water Pump Belts - 12 Cylinder**



## COOLING SYSTEM MAINTENANCE

**CAUTION** Belts are matched and tied in sets of two. Always replace the drive belts in pairs. Never replace just one drive belt even if only one belt is worn. Since the older belts are stretched during hours of engine operation, the circumference of new belts is slightly smaller. A difference in belt size will cause the new belt to carry the full load, resulting in rapid belt failure and possible damage to driven equipment. Disregarding this information could result in product damage and/or personal injury.

6. Inspect the condition of the new auxiliary water pump drive belts. Replace as necessary.

7. Place the new drive belts in the rear groove of the rear crankshaft pulley (directly in front of the first jacket water pump drive belt) (see Figure 4.25-16). Slip the belts into the grooves of both the auxiliary water pump and idler lever pulleys.

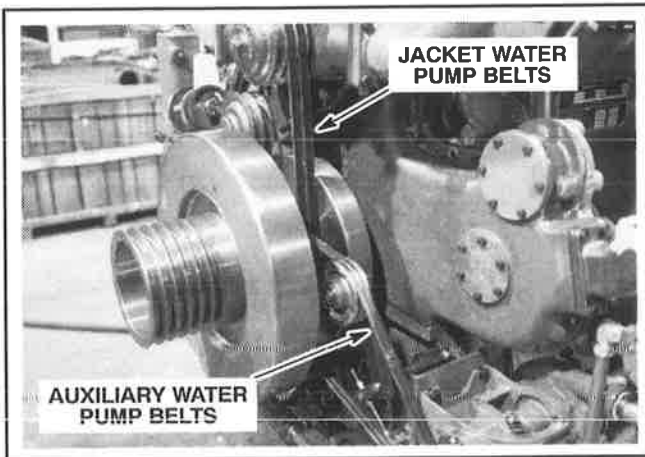


Figure 4.25-16. Jacket And Auxiliary Water Pump Belts - 12 Cylinder

8. To tighten the drive belts, thread the upper thin hex lock nut toward the adjusting lever. The pivot point of the idler lever follows the adjusting lever in a clockwise direction. The upward movement of the idler pulley increases the drive belt tension.

9. Refer to *Auxiliary Water Pump Drive Belt Tension Adjustment* to adjust the belts.

### **WARNING**

Always install the safety guards after completing any service operation. Never operate the engine with the safety guards removed. Disregarding this information could result in product damage, severe personal injury or death.

10. Install the safety guards.

## AUXILIARY WATER PUMP DRIVE BELT TENSION ADJUSTMENT

### **WARNING**

Always install the safety guards after completing any service operation. Never operate the engine with the safety guards removed. Disregarding this information could result in product damage, severe personal injury or death.

**NOTE:** 5115GL engines are not equipped with belts.

1. Remove the safety guard.

**CAUTION** Be sure that the belts are cool when the tension is checked or adjusted. The thermal expansion of warm belts will result in a false tension reading. Disregarding this information could result in product damage and/or personal injury.

2. Using V-Belt Tension Tester (Tool P/N 474016), check the auxiliary drive belt tension.

- Measure the distance between the center lines of pulleys of the longest belt span. Align the bottom of the large O-ring on the "Inches of Span" scale to the measured distance.
- Align the bottom of the small O-ring on the "Deflection Force" scale with the zero mark.
- Place the tension tester squarely on the front drive belt at the center of the longest unsupported span. Apply inward force on the plunger perpendicular to the belt span until the bottom of the large O-ring is even with the top of the rear drive belt (see Figure 4.25-17).
- Remove the tension tester and read the force applied from the bottom of the small O-ring on the deflection force scale. The tension of the belts must be between 5 - 8 lb. (22 - 35.6 N-m).
- Check the rear belt tension in the same manner.

**NOTE:** If the tension tester is not available, moderate hand pressure should deflect the long part of the belt approximately 0.25 - 0.50 in. (6 to 13 mm) or as a general rule, 0.01562 in. (0.4 mm) per 1 in. (25.4 mm) of belt span measured from pulley center to pulley center.



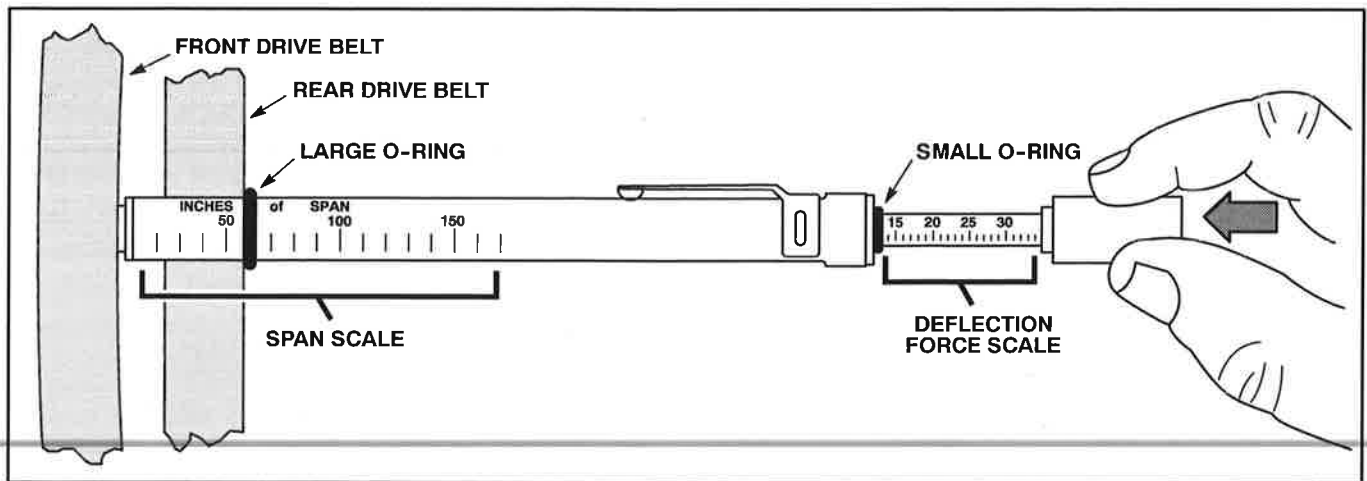


Figure 4.25-17. Drive Belt Tension Tester

**CAUTION** Belts that are too tight result in excessive stretching and overheating. Too much tension may also damage drive components, such as sheaves and shafts, and lead to premature failure of the idler pulley and/or water pump bearings. Disregarding this information could result in product damage and/or personal injury.

**NOTE:** Since the circumference of new belts is somewhat smaller, reuse of the setting established for the discarded drive belts will result in belts that are too tight.

3. To loosen the drive belts, back the upper thin hex lock nut on the threaded rod away from the adjusting lever. The pivot point of the idler lever follows the adjusting lever in a counter-clockwise direction. The downward movement of the idler pulley releases the drive belt tension.

4. When the correct tension is obtained, thread the 3/8 inch elastic stop lock on the upper end of the threaded rod toward the adjusting lever. Be sure that the lock nuts (thin hex and elastic stop) on each side of the adjusting lever are properly tightened.

5. Inspect the belts for proper seating. V-belts should ride on the sides of the pulley sheaves, not on the bottom of the groove.

6. Because of initial stretching, recheck the belt tension after 10 minutes run time. Check the belt tension again after the first 30 minutes run time and then every 250 hours thereafter.

**CAUTION** Belts that are too loose result in belt slippage. Slippage causes burn spots, overheating, rapid wear and breakage. The vibration created by loose belts may also be sufficient to cause unnecessary wear of the pulley grooves. Disregarding this information could result in product damage and/or personal injury.

7. To tighten the drive belts, back the elastic stop lock nut on the upper end of the threaded rod away from the adjusting lever. Use a 3/8 inch deepwell socket for best results.

8. Thread the upper thin hex lock nut toward the adjusting lever. The pivot point of the idler lever follows the adjusting lever in a clockwise direction. The upward movement of the idler pulley increases the drive belt tension.

9. When the correct tension is obtained, thread the elastic stop lock nut on the upper end of the threaded rod toward the adjusting lever. Be sure that the lock nuts (thin hex and elastic stop) on each side of the adjusting lever are properly tightened.

**WARNING**

Always install the safety guards after completing any service operation. Never operate the engine with the safety guards removed. Disregarding this information could result in product damage, severe personal injury or death.

10. Install the safety guards.

## COOLING SYSTEM MAINTENANCE

### JACKET/AUXILIARY WATER PUMP INSPECTION

#### Jacket Water Pump Inspection

5115GL engines jacket water pump inspection is limited to a visual inspection for leaks and visual inspection of the oil sight glass to determine if oil is contaminated with coolant. The location of the sight glass is similar to the sight glass location on the auxiliary water pump (see Figure 4.25-19).

#### **WARNING**

Always install the safety guards after completing any service operation. Never operate the engine with the safety guards removed. Disregarding this information could result in product damage, severe personal injury or death.

1. Remove the safety guard.
2. Inspect the "weep hole" in the casting directly below the water pump pulley (see Figure 4.25-18). The "weep hole" drains any coolant that leaks past the ceramic water pump seal.

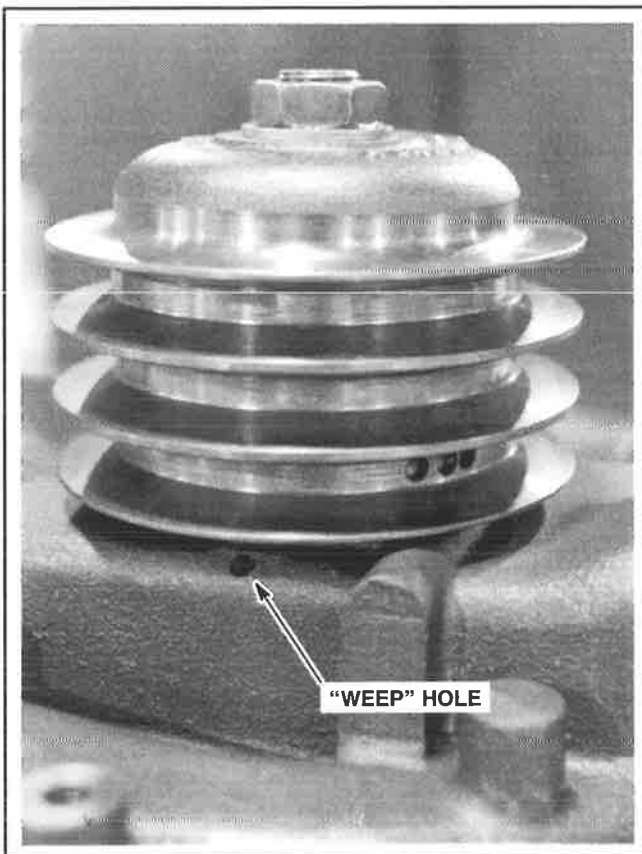


Figure 4.25-18. Jacket Water Pump "Weep" Hole - Water Pump Shown Removed

**CAUTION** The presence of coolant at the "weep hole" indicates that the jacket water pump must be rebuilt. A defective water pump seal results in coolant loss and contamination of the inner ball bearing grease. Disregarding this information could result in product damage and/or personal injury.

3. Notify a Waukesha certified technician if any coolant leakage at the "weep hole" is observed.

#### **WARNING**

Always install the safety guards after completing any service operation. Never operate the engine with the safety guards removed. Disregarding this information could result in product damage, severe personal injury or death.

4. Install the safety guards.

#### Auxiliary Water Pump Inspection

Auxiliary water pumps should be visually checked for leaks. 5115GL engine auxiliary water pumps should be visually checked for leaks and visual inspection of the oil sight glass to determine if oil is contaminated with coolant (see Figure 4.25-19).

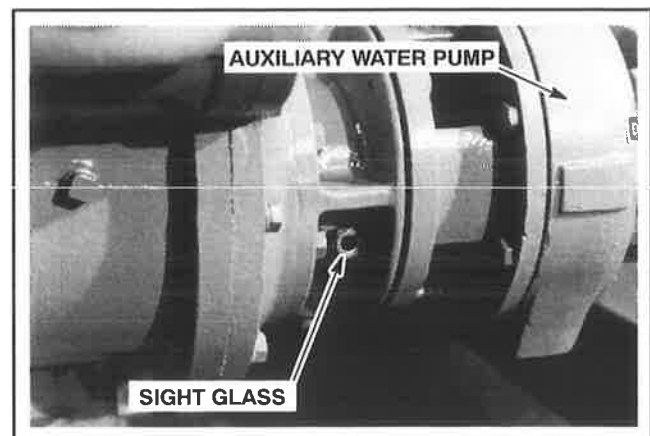


Figure 4.25-19. Auxiliary Water Pump - 5115GL

## SECTION 4.30

### LUBRICATION SYSTEM MAINTENANCE

#### LUBRICATION SYSTEM MAINTENANCE

**Table 4.30-1. Lubrication System**

	6 CYLINDER	12 CYLINDER *	5115GL	16 CYLINDER
Sump capacity, including filter and cooler*	72 gallons (272.5 litres)	99 gallons (375 litres)	99 gallons (376 litres)	165 gallons (625 litres)
Oil pan (Low level mark)	35 gallons (132.5 litres)	35 gallons (132.5 litres)	35 gallons (132.5 litres)	80 gallons (303 litres)
Oil pan (High level mark)	45 gallons (170.3 litres)	45 gallons (170.3 litres)	54 gallons (204.4 litres)	110 gallons (416 litres)
Lube Oil Filter Capacity	20 gallons (75.7 litres)	36 gallons (136.3 litres)	36 gallons (136.3 litres)	45 gallons (170 litres)
Oil Cooler Capacity	(8 in.) 6.9 gal. (26.1 L) (10 in.) 10 gal. (37.8 L)	(8 in.) 6.9 gal. (26.1 L) (10 in.) 10 gal. (37.8 L)	9.0 gallons (34.1 litres)	10 gallons (38 litres)

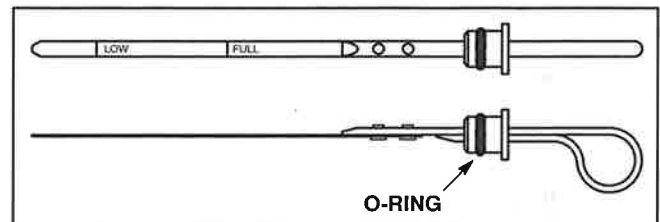
**NOTE:** \* Does not include 5115GL model.

#### OIL FILL - INITIAL PROCEDURE

The oil capacities listed in Table 4.30-1 represent approximate amounts. Use the initial fill to determine the actual amount of oil required. Table 4.30-2 lists oil recommendations.

**CAUTION** The lube oil piping must be purged of all slag and debris before the engine is first started. Before proceeding with the oil fill procedure, refer to the purging instructions in this section. Disregarding this information could result in product damage and/or personal injury.

1. Remove the cap from the oil filler pipe on the lower rear left side of the engine (see Figure 4.30-2).
2. Refer to *Oil Filter Maintenance*, and fill the oil filter with the proper grade oil.
3. Insert the make-up line and add lube oil to the oil pan. Periodically remove the dipstick and take note of the reading.
4. Continue to add oil to the oil pan until the level reaches the "full" mark on the dipstick (see Figure 4.30-1).
5. Stop adding oil and start the prelube pump. The prelube pump must be run to fill the oil lines, oil cooler, the full-flow lube oil filter and oil strainer. It also ensures that the bearings, turbochargers and other moving parts of the engine are properly lubricated.



**Figure 4.30-1. Dipstick**

**CAUTION** Filter must be filled with lubricating oil before first start and after each element change. Disregarding this information could result in product damage.

6. Depress the bypass valve plunger inside filter to allow air to escape. Before first startup, vent air through the cover vent while the prelube pump is still running. A continuous flow of oil from the vent line is required and indicates that all air has been removed from the lube oil system.
7. Run the prelube pump until pressure is indicated on the oil pressure gauge. Stop the prelube pump, wait a few minutes for the oil to drain back into the crankcase, check the dipstick and add oil to the oil pan until the level returns to the "full" mark.

## LUBRICATION SYSTEM MAINTENANCE

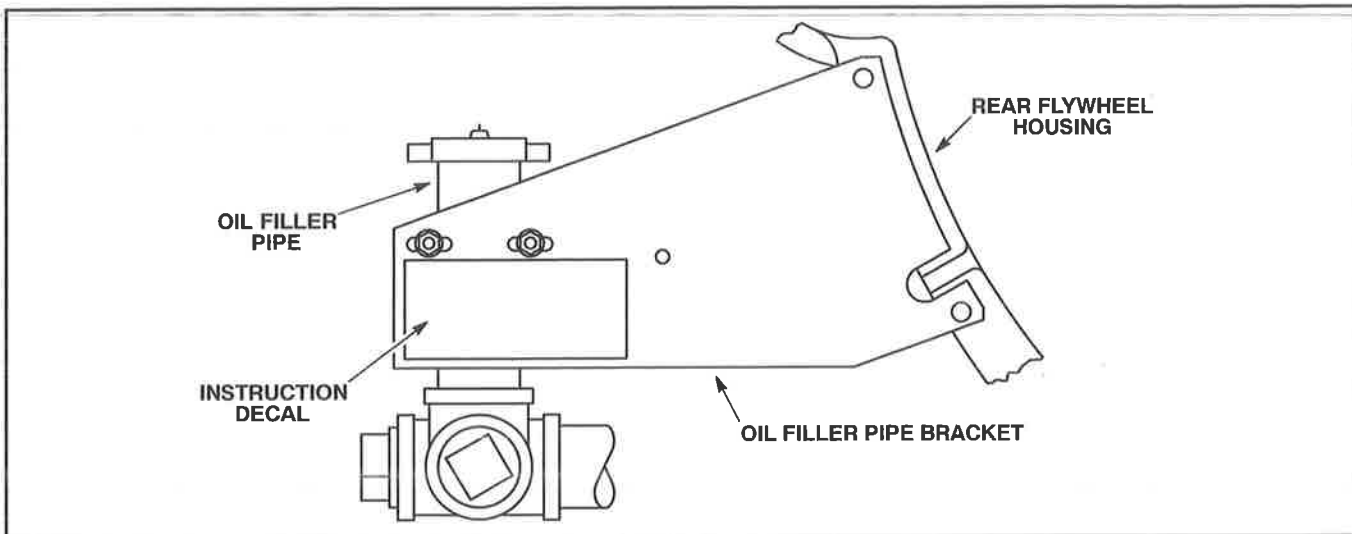


Figure 4.30-2. Oil Filler Pipe

8. Install the oil filler cap, start the engine and wait until the lube oil has warmed up to its normal operating temperature. Shut the engine down, wait for the oil to drain back into the pan and then check the level one more time. Add oil if the level is below the "full" mark.

9. Check the crankcase oil level daily before the engine is started. The blade of the dipstick is marked "low" and "full." Always maintain the oil level at the "full" mark. Both marks on the dipstick are "static lines." The dipstick does not indicate where the level of the oil should be when the engine is running.

### OIL COOLER AND LUBE OIL FILTER INSTALLATION REQUIREMENTS

1. All piping connections to and from the engine and between lubrication system accessories are to be supplied by the customer. Place the lube oil filter and lube oil cooler assemblies as close to the engine as possible. All customer connections to the engine must be flexible.

2. Verify that all lines between the engine and the lube oil filter and lube oil cooler assemblies are clean and free from scale.

3. Filter must be filled with lubricating oil before first start and after element change. Depress bypass valve plunger inside filter to allow air to escape. Before first startup, vent air thru cover vent while prelube pump is running. A continuous flow of oil from the vent line is required, and indicates that all air has been removed from the system.

4. Refer to *Lube Oil Pressure Adjustment* and adjust the lube oil pressure.

### PURGING THE LUBE OIL SYSTEM PIPING

The external lube oil piping must be purged of all dirt, weld spatter and slag. The purging procedure must be performed during the initial oil fill.

1. Remove the four capscrews and washers from the strainer head to detach the element housing (see Figure 4.30-3).

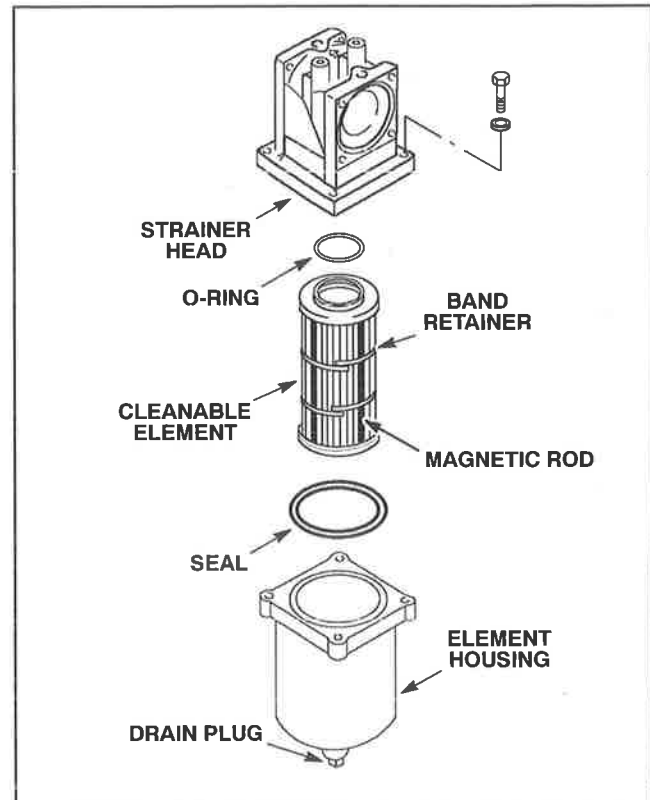


Figure 4.30-3. Lube Oil Strainer Assembly

2. Pull down on the stainless steel wire mesh element to detach it from the head. Install the paper element provided. The paper element has a nominal filter rating of 20 microns.
3. Fill the engine with oil (see *Initial Fill* in this section) and run the prelube pump for a minimum of one hour. During this period, use a ballpeen hammer and lightly tap on all pipe welds to dislodge any internal slag.
4. Remove the paper element from the strainer after the hour has elapsed.
5. Install the second paper element; run the prelube pump for a second hour (minimum).
6. Inspect the second paper element for cleanliness after the second hour has elapsed. Since all slag and debris should have been removed from the piping by the first paper element during the first hour the prelube pump was run, the second element should only be used to verify cleanliness. If the second element is dirty, install a new paper element and repeat the procedure until the element comes out clean.

**CAUTION** The paper element is only to be used for flushing the lubrication piping during initial startup of new and rebuilt engines. Install the stainless steel element after the purging procedure is completed. Do not run the engine with the paper element in place. The paper element cannot withstand engine operating pressures and will collapse, allowing unfiltered oil to enter the engine.

7. Remove the paper element after verifying cleanliness and discard.
8. Install the stainless steel wire mesh element, and element housing to the strainer head, with O-ring, seal, four capscrews and washers.

### CRANKCASE OIL LEVEL CHECKING

Check the crankcase oil level daily before the engine is started. For convenience, a dipstick is located on both the right and left side of the oil pan (see Figure 4.30-1). The blade of the dipstick is marked "low" and "full." Always maintain the oil level at the "full" mark. Both marks on the dipstick are "static lines." The dipstick does not indicate where the level of the oil should be when the engine is running.

When checking the oil level, carefully examine the condition of the oil on the dipstick. Replace the oil any time it appears diluted, thickened by sludge or otherwise deteriorated. The useful life of the oil depends on a number of factors, which include the engine load, temperature, fuel quality, atmospheric dirt, moisture and

the level of maintenance. If oil performance problems arise, consult your oil supplier.

Always pay close attention to engine operating temperatures. If engine jacket water and oil temperatures are maintained according to engine specifications, particularly during periods of light load operation, the problems resulting from condensation of corrosive vapors in the crankcase can be minimized.

When using an engine oil for which there is no previous operating experience, a detailed oil analysis by qualified professionals is strongly recommended. A well monitored maintenance program also should be established for the first year of usage and the performance of the engine should be carefully observed against all external operating conditions. This procedure will help to determine if the selected oil is really suitable for your particular operation.

**NOTE:** If any questions arise with regard to the foregoing information, do not hesitate to call the WED Product Support or Application Engineering Departments. The engine operator may also wish to refer to Service Bulletin 12-1880V, or latest revision, for more information on lubricating oils.

### OIL CHANGE

#### **WARNING**

Hot oil can cause severe burns. Allow oil to cool prior to working on lube oil system components. Wear protective equipment and use caution while working on lube oil system components. Failure to follow proper procedures could cause severe personal injury or death.

To change the oil, drain the oil pan and all lube oil system accessories; oil cooler, full-flow oil filter and lube oil strainer. Proceed as follows:

**NOTE:** Drain oil when warm for best results.

1. Oil pan: remove the 2 inch square head drain plug. For convenience, four drain plugs are provided, one at each corner of the oil pan. retain an oil sample for oil analysis. Install the drain plugs when the oil has drained.

**NOTE:** Installation of a customer-supplied ball valve and pump facilitates draining of the oil pan.

2. Oil Cooler: remove the drain plug at the bottom of the oil cooler shell midway between the inlet and rear bonnets. Install the drain plug when the oil has drained.

## LUBRICATION SYSTEM MAINTENANCE

3. Full-Flow Lube Oil Filter: remove the upper drain plug from the oil filter housing to drain sludge and dirty oil from the filter element chamber. Remove the lower plug to drain oil from the clean oil chamber (see Figure 4.30-11). Install the drain plugs when the oil has drained.

4. Lube Oil Strainer: remove the drain plug (3/8 inch) at the bottom of the strainer element housing (see Figure 4.30-3). Install the drain plug when the oil has drained.

5. When the oil has drained, insure all the drain plugs are reinstalled.

6. Refer to *Oil Pan Maintenance*, and clean the oil pan.

**CAUTION** Filter must be filled with lubricating oil before first start and after each element change. Disregarding this information could result in product damage.

7. Refer to *Oil Filter Maintenance*, and replace the oil filter elements and fill the oil filter assembly with oil (see Table 4.30-1 and Table 4.30-2).

8. Refer to *Initial Fill Procedures*, and fill the engine with oil (see Table 4.30-1 and Table 4.30-2).

9. Refer to *Lube Oil System Air Bleed*, and bleed trapped air from the lube oil system.

## OIL PAN MAINTENANCE

**NOTE:** Since it is necessary to drain the oil pan and lube oil system accessories, schedule the cleaning during a regular oil change interval.

**NOTE:** Drain oil when warm.

1. Drain the oil pan, oil cooler, full-flow oil filter and lube oil strainer (see *Oil Change* for more information).

2. Loosen the oil pan door clamp capscrews (see Figure 4.30-4 and Figure 4.30-5). Rotate the assembly about 45 degrees to remove the door from the access hole.

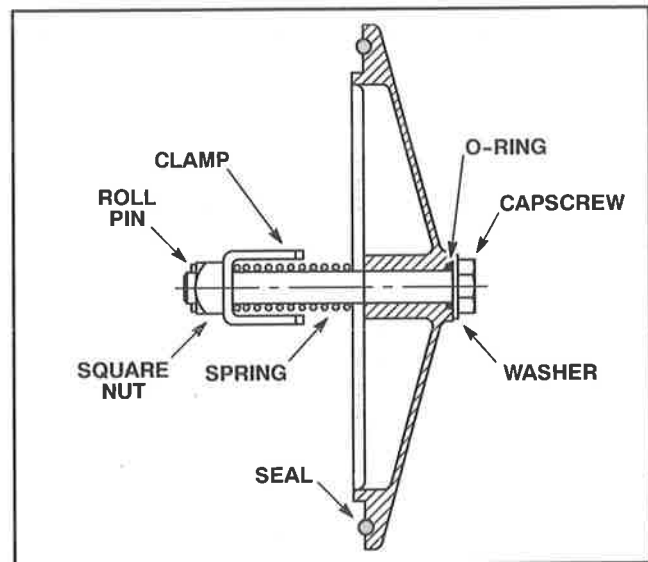


Figure 4.30-4. Oil Pan Door - Previous Production

Table 4.30-2. Oil Recommendations By Model And Fuel

MODEL/FUEL	OIL REQUIREMENTS
VHP 2895, 3521, 5108, 5790, 7042, 9390 G, GSI, (Rich Burn or Lambda 1) Naturally Aspirated and Turbocharged/ Natural Gas/HD-5 Propane <sup>1 2 3 4</sup>	NATURAL GAS - 0.35% ash minimum, oil specifically formulated for gas engines, using highly refined mineral oil base stocks, with a minimum of 0.35% sulfated ash by weight with both metallic and ashless additive systems. A maximum of 0.10% zinc is recommended.
VHP 2895, 5108, 5790 GL Turbocharged and Lean Burn (Lambda 1.5 - 2)/Natural Gas/HD-5 Propane <sup>1 2 3 4</sup>	NATURAL GAS - 0.35% ash minimum, oil specifically formulated for gas engines, using highly refined mineral oil base stocks, with a minimum of 0.35% sulfated ash by weight with both metallic and ashless additive systems. A maximum of 0.10% zinc is recommended.
VHP 3521, 5115, 7042, 9390 GL Turbocharged and Lean Burn (Lambda 1.5 - 2)/Natural Gas/HD-5 Propane <sup>1 2 3 4</sup>	NATURAL GAS - Oil with a <i>nominal</i> 1% sulfated ash by weight. This gas engine oil must use highly refined mineral oil base with a minimum of 0.9% and a maximum of 1.7% sulfated ash by weight with both metallic and ashless additive systems. A maximum of 0.10% zinc is recommended.

**NOTE:** <sup>1</sup> See Table 4.30-11 and Table 4.30-12 for change intervals.

<sup>2</sup> See Table 4.30-8 for condemning limits.

<sup>3</sup> Oil with 0.35% ash or less may be used in naturally aspirated and catalyst equipped naturally aspirated or turbocharged engines with the understanding that valve recession may occur, thus shortening the normally expected valve and seat life.

<sup>4</sup> The quality of oil filtration will directly affect engine component life. Waukesha's basic filtration requirement is 90% efficient at 15 microns for all full flow elements, and 98% efficient at 25 microns for cleanable metal mesh elements. Waukesha's complete oil filter performance specification is shown in Waukesha specification sheets S08486 and S08486-1.

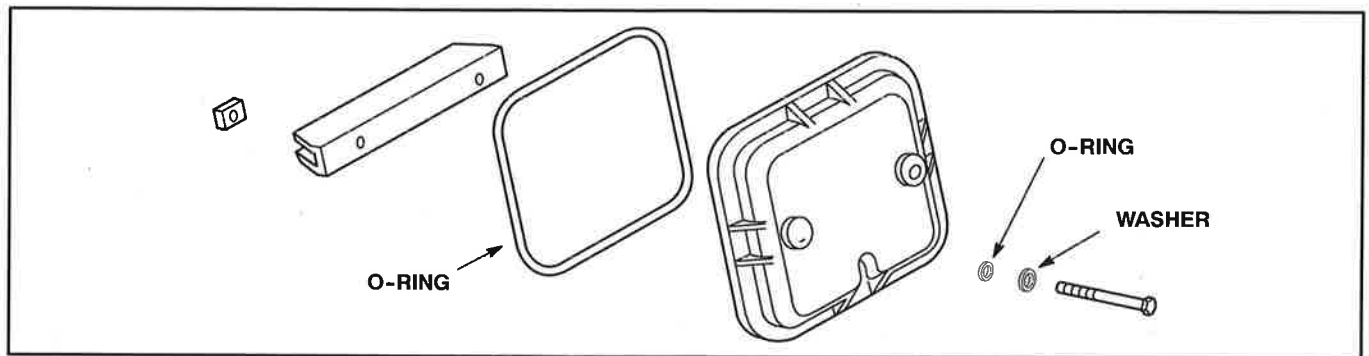


Figure 4.30-5. Oil Pan Door Assembly - Current Production

3. A small pool of oil about 3/4 inch deep will normally accumulate on each end of the oil pan where the casting is recessed. Only a thin film will cover the other internal surfaces. Using absorbant cloths, wipe the oil pan clean. Thoroughly clean the channel that connects the two recessed areas.

4. Clean the oil pickup screen (see *Oil Pickup Screen Maintenance*).

5. Install the oil pan doors. Hold each door so that the rear clamp is 45 degrees from the vertical position. Insert the clamp into the oil pan access hole. Holding the door against the face of the access hole, rotate the door until the clamp is in the horizontal position. Tighten the door clamp capscrew.

6. Refer to *Oil Change* and refill the engine with the proper quantity and grade of lubrication oil (see Table 4.30-1 and Table 4.30-2).

### OIL PICKUP SCREEN MAINTENANCE

#### Oil Pickup Screen Removal - 6 Cylinder

1. Remove the four capscrews and lock washers to detach the pickup screen assembly from the oil elbow and cover bracket (see Figure 4.30-6).

2. Remove the pickup screen assembly from the oil pan.

3. Remove the baffle and oil tubes from the pickup screen.

4. Scrape the old gasket material from the oil tube flanges and baffle box. Old gasket material left on the mating surfaces may cause air or unfiltered oil to leak into the oil tubes.

5. Remove two capscrews, lock washers, gasket and oil elbow from the crankcase.

6. Remove two capscrews, lock washers and cover bracket from the crankcase.

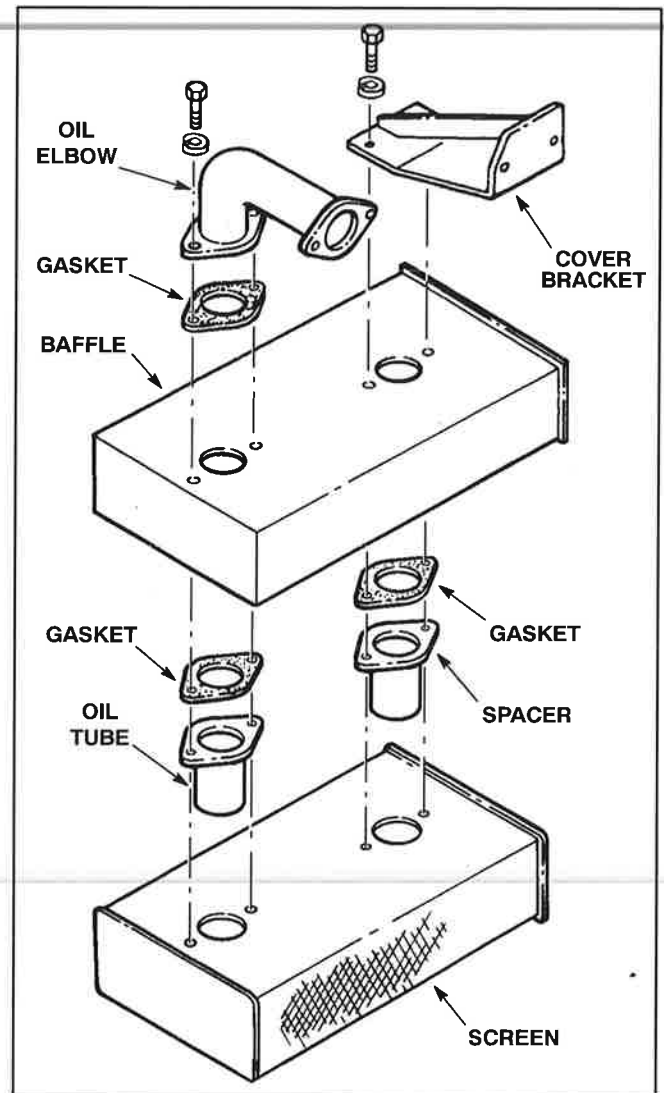


Figure 4.30-6. Oil Pickup Screen Assembly - 6 Cylinder

## LUBRICATION SYSTEM MAINTENANCE

### Oil Pickup Screen Cleaning And Inspection - 6 Cylinder

1. Clean all parts of the assembly in a non-volatile cleaning solution or solvent. Flush the screen from the inside out for best results.

### **⚠ WARNING**

**Compressed air can pierce the skin and cause severe injury. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.**

2. Thoroughly dry all parts with low pressure compressed air.

3. Inspect the pickup screen for tears or holes. Replace the screen if damaged.

4. Inspect the baffle box for broken welds, split seams or cracks around the oil tube holes. Replace the baffle if damaged.

### Oil Pickup Screen Installation - 6 Cylinder

1. Loosely install the cover bracket in the crankcase with two capscrews and lock washers.

2. Loosely install the oil elbow in the crankcase with gasket two capscrews and lock washers.

3. Apply a fast setting gasket adhesive, such as 3M Scotch-Grip™ Rubber And Gasket Adhesive, on the oil tube flanges. Position new gaskets on the flanges.

4. Scrape the old gasket material from the oil tube flanges and baffle box. Old gasket material left on the mating surfaces may cause air or unfiltered oil to leak into the oil tubes.

5. Install the oil tubes in the screening element. Place the baffle over the screen aligning the holes with those in the flange gaskets.

6. Obtain a new gasket for the elbow and apply gasket adhesive to one side. Press the sticky side of the gasket onto the baffle aligning the holes with those in the box.

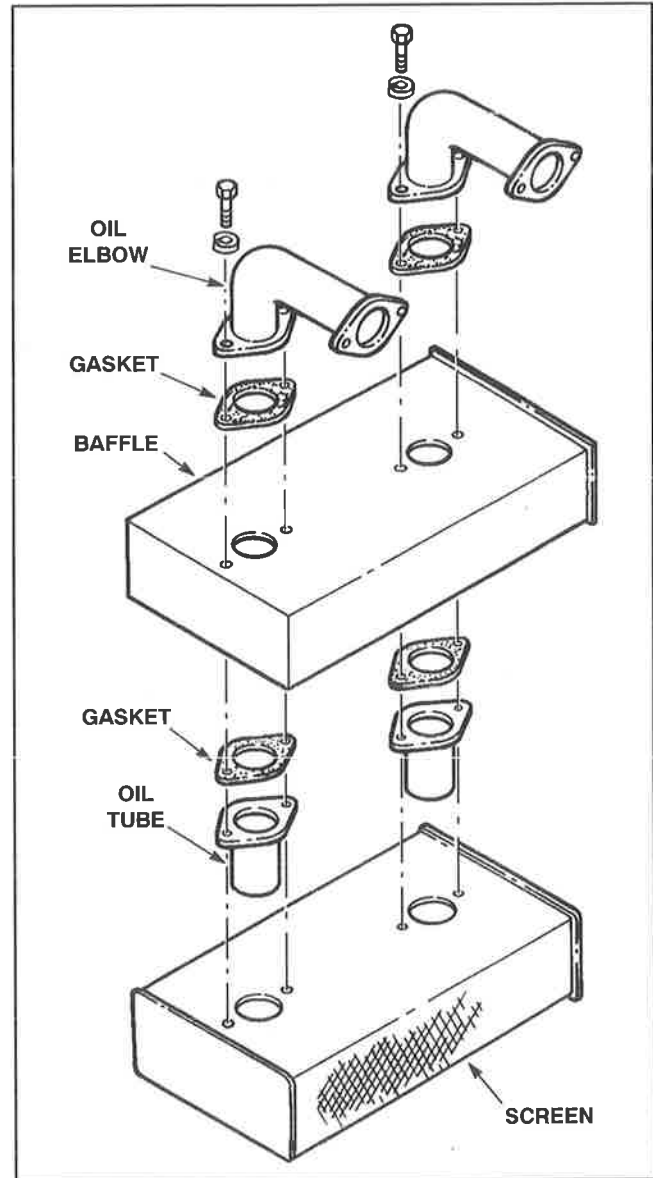
7. To ensure proper alignment, install the four capscrews and lock washers to hold the pickup screen assembly together. After the unit is positioned in the oil pan, remove one capscrew. Slide the capscrew through the elbow or cover bracket and thread it back into the pickup screen assembly. Follow this procedure with the remaining three capscrews. Wrench tighten only after all capscrews are in place.

8. Tighten the four capscrews to secure the oil elbow and cover bracket to the crankcase.

### Oil Pickup Screen Removal - 12 Cylinder

**NOTE: 5115GL procedures are listed separately.**

1. Remove the four capscrews and lock washers to detach the pickup screen assembly from the two oil elbows (see Figure 4.30-7).



**Figure 4.30-7. Oil Pickup Screen Assembly - 12 Cylinder**

2. Remove the pickup screen assembly from the oil pan.

3. Remove the baffle and oil tubes from the pickup screen.



4. Scrape the old gasket material from the oil tube flanges and baffle box. Old gasket material left on the mating surfaces may cause air or unfiltered oil to leak into the oil tubes.

### Oil Pickup Screen Cleaning And Inspection - 12 Cylinder

1. Clean all parts of the assembly in a non-volatile cleaning solution or solvent. Flush the screen from the inside out for best results.

### WARNING

**Compressed air can pierce the skin and cause severe injury. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.**

2. Thoroughly dry all parts with low pressure compressed air.

3. Inspect the pickup screen for tears or holes. Replace the screen if damaged.

4. Inspect the baffle box for broken welds, split seams or cracks around the oil tube holes. Replace the baffle if damaged.

### Oil Pickup Screen Installation - 12 Cylinder

1. Apply a fast setting gasket adhesive, such as 3M Scotch-Grip™ Rubber And Gasket Adhesive, on the oil tube flanges. Position new gaskets on the flanges.

2. Scrape the old gasket material from the oil tube flanges and baffle box. Old gasket material left on the mating surfaces may cause air or unfiltered oil to leak into the oil tubes.

3. Install the oil tubes in the screening element. Place the baffle over the screen aligning the holes with those in the flange gaskets.

4. Obtain two new gaskets for the elbows and apply gasket adhesive to one side. Press the sticky side of the gasket onto the baffle aligning holes with those in box.

5. Verify that the two elbow flanges are clean. Old gasket material or adhesive left on the mating surfaces may cause air or unfiltered oil to leak into the elbows.

6. To ensure proper alignment, install the four capscrews and lock washers to hold the pickup screen assembly together. After the unit is positioned in the oil pan, remove one capscrew. Slide the capscrew through the elbow and thread it back into the pickup screen assembly. Follow this procedure with the remaining three capscrews. Wrench tighten only after all capscrews are in place.

### Oil Pickup Screen Removal - 5115

1. Remove the two nylok capscrews and washers to detach the pickup screen assembly from oil pan floor (see Figure 4.30-8).

2. Moving the pickup screen slightly from side to side while pulling back on the pickup screen assembly, pull the oil outlet tube and the pickup screen assembly. This should allow the pickup screen assembly to be removed from the oil pump suction manifold on the front of the oil pan.

3. With the pickup screen assembly still loose in the oil pan, remove four nylok capscrews, washers and the outlet tube from the pickup screen assembly.

4. Remove the pickup screen assembly and the oil outlet tube from the oil pan.

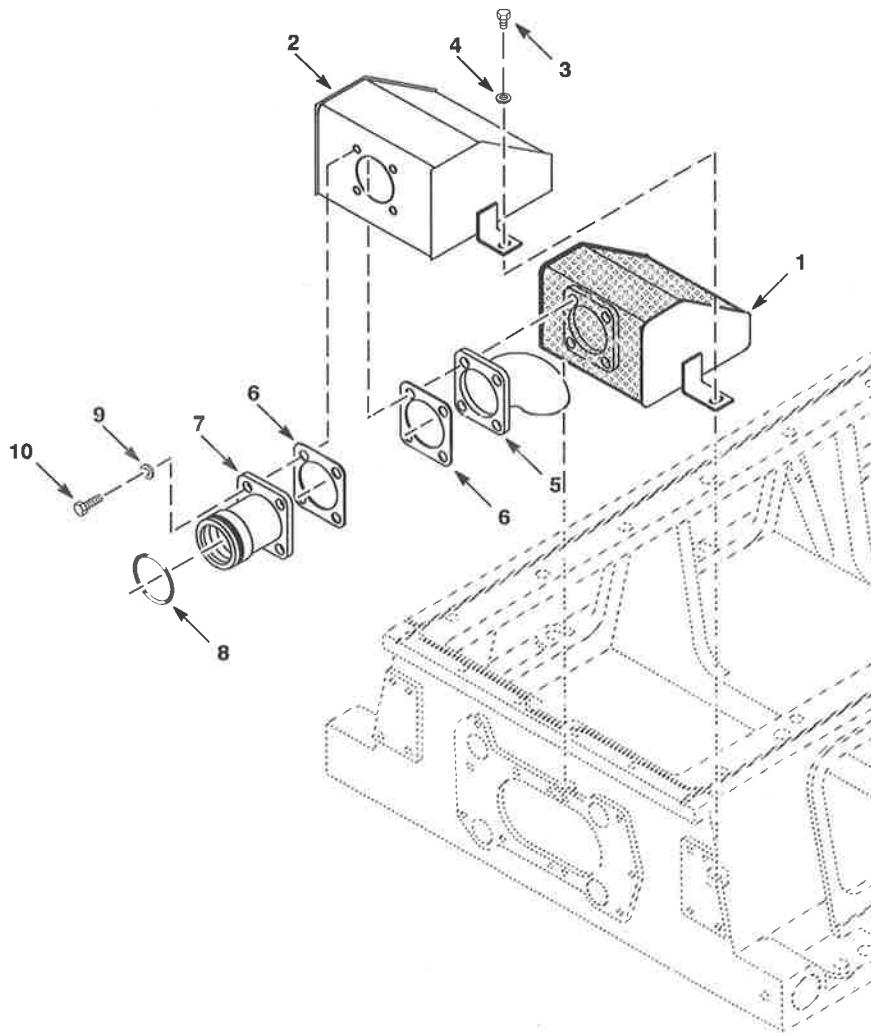
5. Remove the tube assembly from inside the pickup screen assembly.

6. Remove the screen from the baffle.

7. Scrape the old gasket material from the oil tube flanges and baffle box. Old gasket material left on the mating surfaces may cause air or unfiltered oil to leak into the oil tubes.

8. Remove and discard the O-ring from the oil outlet tube.

# LUBRICATION SYSTEM MAINTENANCE



**ITEM NUMBER AND DESCRIPTION**

1	Oil Screen Asm.	4	Flat Washer	7	Outlet Tube Asm.	10	Nylok Capscrew
2	Oil Screen Baffle	5	Tube Asm.	8	O-ring		
3	Nylok Capscrew	6	Lube System Gasket	9	Flat Washer		

**Figure 4.30-8. Oil Pickup Screen Assembly - 5115**

## Oil Pickup Screen Cleaning And Inspection - 5115

1. Clean all parts of the assembly in a non-volatile cleaning solution or solvent. Flush the screen from the inside out for best results.

### **WARNING**

Compressed air can pierce the skin and cause severe injury. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.

2. Thoroughly dry all parts with low pressure compressed air.

3. Inspect the pickup screen for tears or holes. Replace the screen if damaged.

4. Inspect the baffle box for broken welds, split seams or cracks around the oil tube holes. Replace the baffle if damaged.

## Oil Pickup Screen Installation - 5115

1. Apply a fast setting gasket adhesive, such as 3M Scotch-Grip™ Rubber And Gasket Adhesive, on the oil tube flanges. Position new gaskets on the flanges.
2. Scrape the old gasket material from the oil tube flanges and baffle box. Old gasket material left on the mating surfaces may cause air or unfiltered oil to leak into the oil tubes.
3. Obtain two new gaskets and apply gasket adhesive to one side. Press the sticky side of the gaskets on the inside and outside of the baffle, aligning the holes with those in the box.
4. Install a new O-ring on the oil outlet tube.
5. Install the oil tube in the screening element. Place the baffle over the screen aligning the holes with those in the flange gaskets.
6. Position the screen assembly in the oil pan.
7. Install the the oil outlet tube on the screen assembly with four nylok capscrews and washers.
8. Moving the pickup screen slightly from side to side while pushing forward on the pickup screen assembly, install the oil pickup assembly in the oil pump suction manifold on the front of the oil pan.

**CAUTION** Insure the oil outlet tube is completely seated in the oil pump suction manifold or damage to equipment could result.

9. Secure the pickup screen assembly to the oil pan with two nylok capscrews and washers. If the holes do not line up, it is an indication that the oil outlet tube is not completely seated in the oil pump suction manifold on the front of the oil pan.

## Oil Pickup Screen Removal - 16 Cylinder

1. Remove two capscrews and washers to detach the baffle and screen flanges from the oil pan floor (see Figure 4.30-9).
2. Remove the two ferry head capscrews and lockwashers from the elbow outlet flange.
3. Clip and remove the lockwire from the two ferry head capscrews on the elbow inlet flange (see Figure 4.30-10). Loosen the capscrews and remove the pickup screen assembly from the oil pan.
4. Remove the elbow, tube and and baffle from the pickup screen. remove and discard all gaskets. Scrape off any old gasket material left on the mating surfaces, if necessary.

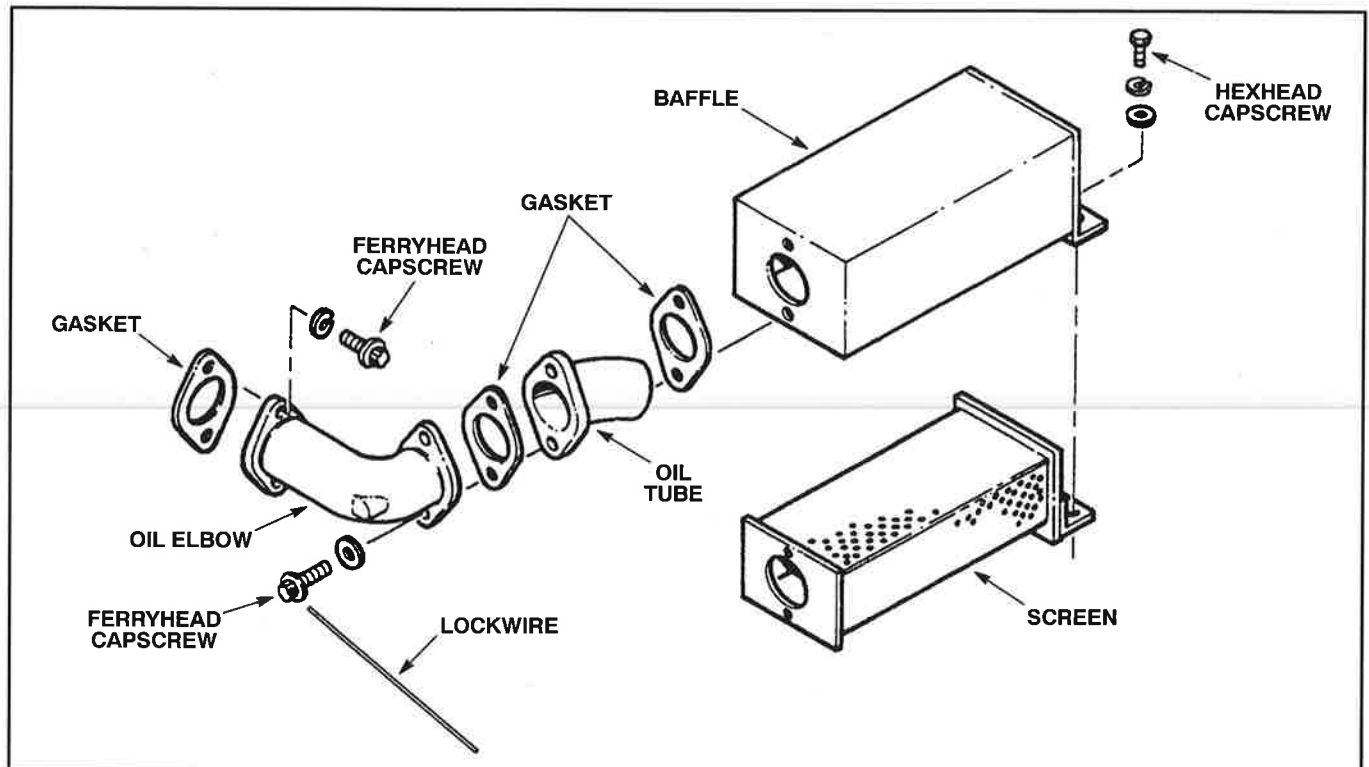


Figure 4.30-9. Oil Pickup Screen Assembly - 16 Cylinder

## LUBRICATION SYSTEM MAINTENANCE

### Oil Pickup Screen Cleaning And Inspection - 16 Cylinder

1. Clean all parts of the assembly in a non-volatile cleaning solution or solvent. Flush the screen from the inside out for best results.

#### **WARNING**

**Compressed air can pierce the skin and cause severe injury. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.**

2. Thoroughly dry all parts with low pressure compressed air.

3. Inspect the pickup screen for tears or holes. Replace the screen if damaged.

4. Inspect the baffle box for broken welds, split seams or cracks around the oil tube holes. Replace the baffle if damaged.

### Oil Pickup Screen Installation - 16 Cylinder

1. Install a new gasket on the inlet side of the oil tube flange. Position the baffle over the screen and insert the tube.

2. Position a new gasket on the elbow inlet flange. Install the two ferry head capscrews and washers to hold all parts of the assembly together. Use the two screws with the head holes (see Figure 4.30-9) and finger tighten only.

3. Position the assembly in the oil pan. Position a new gasket on the elbow outlet flange and install the oil outlet flange on the side of the oil pan with with two ferry head capscrews and lockwashers.

4. Install the pickup screen to the oil pan floor with two capscrews and lock washers.

5. Wrench tighten the elbow inlet flange capscrews. Slide a new lockwire through the hole in the heads of the capscrews (see Figure 4.30-10). Twist the ends of the wire together until taut.

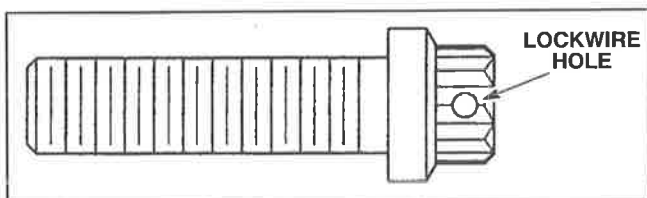


Figure 4.30-10. Ferry Head Capscrew - 16 Cylinder

### OIL COOLER MAINTENANCE

Drain the oil from the oil cooler at each oil change.

Clean and inspect the oil cooler annually. Inspect the oil cooler sooner if an increase in oil temperature cannot be traced to a malfunctioning auxiliary water pump, loose belts, a faulty thermostat or excessive engine load. Plugged tubes or scale deposits inhibit the flow of coolant which reduces oil cooling effectiveness.

**NOTE:** Schedule the oil cooler cleaning during a regular oil change interval, since it is necessary to drain the oil pan and lube oil system accessories.

### LUBE OIL SYSTEM AIR BLEED

Air bleed the lube oil system at least once each day. Proceed as follows:

**NOTE:** The petcock on the full-flow oil filter cover is the only air bleed through which the lube oil system may be purged of air pockets.

1. **Initial Bleed:** start the prelube pump and open the filter cover petcock.

2. Close the petcock when oil begins to flow out in a steady stream.

3. **Check Bleed:** start the engine and reopen the filter cover petcock.

4. Close the petcock when oil begins to flow out in a steady stream.

5. **Final Bleed:** once the engine is running at normal operating temperature, reopen the filter cover petcock.

6. Close the petcock when oil begins to flow out in a steady stream.

## LUBE OIL FILTER MAINTENANCE

### Lube Oil Filter Element Replacement

Full-flow lube oil filter elements should be replaced whenever the lube oil is changed and may often require more frequent replacement.

When the filter is new, the drop in oil pressure through the filter is around 2 - 3 psi (14 - 21 kPa) under normal operating temperatures. To determine the pressure differential, subtract the reading of the oil filter outlet pressure gauge from the reading of the inlet pressure gauge. When the pressure differential rises to 12 - 15 psi (83 - 103 kPa), the filter elements are clogged and must be replaced.

**NOTE:** If oil filter inlet and outlet pressure gauges are not provided, they may be ordered from this manufacturer.

1. Drain both chambers of the full-flow oil filter. Two drain plugs are provided in the oil filter housing (see Figure 4.30-11). Remove the upper plug to drain sludge and dirty oil from the filter element chamber. Remove the lower plug to drain oil from the clean oil chamber.

### **WARNING**

The cover compresses powerful springs on the filter element posts. Use special care to remove the oil filter cover, to avoid severe personal injury or death.

**NOTE:** Based on environmental and engine operating conditions, the lubrication oil may require changes that are much more frequent than those recommended by this manufacturer. Many variables are involved in determining the proper time between oil changes, some of which may not even be known until after a problem develops. The oil type, the severity of the environment and the internal condition of the engine are only a few of many variables that have a direct effect on the frequency at which the oil must be changed.

2. To remove the oil filter cover safely, locate the longest bolts. The long bolts extend about 1-1/4 inches below the flange at the top of the oil filter housing. The short bolts are flush with the bottom of the flange (see Table 4.30-3).

Table 4.30-3. Oil Filter Capscrew Pattern

Engine	Oil Filter Shell ID	Number Of Short Bolts	Number Of Long Bolts	Distance Between Long Bolts
6 Cylinder	12"	6	2	180°
12 Cylinder	16"	9	3	120°
16 Cylinder	18"			

3. Leaving the longest bolts in place, remove the short bolts working in a clockwise direction.

### **WARNING**

Alternately loosen the long bolts of the filter cover an equal amount of turn. Failure to follow this procedure could cause the filter cover to spring up, causing severe personal injury or death.

4. Loosen the long bolts giving each an equal amount of turn. Alternately loosen each of the long bolts to slowly ease the filter cover up. See Figure 4.30-11.

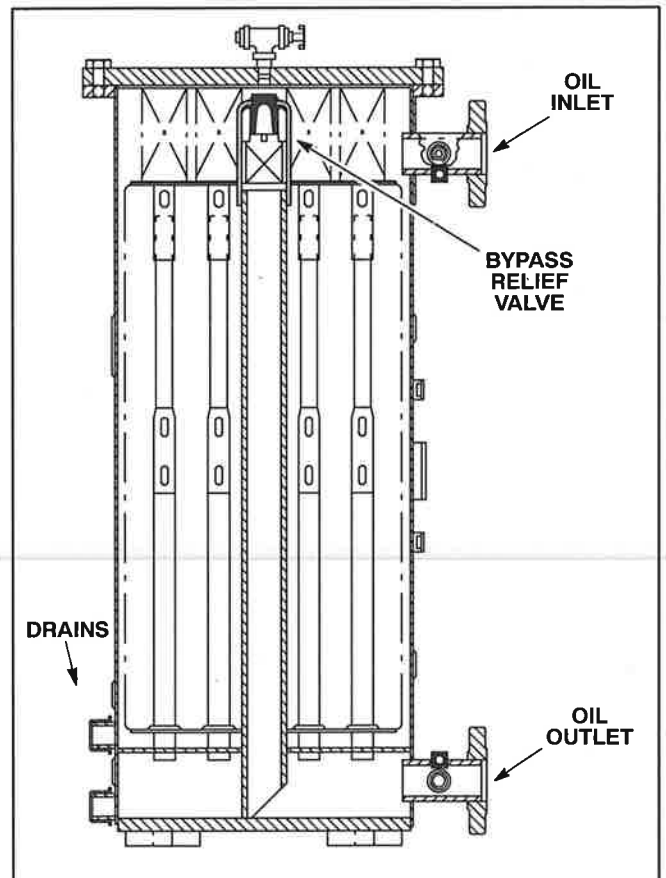


Figure 4.30-11. Lube Oil Filter

## LUBRICATION SYSTEM MAINTENANCE

5. Remove the lube oil filter elements (see Figure 4.30-12). Inspect the bypass relief valve for wear. The oil filter has one relief valve. Refer to *Lube Oil Filter Relief Valve Inspection* for more information.

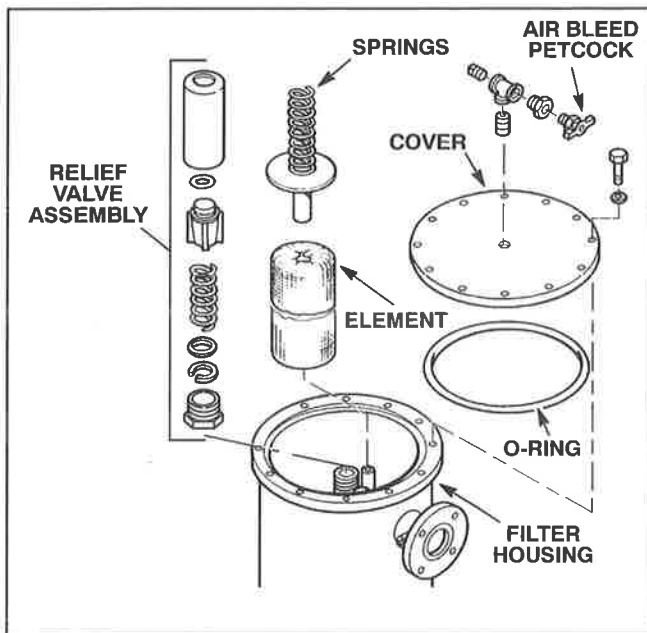


Figure 4.30-12. Full-Flow Lube Oil Filter

6. Install the new lube oil filter elements (see Table 4.30-4). Slide one 32 inch element over each filter element post (see Figure 4.30-13, Figure 4.30-14, and Figure 4.30-15).

Table 4.30-4. Engine Filter Elements

ENGINE	FILTER ELEMENT POSTS	32 INCH ELEMENTS REQUIRED	16 INCH ELEMENTS REQUIRED
6 Cylinder	4	4	8
12 Cylinder	7	7	14
16 Cylinder	10	10	20

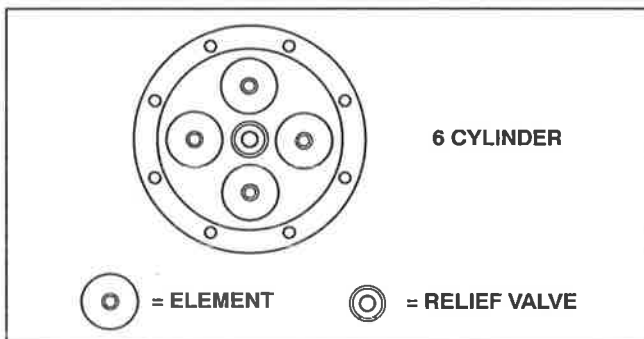


Figure 4.30-13. Filter Element/Relief Valve Configuration - 6 Cylinder

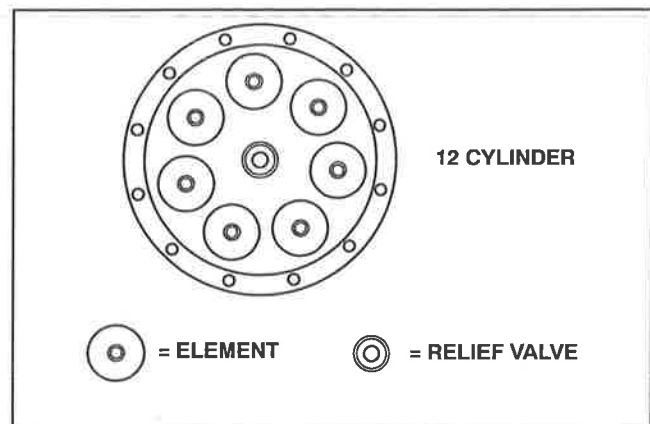


Figure 4.30-14. Filter Element/Relief Valve Configuration - 12 Cylinder

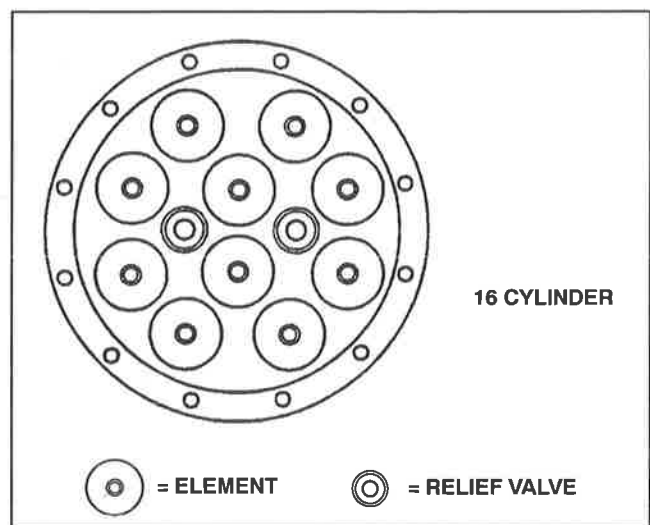


Figure 4.30-15. Filter Element/Relief Valve Configuration - 16 Cylinder

**CAUTION** Those filter elements that are stamped with an arrow must be installed with the arrow pointing down. Elements that have a band around the center may be installed with either end pointing down. Disregarding this information could result in product damage.

7. Replace the drain plugs in the oil filter housing.
8. Fill the filter assembly with clean lubricating oil, see Table 4.30-1 for capacities.
9. Allow air to escape by depressing the bypass relief valve piston(s).

10. Reinstall the lube oil filter cover. The filter cover O-ring should be replaced every 1500 hours, any time it has taken a permanent set or if it appears damaged, whichever comes first. Torque the filter cover capscrews to 35 - 37 ft-lb (47 - 50 N·m) in a crisscross pattern.

11. To release the remaining air, start the prelube pump and open the filter cover petcock. Close the petcock when oil flows out in a steady stream.

**NOTE:** Air bleed the lube oil circuit at least once each day. The petcock on the full-flow oil filter cover is the only location through which the lube oil system may be purged of air pockets (see Lube Oil Filter Air Bleed in this section for more information).

**NOTE:** Waukesha highly recommends adding a bypass filtration system to the standard full-flow lube oil filter, especially for those engines operating in harsh environments. In operation, a small portion of the lube oil is routed from the pump through special bypass filters and then back to the oil sump. Particles as small as one micron are effectively removed as the oil flows through the bypass filter elements. An orifice in the filter housing inlet controls the flow to approximately 10 percent of the rated flow to the engine. In an hour, this operation filters a quantity of oil equal to roughly five times the system capacity. Use of the bypass filtration unit does not alter the recommended oil change interval, since the filter is designed to reduce engine wear, not prolong lube oil life.

## LUBE OIL FILTER RELIEF VALVE INSPECTION

The full-flow lube oil filter housing contains a bypass relief valve.

When the elements are new, the drop in oil pressure through the filter is minimal, around 2 - 3 psi (14 - 21 kPa) under normal operating temperatures. If the pressure differential reaches 28 - 32 psi (193 - 221 kPa), the relief valve begins to open and oil bypasses the filter elements enroute to the lube oil strainer. The relief valve is fully open at approximately 40 psi (276 kPa).

Inspect the relief valve(s) for wear at least once each year or after every 8,000 hours of operation, whichever comes first.

1. Remove the relief valve assembly from the bypass tube (see Figure 4.30-12).
2. Remove the reducing bushing from the relief valve body, if provided.
3. Remove the retaining ring, washer, spring and piston from the relief valve body (see Figure 4.30-16).

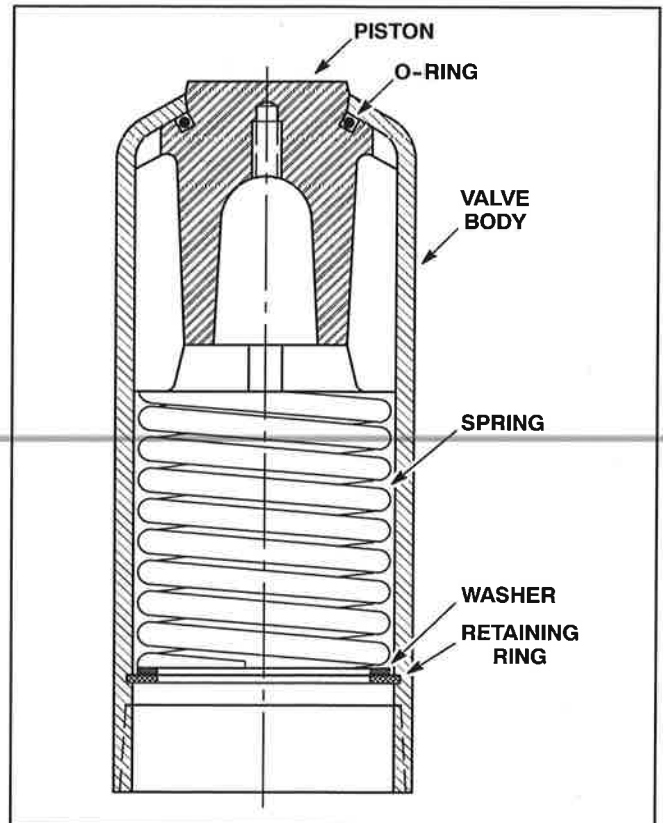


Figure 4.30-16. Lube Oil Filter Relief Valve Assembly

4. Remove the O-ring from the relief valve piston. Inspect the area above the O-ring for excessive wear. Replace if gouged or deeply scratched.
5. Install a new O-ring on the relief valve piston.
6. Install the piston, spring, washer and retaining ring in the relief valve body.
7. Install reducing bushing on the relief valve body.
8. Install the relief valve assembly on the bypass tube.

## LUBRICATION SYSTEM MAINTENANCE

### LUBE OIL STRAINER MAINTENANCE

Clean the lube oil strainer element at each oil change.

1. Remove the plug (3/8 inch) at the bottom of the element housing to drain the strainer assembly of oil (see Figure 4.30-17).

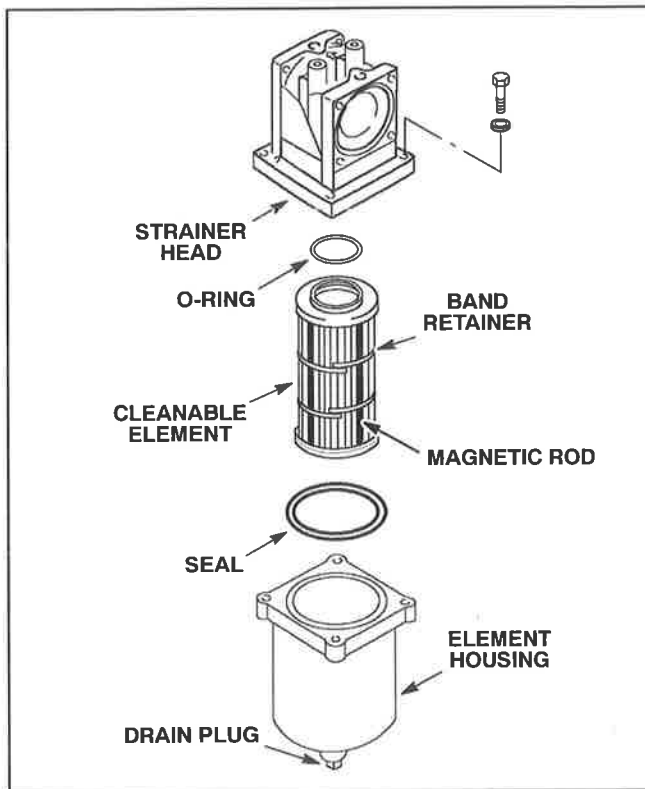


Figure 4.30-17. Lube Oil Strainer Assembly

2. Remove the four capscrews and washers from the strainer head to detach the element housing.

3. Remove the rubber seal from the inside groove at the top of the element housing.

4. Pull down on the stainless steel wire mesh element to detach it from the head.

5. Remove the two band retainers and the two magnetic rods externally mounted on the element.

6. Clean the element in solvent. Flushing the element from the inside out produces the best results.

**CAUTION** High pressure compressed air may damage the strainer element.

7. Drip dry the element or air blow dry from the inside out using low pressure compressed air.

8. Inspect the element for tears or holes. Replace the element if damaged.

9. Inspect the strainer element O-ring for cuts, tears or loss of elasticity. Replace if necessary. Place the O-ring in the inside groove at the top of the wire mesh element. Using a small paintbrush, lubricate the O-ring with clean engine oil.

10. Place the two magnetic rods in the element grooves and install the two band retainers.

11. Slide the element up onto the inside flange of the strainer head.

12. Inspect the element housing seal for cuts, tears or loss of elasticity. Replace if necessary. Place the seal inside the groove at the top of the element housing. Lubricate the O-ring with clean engine oil.

13. Install the drain plug (3/8 inch) in the bottom of the element housing.

14. Install the four capscrews and washers to secure the element housing to the strainer head.

**CAUTION** Special paper elements are required for initial startup of new and rebuilt engines. Disregarding this information could result in product damage.

**NOTE:** See Purging The Lube Oil System Piping for instructions.



## MAGNETIC PLUG MAINTENANCE

Inspect and clean the magnetic plugs at each oil change. Proceed as follows:

1. Remove the magnetic plugs (see Figure 4.30-18). The number of magnetic plugs and their locations are as follows (see Table 4.30-5).

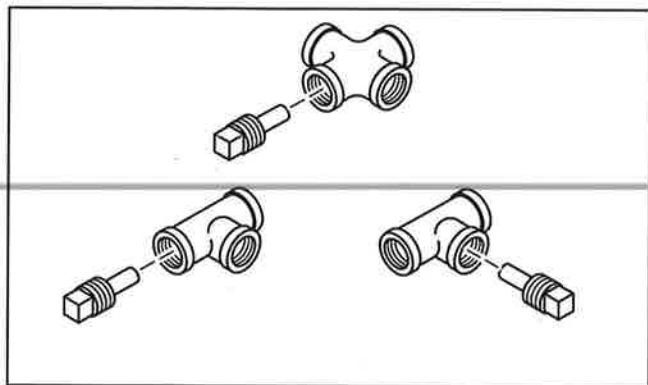


Figure 4.30-18. Magnetic Plugs

Table 4.30-5. Magnetic Plug Locations

ENGINE	PLUGS	SPECIFIC ENGINE LOCATION	
6 Cyl	1	Rocker arm oil header supply line	front left
	1	Turbocharger oil supply line	rear left
12 Cyl	1	Rocker arm oil header supply line	front vee
	1	Rocker arm oil header supply line	rear vee
	1	Turbocharger oil supply line	rear right
16 Cyl	1	Rocker arm oil header supply line	front vee
	1	Turbocharger oil supply line	center vee

2. Clean the magnetic plugs in solvent, if necessary. Wipe the plugs clean to ensure that all ferrous metal debris is removed.

3. Apply Perma Lok® Heavy Duty Pipe Sealant with Teflon® to the threads, and install the magnetic plugs into their locations and wrench tighten.

## IN-LINE LUBRICATOR

Refer to Section 4.45, *In-line Lubricator* for information on this component.

## LUBE OIL PRESSURE ADJUSTMENT

1. Run the engine until the lube oil reaches normal stabilized operating temperature. Take note of the oil header pressure as indicated by the panel mounted oil pressure gauge.
2. Locate the pressure regulating valve at the oil cooler outlet (see Figure 4.30-19). Loosen and back off the jam nut (1/2 inch) on the adjusting screw.
3. Adjust the pressure regulating valve to maintain an oil header pressure of 55 psi (380 kPa) for 6 and 12 cylinder engines, and 50 psi (345 kPa) for 16 cylinder engines, with the lube oil pressure stabilized at normal operating temperature of 180° F (82° C), and the engine fully loaded. Turn the adjusting screw in to increase the oil pressure. To decrease the oil pressure, turn the adjusting screw out.
4. Tighten the jam nut (1/2 inch) to lock the setting of the adjusting screw.

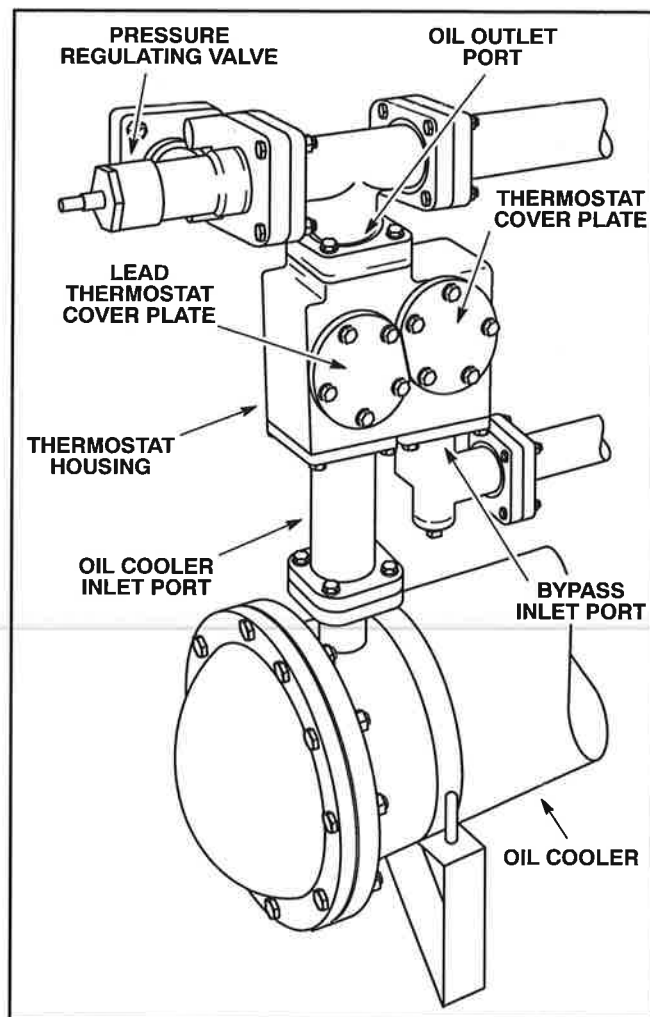


Figure 4.30-19. Lube Oil Temperature Control Valve

## LUBRICATION SYSTEM MAINTENANCE

### PRELUBE Y-STRAINER MAINTENANCE

Clean the Y-strainer screen at each oil change (see Figure 4.30-20). Proceed as follows:

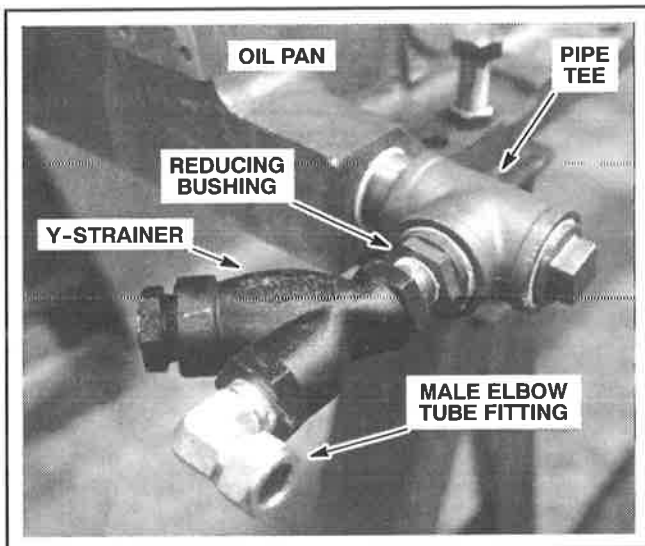


Figure 4.30-20. Y-Strainer - 12 Cylinder

1. Drain the oil pan and all lube oil system accessories, oil cooler, full-flow oil filter and lube oil strainer.
2. Locate the Y-strainer in the oil pan to prelube pump oil line.
3. Remove the plug from the Y-strainer (see Figure 4.30-21).

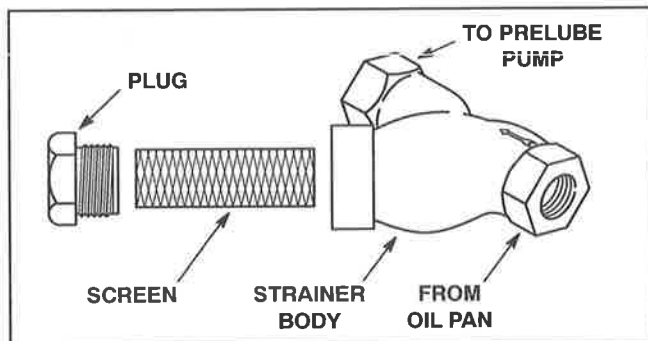


Figure 4.30-21. Prelube Y-Strainer

4. Pull out the cylindrical steel mesh screen.
5. Flush the screening element in a non-volatile cleaning solution or solvent.

### **⚠ WARNING**

Compressed air can pierce the skin and cause severe personal injury or death. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.

**⚠ CAUTION** High pressure compressed air may damage the screening element. Disregarding this information could result in product damage and/or personal injury.

6. Drip dry the screen or use low pressure compressed air.
7. Inspect the screen for tears or holes. Replace if damaged.
8. Slide the screen back into the Y-strainer.
9. Apply Perma Loc® heavy duty pipe sealant or the equivalent onto the male threads of the plug and the female threads of the Y-strainer body.
10. Thread the plug into the Y-strainer and wrench tighten.

**MICROSPIN™ MAINTENANCE**

Initial centrifuge servicing should be about four weeks after startup, sooner if the oil is heavily contaminated. A maximum buildup of 0.75 in. (19.05 mm) is allowed on the centrifuge paper insert. Noting the buildup, will help in establishing a cleaning interval.

**Centrifuge**

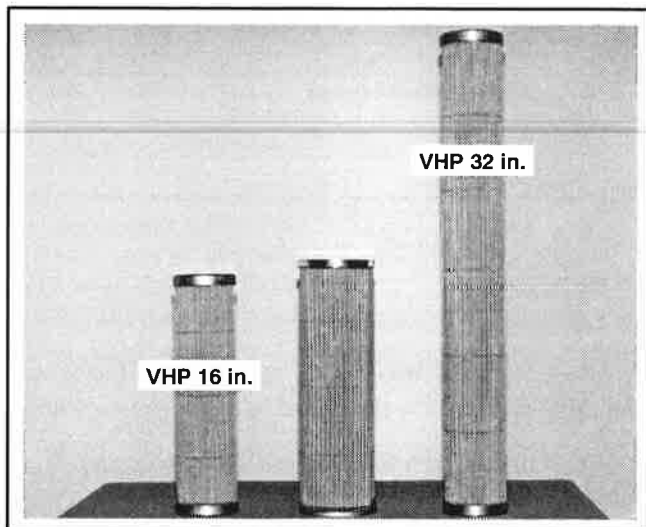
**⚠ WARNING**

**Solvents may be flammable and give off dangerous fumes. Read and follow the manufacture's recommendations to avoid severe personal injury or death.**

Under normal operating conditions, the centrifuge should be cleaned and its paper insert removed, at every scheduled oil change, or as experience dictates. The centrifuge can be cleaned while the engine remains running provided the oil supply valve is shut off (see *Disassembly* for proper procedures).

**Cleanable Filter Elements**

The cleanable oil elements (see Figure 4.30-22), should be removed from the oil filtration canister, and cleaned in a solvent tank at every other regularly scheduled oil change, or when the oil pressure differential between the canister inlet and outlet, exceeds 15 psi (103 kPa). If an oil pressure differential of 2 - 15 psi (14 - 103 kPa), cannot be obtained after normal cleaning, the cleanable filter elements may be ultrasonically cleaned. It is recommended that an oil pressure gauge be installed, to monitor the oil "ΔP" pressure. The engine must be shutdown to service the cleanable oil filters.



**Figure 4.30-22. Cleanable Oil Filter Elements - All VHP, AT, F817G, F1197G, And VGF (Vee) Engines**

**Disassembly of MICROSPIN™ P/N 489189 Centrifuge**

**⚠ WARNING**

**The oil supply valve must be shut off before servicing the MICROSPIN™ centrifuge. Allow two minutes before proceeding with servicing the MICROSPIN™ centrifuge to allow the rotor to stop spinning and the oil pressure to drop to zero. Failure to shut off the oil supply valve can cause severe oil burns.**

1. Shut off the oil supply valve and wait two minutes for the oil pressure to drop to zero and the rotor to stop spinning.

**⚠ WARNING**

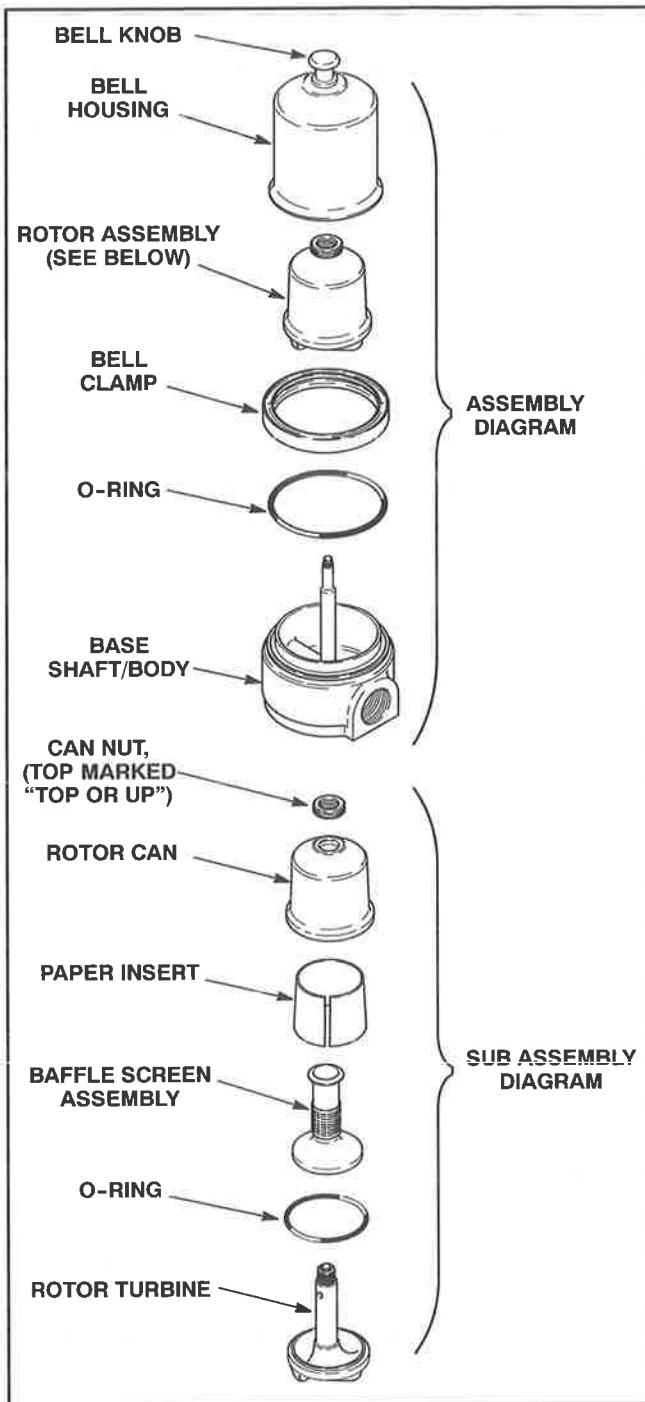
**Oil and parts may be extremely hot. Always use caution when servicing the unit to avoid severe personal injury or death.**

2. Loosen and remove the side bell clamp (see Figure 4.30-23).
3. Turn the bell knob counterclockwise until it is free.
4. Grasp the top bell knob and remove the bell housing from the base (this will expose the rotor assembly).
5. Insert a screwdriver under the rotor assembly and raise the rotor assembly up 1 - 2 in. (25.4 - 50.8 mm) to allow oil to drain from the rotor into the body base. When the oil is drained from the rotor assembly, lift it straight up until it clears the base shaft.
6. Position the unit on a clean work table, and remove the knurled can nut from the rotor assembly.

**⚠ CAUTION Use caution during disassembly to avoid damage to the brass bushings.**

7. Invert the rotor assembly and place it on a clean work table.
8. Holding the rotor can with both hands, press down until the can separates from the rotor.
9. Clean the baffle screen assembly, rotor and jets. Replace the O-ring if necessary.

# LUBRICATION SYSTEM MAINTENANCE



**Figure 4.30-23. Service And Cleaning Of MICROSPIN™ P/N 489189 Centrifuge**

## MICROSPIN™ Centrifuge Cleaning - P/N 489189

1. Remove the paper insert from the rotor can by inserting a narrow flat tool between the paper insert and the rotor can. Run the tool around the inside of the can and remove the paper insert. Clean the contaminant build up in the rotor can, and insert a new paper insert.

### **⚠ WARNING**

Solvents may be flammable and give off dangerous fumes. Read and follow the manufacture's recommendations to avoid severe personal injury or death.

**⚠ CAUTION** Remove rubber O-rings prior to placing parts in the solvent tank, to prevent damage to equipment.

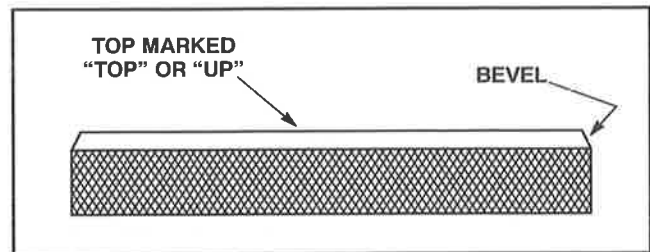
2. Clean the baffle screen assembly, rotor turbine, rotor can, covers and jets, in a suitable solvent tank.

## MICROSPIN™ Centrifuge Assembly - P/N 489189

1. Install the baffle screen and new O-ring on the turbine rotor.

**⚠ CAUTION** The knurled can nut must be tightened hand tight only, or damage to equipment could result.

2. Position the rotor can with a new paper insert in place, (see Figure 4.30-23) on the turbine rotor. Insuring that the side of the knurled can nut marked "TOP" or "UP" is on top, (see Figure 4.30-24) tighten the knurled can nut, **hand tight only**, to secure the assembly.



**Figure 4.30-24. Can Nut - Side View**

3. Position the turbine rotor assembly to the base, (over the base shaft). Check to insure that the rotor spins freely.
4. Install the bell housing to the base, using a new O-ring (if necessary) and hand tighten the bell nut.
5. Install and hand tighten the bell housing clamp finger tight.
6. Retighten the bell nut, hand tight.
7. Open the oil supply valve to start the centrifuge. Check for oil leaks.

### OIL RECOMMENDATIONS

Waukesha recommends the use of oil formulated specifically for gas engines and meeting minimum ash requirements based on engine makes and models. The ash forming constituents in oil formulations provide detergency, corrosion protection and anti-wear protection. In addition, the ash produced during combustion of these additives will provide protection against valve face and seat recession. If you are experiencing excessive 0.002 in. (0.05 mm), or greater, per thousand hours, valve recession, a switch to a higher ash gas engine oil should be considered. Consult your oil supplier for appropriate recommendations.

Engines utilizing high ash oils which have had good operating experience on these oils may continue with Waukesha's previous oil recommendations.

Waukesha provides these current lubricating oil recommendations as a guideline.

### LUBRICATING OIL PERFORMANCE

There are hundreds of commercial crankcase oils marketed today. Obviously, engine manufacturers or users cannot completely evaluate the numerous commercial oils. The current edition of the EMA Lubricating Oil Data Book, is available for purchase from Engine Manufacturers' Association, 401 North Michigan Ave, Chicago, IL 60611-4267, Phone (312) 644-6610, Fax (312) 321-5111. This document, provides a tabulation of lubricant producers and marketers, together with the performance classification for which the producers have indicated their products are qualified.

The performance of a lubricant, like that of any manufactured product, is the responsibility of the refiner and supplier.

The Waukesha Engine Warranty is limited to the repair or replacement of parts that fail due to defective material or workmanship during the warranty period. The Waukesha Warranty does not include responsibility for satisfactory performance of the lubricating oil.

With the exception of cogeneration and special or prototype installations, Waukesha Engine Division has made it a practice not to recommend oil by brand name.

### OIL DESIGNATIONS

Oil is designated in several ways: American Petroleum Institute (API), Society of Automotive Engineers (SAE), American Society for Testing and Materials (ASTM), performance classifications, and Military Designation. Since no gas engine industry oil performance designations exist, it is the responsibility of the engine operator to verify with their oil supplier, that the oil they select has proven field performance in their specific engine make and model engine. This oil must also meet the minimum requirements specified by Waukesha as listed in Table 4.30-2.

### OIL ADDITIVES

Quality oils formulated specifically for natural gas engines have sufficient additives to meet requirements. Waukesha does not recommend the addition of oil additives to these quality oils.

### CATALYST CONTAMINANTS

The following contaminants are known catalyst deactivators and should be avoided when selecting lubricating oils for installations with catalysts since they contribute to shortened catalyst life: heavy and base metals such as lead, mercury, arsenic, antimony, zinc, copper, tin, iron, nickel, chrome, sulfur and phosphorus. These individual elements should not exceed 1 ppm or collectively exceed 5 ppm at the catalyst inlet. Specific exceptions: phosphorus or silicon compounds in the exhaust are not to exceed 1 ppm and sulfur compounds in the exhaust are not to exceed 100 ppm.

Do not confuse the concentration of these elements *AT THE CATALYST INLET* with the concentration of these elements in the lube oil itself.

### OIL FILTRATION REQUIREMENT

The quality of oil filtration will directly affect engine component life.

Waukesha's basic filtration requirement is 90% efficient at 15 microns for all full flow elements, and 98% efficient at 25 microns for cleanable metal mesh elements.

Waukesha's complete oil filter performance specification is shown in Waukesha specification sheets S08486 and S08486-1.

## LUBRICATION SYSTEM MAINTENANCE

### WAUKESHA COGENERATION INSTALLATIONS - OIL RECOMMENDATIONS

Waukesha Engine Division does not ordinarily recommend lube oils by brand name. However, based on actual field experience, the oils listed in Table 4.30-6 are specified for cogeneration installations with forced hot water cooling systems 212° F - 265° F (100° C - 129° C) or ebullient cooling 250° F (121° C).

**Table 4.30-6. Recommended Lube Oils For  
Cogeneration Applications - Using Pipeline Quality Gas**

BRAND	TYPE	PERCENT OF SULFATED ASH
Chevron HDAX Low Ash	SAE 40	0.45
Estor Super Exxon Co. USA, Exxon Co. International	SAE 40	0.45
Estor Elite (Synthetic) Esso Imperial Oil, Exxon Co. USA	SAE 20 W40	0.45
Estor Select 40 Esso Imperial Oil, Exxon Co. USA	SAE 40	0.95
Mobil Pegasus 1 (Synthetic)	SAE 15 W40	0.48
Mobil Pegasus 80	SAE 40	0.48
Mobil Pegasus 89	SAE 40	0.99
Mobilgard 450	SAE 40	1.65
Mobil Pegasus 485	SAE 40	0.38
Petro Canada, CG40	SAE 40	0.73
Shell Mysella MA SIPC (Outside USA only)	SAE 40	0.90

It is especially important that the lube oils used in cogeneration applications utilize base stocks with good thermal stability. With a minimum of 4000+ hours of experience, the lube oils listed in Table 4.30-6 are known to give satisfactory performance in high temperature cooling systems' applications.

Additions to the list of approved oils may be made if substantiating data is provided for an oil meeting the following criteria:

- Used in similar applications 212° F (100° C) to 265° F (129° C) jacket water temperatures.
- Minimum of 12 months operation. Documented with engine inspection data.
- No signs of oil degradation or lacquering problems (based on normal oil change interval, the engine should be clean).

**SOUR GAS, ALTERNATE FUEL GAS, AND LANDFILL GAS RECOMMENDATIONS**

**⚠ WARNING**

**Waukesha Engine Division assumes no liability or responsibility for damage to the environment, or severe personal injury or death caused by using landfill gases or sour gases. It is the customer's sole responsibility to carefully analyze any gases they chose to use. Use of these gases is at the customer's own risk.**

Alternate fuel sources are attracting increasing interest today as a low cost fuel or because of environmental concerns. Waukesha, being the leader in developing engine systems to accommodate these alternate fuels, is aware of problems due to sulfur compounds (H<sub>2</sub>S, etc.), siloxanes and halide constituents in these fuels. Hydrogen sulfide (H<sub>2</sub>S), siloxanes and total organic halide as chloride (TOH/Cl) bring with them totally different problems to the engine and lubricating oils.

Waukesha has limited fuel trace gases to the following:

- Sulfur bearing compounds (H<sub>2</sub>S, etc.) content in fuel gas to 0.1%, (1000 ppm) by volume. However, it is not unusual to encounter biomass gas, or field gas, with much higher percentages of sulfur bearing compounds (H<sub>2</sub>S, etc.). Gas exceeding 0.1% sulfur bearing compounds must be treated.
- Maximum organic halide content, expressed as chloride, (TOH/Cl) in landfill gas is limited to 150 micrograms per liter (µg/l).
- Maximum liquid fuel hydrocarbons at the coldest expected engine mounted regulator fuel outlet temperature are limited to 2% total by gaseous volume.
- Maximum permissible free hydrogen content is 12% by volume.
- Maximum total siloxanes for engine models with a prechamber fuel system is 25 µg/l. If greater than 25 µg/l total siloxanes are present at the inlet to the engine mounted fuel regulator, clean commercial quality natural gas must be supplied to the pre-chamber fuel system. Waukesha currently does not limit total siloxane content in the fuel gas to engines which do not have a prechamber fuel system.

When dealing with halogens or halogen compounds in landfill gas, the subject becomes far too complicated to address here as it relates to the selection of a lubricating oil, used oil analysis, and drain interval. It follows that those customers operating on landfill gas review Waukesha Engine's Fuel Specification S7884-6 to fully understand the ramifications of operating an engine on landfill gas. This document, as well as Service Bulletin 16-2701, prescribes specific

fuel gas sampling techniques, fuel gas analysis, handling of abrasive fuel constituents, and limitations on total organic halide as chloride, to achieve reasonable engine life. Lubricating oil requirements change as the TOH/Cl increases.

**RECOMMENDED LUBE OILS FOR LANDFILL GAS APPLICATIONS**

Waukesha recommends lubricating oils specifically formulated for landfill gas (see Table 4.30-7). However, care must be taken that oils formulated for a particular fuel type not be used beyond their recommendations. Some landfill gas formulated lube oils, can cause excessive build-up of abnormal ash deposits in the combustion chamber, when used outside of their recommendations. Landfill gas engine oils should only be used for engines applied to landfill gas operation, not digester gas operation.

**Table 4.30-7. Recommended Lube Oils For Landfill Gas Applications**

BRAND	TYPE	PERCENT OF SULFATED ASH
Mobil Pegasus 446	SAE 40	0.95
Chevron HDAX LGF	SAE 40	0.71

The best approach would be to filter or absorb corrosives in the fuel gas before they reach the engine. There are increasing claims for filtration and absorption by various companies manufacturing and promoting these types of product. Waukesha makes no endorsement of these products or service. Their performance is solely the responsibility of their manufacturers.

## LUBRICATION SYSTEM MAINTENANCE

### RECOMMENDATIONS FOR FUEL GAS FILTRATION OF SOLIDS AND LIQUIDS

#### Solid Particulate Removal:

Coalescer shall have an absolute rating of 5 microns (0.3 microns for landfill applications) for solid particulate removal.

#### Liquid and Aerosol Removal From Fuel Gas:

Coalescer shall remove entrained liquid and aerosol contaminants of 0.3 micron or larger.

- Fuel gas compressor lubricating oil carryover must be removed from the fuel stream. A coalescing filter with a 0.3 micron rating is adequate in most cases. Even though this oil is hydrocarbon based and combustible, it contains an additive package with calcium and other undesirable elements and compounds. Failure to remove this carryover oil can lead to fuel regulator problems, excessive spark plug and combustion chamber deposits, cylinder varnish, ring sticking, and other problems.
- Liquid water is not allowed in the fuel because it frequently results in fouling and corrosion. Particular attention must be paid to landfill and digester gasses since these gases are commonly received saturated with water. Due to extremely small clearances in the admission and check valves, absolutely no water can be tolerated in a prechamber fuel system. To insure that no liquid water forms in the fuel system, Waukesha specifies that the dew point of the fuel gas should be at least 20° F (11° C) below the measured temperature of the gas at the engine mounted regulator inlet. On engines without prechamber fuel systems, saturated, (100% relative humidity) fuel gas at the carburetor inlet is acceptable. A 0.3 micron coalescing filter will remove any liquid water droplets being carried along with the fuel stream. The water content of the gas can then be reduced to an acceptable level by several methods.
  - F. Condensation of excess moisture by refrigerating the fuel gas to no higher than 40° F (4° C) followed by reheating of the gas to 85° - 95° F (29° - 35° C). This process will also remove significant amounts of halogenated and heavy hydrocarbons and volatile siloxanes.
  - G. Selective stripping with a chemical process.
  - H. By heating: If the gas is 30° F (17° C) or more **above** the ambient temperature, it can be cooled by passing it through a heat exchanger or refrigeration system, then reheated, in manner similar to Step A. If the gas is 20° F (11° C) or more below the ambient temperature, it can be heated. In both cases, the fuel system after the heating operation should be insulated. Heating of

the fuel gas is limited to the maximum allowable temperature of 140° F (60° C).

- Glycol is not permitted in fuel gas because it can affect the engine in adverse ways. The lubricating qualities of the oil may be reduced, resulting in bearing failure, piston ring sticking, excessive wear, and other problems. A 0.3 micron rated coalescing filter will remove liquid glycol from the fuel stream.

#### Design Criteria:

Coalescer Filter Housing to be of the cylindrical type, vertically mounted. The housing shall contain two sump chambers, such that the lower sump collects heavier liquid dropouts immediately downstream of the gas inlet, while the upper sump collects liquids draining off the coalescer cartridge(s).

The coalescer design shall utilize an inside to outside gas flow path through the coalescer cartridge.

#### Recommended Coalescing Filter:

Pall Process Filtration Company  
Model CC3LG7A

The following recommendations will minimize corrosion problems normally encountered with fuel gas containing H<sub>2</sub>S and TOH/Cl:

#### • Recommendation #1

Select a gas engine lubricating oil with a high alkalinity reserve, 7 to 13 TBN (Total Base Number). Alkalinity reserve in the lube oil is measured in TBN. The higher the TBN, the more reserve.

Contact your oil supplier or consult the EMA Lubricating Oils Data Book for an appropriate choice. Also follow the appropriate ash content percent by weight for the specific engine model.

#### • Recommendation #2

Used oil analysis is mandatory for alternate fuel applications. Lube oil change periods are determined by TBN, TAN (Total Acid Number), oxidation and nitration level in the used oil samples. The user must change the oil when the TBN level falls to 30% of the new oil value or TAN increases by 2.0 above the new oil value. The method of measuring TBN in used oil must be ASTM-D2896.

DEXSIL<sup>®</sup> Corporation, has developed the Q2000 field test kit, as a test for chlorine contamination of engine oil exposed to chlorine containing fuels, as in landfill gas. This field test kit is highly accurate, and allows the operator to obtain timely test results in the field. The oil must be sampled every 50 hours, in order to establish a "trend". Waukesha has experienced good results with this kit. Order information may be obtained from DEXSIL<sup>®</sup> Corporation, One Hamden Park Drive, Hamden, CT 06517.



**CAUTION** TOH/CI does not affect TBN levels the same as sulfur compounds. Therefore, the 30% of new oil TBN value, as an indicator of a change interval only applies to the applications where fuel gas does not contain halides. Disregarding this information could result in product damage.

• **Recommendation #3**

Increase the jacket water temperature to 210° - 235° F (99° - 113° C) and lube oil temperatures to 185° - 200° F (85° - 93° C). Increased temperatures will reduce condensation, which will reduce the concentration of acids within the crankcase. High temperature thermostats are available for most models.

If you have any question on lubricants to be used with alternate fuel gases, contact the Product Support Department or Application Engineering Department prior to selecting a lubricating oil.

**LUBE OIL CONDEMNING LIMITS**

**WARNING**

**Engine oil is extremely hot and is under pressure. Use caution when sampling engine oil for analysis. Failure to follow proper procedures could cause severe personal injury or death.**

Lubricating oil condemning limits are established by the engine manufacturer's experience and/or used oil testing.

Laboratory testing will determine the used oil's suitability for continued use. Used oil testing should cover the data shown in Table 4.30-8.

**Table 4.30-8. Used Oil Testing And Condemnation**

TEST	CONDEMNING LIMIT
Viscosity	-20/+30% Change
Flash Point	Below 356° F (180° C)
Total Base Number (TBN) (ASTM-D2896)	30% of New Oil Value (Not applicable to TOH/CI)
Total Acid Number (TAN)	2.0 Rise Above New Oil Value
Oxidation (Abs/Cm)	25
Nitration (Abs/Cm)	25
Water Content	Above 0.10% Wt.
Glycol	Any Detectable Amount
Wear Metals	Trend Analysis
Chlorine	900 ppm

**CAUTION** Actual oil change intervals to be determined by engine inspection and oil analysis in conjunction with the condemning limits. Disregarding this information could result in product damage.

In the interest of developing a reasonable life expectancy for Waukesha engines operating on fuel gas laden with some level of halogens, our experience dictates the following:

- To achieve the life expectancy of an engine operating on pipeline quality natural gas, remove all halogen compounds (as well as abrasives) from the fuel gas.
- Reasonable life can be expected if Total Organic Halide as Chloride Concentration (TOH/CI) of the fuel does not exceed 150 micrograms per liter (µg/l). Total Organic Halide as Chloride (TOH/CI) equals the sum of all halogenated compounds expressed as chloride in micrograms/litre as chloride (µCl/L) at STP (Standard Temperature and Pressure). Reasonable life can also be expected with increased maintenance and operating adjustments to the engine.
- Typical changes in maintenance and operation at this level are:
  - Decreased oil change interval (150 hours to start)
  - Condemn oil when 900 ppm chlorine level in used oil is reached. This will aid in establishing an oil change interval.
  - Lubricating oil analysis each 50 hours maximum
  - Elevated jacket water temperature 212° F - 235° F (100° C - 113° C)
  - Elevated lube oil temperature to 185° F - 200° F (85° C - 93° F)
  - Use of high TBN oil (7.0 - 13.0)
  - Bypass lubrication oil filtration. Waukesha Engine has announced the introduction of the MICROSPIN® cleanable lube oil filtering system. The MICROSPIN® system utilizes the cleaning capabilities of a centrifuge, coupled with cleanable filter elements. The MICROSPIN® system utilizes Waukesha's current lube oil filtration canister for the cleanable elements. The centrifuge is installed as a bypass system, working in conjunction with the cleanable filter elements.
- TOH/CI above 150 micrograms chloride/litre require pre-treatment of the fuel in order to make it suitable for use in a reciprocating engine.

DEXSIL® Corporation, has developed the Q2000 field test kit, as a test for chlorine contamination of engine oil

## LUBRICATION SYSTEM MAINTENANCE

exposed to chlorine containing fuels, as in landfill gas. This field test kit is highly accurate, and allows the operator to obtain timely test results in the field. The oil must be sampled every 50 hours, in order to establish a "trend". Waukesha has experienced good results with this kit. Order information may be obtained from DEXSIL® Corporation, One Hamden Park Drive, Hamden, CT 06517.

### OIL VISCOSITY SELECTION

The operating temperature of the oil in the sump or header is the best guide for selecting the proper SAE grade of oil. When the oil temperature is unknown, add 120° F (67° C) to the ambient temperature to obtain the estimated sump oil temperature (see Table 4.30-9).

**Table 4.30-9. Sump And Header Temperatures And SAE Number**

1000 CU. IN. (16.4 L) DISPLACEMENT AND LARGER		
Sump Temperatures	Header Temperature	SAE Number
160° - 230° F (71° - 110° C)	160° - 210° F (71° - 99° C)	40
Below 160° F (71° C)	Below 160° F (71° C)	30

**NOTE:** Engines of 1000 cu. in. (16.4 L) displacement and above, should not be operated with header oil temperature below 140° F (60° C). Engines of this type which exceed 195° F (91° C) header temperature or 215° F (102° C) sump temperature should have reduced oil change intervals.

### MULTI-VISCOSITY OILS

Use multi-viscosity oils only for engines in cold starting applications. Multi-viscosity oil may deteriorate in continuous operation, allowing the oil to lose viscosity through shearing. In this state, the oil may not supply sufficient lubricating films and/or pressure. Therefore, utilize an oil analysis program to determine the oil change intervals.

### SYNTHETIC OILS

Based on developments by Exxon Corporation and Mobil Oil Corporation and the release of their synthetic lubricating oils, Waukesha Engine Division now recognizes these products as being suitable for all Waukesha stoichiometric and lean burn gas engines. Table 4.30-6 lists the synthetic oils available.

When synthetic lubricating oils are selected, it is suggested that you contact Waukesha Engine Division for change interval recommendations. Typically, synthetic oil change intervals are 3 to 5 times longer than those of mineral oils. Oil filter change intervals remain at 1000 to 1500 hours of operation.

**Synthetic oils are not recommended for alternate fuel gas applications without prior approval by Waukesha Engine Division.**

### LOW AMBIENT TEMPERATURE OPERATION

At low ambient temperatures, use an oil which will provide proper lubrication when the engine is hot and working. For engines of 1000 cu. in. (16.4 L) and above, operating at ambients below 50° F (10° C) lube oil and jacket water heaters are required to warm oil and water for fast starting and loading of engines. Waukesha Engine Division will supply information on these starting devices upon request.

### LUBE OIL CONSUMPTION RATES

Typical lube oil consumption rates have been updated for all Waukesha engines (see Table 4.30-10).

**Table 4.30-10. Oil Consumption**

MODEL	LBS/HP-HR	GRAMS/HP-HR	GRAMS/KW-HR
All	0.0002 - 0.002	0.091 - 0.910	0.121 - 1.22

**NOTE:** Lube oil consumption rates given above are a general guide and not meant to be used for Condemning Limits or determining overhaul requirements.

### FORMULAS FOR DETERMINING OIL CONSUMPTION RATES

The following formulas may be useful in determining whether the oil consumption rate of the engine is normal.

$$\frac{\text{LBS}}{\text{HP} - \text{HR}} = \frac{7.3 \times \text{Number of Gallons of Oil Used}}{\text{HP} \times \text{Hours of Operation}}$$

$$\frac{\text{LBS}}{\text{HP} - \text{HR}} = \frac{1.82 \times \text{Number of Quarts of Oil Used}}{\text{HP} \times \text{Hours of Operation}}$$

$$\frac{\text{Grams}}{\text{HP} - \text{HR}} = \frac{875 \times \text{Number of Litres of Oil Used}}{\text{HP} \times \text{Hours of Operation}}$$

$$\frac{\text{Grams}}{\text{kW} - \text{HR}} = \frac{875 \times \text{Number of Litres of Oil Used}}{\text{kW}(\text{corrected}) \times \text{Hours of Operation}}$$

## RECOMMENDED OIL CHANGE INTERVALS

**CAUTION** The use of some types of oil, as well as dusty environment, marginal installation, internal engine condition and/or operating the engine with malfunctioning carburetion or injection equipment may require more frequent oil changes. Waukesha Engine recommends the lubricating oil be monitored with a professional oil analysis program. Extended oil change intervals may cause varnish deposits, oil oxidation, or sludge conditions to appear in the engine, which an oil analysis cannot detect. Contact your local Waukesha Distributor for periodic engine maintenance. Disregarding this information could result in product damage.

**Table 4.30-11. Recommended Oil Change Intervals For Engines Receiving Normal Maintenance**

ENGINE MODEL	ISO STANDARD OR CONTINUOUS POWER RATING	ENGINES OPERATED IN EXCESS OF ISO STD. POWER	LIGHT LOAD OPERATION	EBULLIENT COOLED OR HOT WATER SYSTEM WITH ENGINE WATER TEMPERATURE 200° F (93° C) OR ABOVE *	STANDBY DUTY
<b>For Engines Operating With Oil Header Temperatures 195° F (91° C) Or Below</b>					
* Natural Gas HD-5 Propane	1500 hours	500 hours	1500 hours	500 5115GL = 1500 hours *	250 hours or annually

*NOTE: Change lube oil filter elements when lube oil is changed.*

*\* 5115GL rated at 220° F (104° C).*

**Table 4.30-12. Recommended Oil Change Intervals For Engines Receiving Normal Maintenance And Using Gaseous Fuel Containing H<sub>2</sub>S In Excess Of Published Limits.**

ENGINE MODEL	ISO STANDARD OR PRIME POWER RATING	ENGINES OPERATED IN EXCESS OF ISO STD. POWER	LIGHT LOAD OPERATION	EBULLIENT COOLED OR HOT WATER SYSTEM WITH ENGINE WATER TEMPERATURE 200° F (93° C) OR ABOVE *	STANDBY DUTY
<b>For Engines Operating With Elevated Oil Sump Temperature</b>					
VHP Series	360 hours	250 hours	360 hours	360 hours	250 hours or annually

*NOTE: Change lube oil and fuel filter elements when lube oil is changed.*

**Table 4.30-13. Duty Cycle Definitions**

<b>ISO Standard Or Continuous Power Rating:</b>	The highest load and speed which can be applied 24 hours a day, 7 days a week, 365 days per year, except for normal maintenance. It is permissible to operate the engine at up to ten percent overload or maximum load indicated by the intermittent rating, whichever is lower, for two hours in each 24 hour period.
<b>Generator Standby Power Rating:</b>	In a system used as a backup or secondary source of electrical power, this rating is the output the engine will produce continuously (no overload), 24 hours per day, for the duration of the prime power source outage.
<b>Intermittent Power Rating:</b>	This rating is the highest load and speed that can be applied in variable speed mechanical system application only. Operation at this rating is limited to a maximum of 3500 hours per year.
<b>Generator Peak Shaving:</b>	Peak shaving is operation of an engine for a limited time to meet short term peak power requirements. Speed, loading, and hours per year of operation will affect the recommended oil change interval.
<b>Light Load Operation:</b>	25% or less of the continuous duty rating.

# LUBRICATION SYSTEM MAINTENANCE

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## SECTION 4.35

### EXHAUST SYSTEM MAINTENANCE

#### EXHAUST SYSTEM MAINTENANCE

##### EXHAUST SYSTEM BACKPRESSURE MEASUREMENT

Monitor the exhaust system backpressure daily. The maximum backpressure must not exceed specification.

Refer to Table 4.35-1 for exhaust system backpressure values.

1. Drill and tap a hole (1/4 inch NPT) in the customer supplied exhaust piping. Place the hole 12 in. (305 mm) downstream from the mating flange of the Waukesha supplied flexible exhaust connection. The measurement must be taken before the silencer or catalytic converter, if provided, and should be away from any bend or elbow in the exhaust piping.
2. Install a tubing connector in the hole. Use only non-corroding stainless steel fittings.
3. Connect one end of a water manometer to the connector and vent the free end to the atmosphere. The manometer line fitting must not protrude beyond the inner surface of the exhaust pipe or an inaccurate reading may result.
4. Measure the exhaust backpressure at rated speed and load. Corrective action must be taken if the backpressure exceeds the specified limit.
5. Excessive exhaust backpressure may be due to one or more of the following conditions:
  - A. Undersized piping
  - B. Elbows, bends or sudden enlargements in the piping
  - C. Plugged catalytic converter
  - D. Pipe obstructions
  - E. Exit losses

#### EXHAUST SYSTEM TEMPERATURE MONITORING

Exhaust temperatures can be an important diagnostic tool. A very high exhaust temperature might indicate that the air/fuel ratio is too rich. A very low temperature may mean that a cylinder is not firing.

The maximum exhaust temperature variation (on an engine running at rated speed and load on natural gas fuel) between cylinders on the same bank is approximately 100° F (47° C). The maximum exhaust temperature variation between respective cylinders on different banks (1R versus 1L, 2R versus 2L, etc.) is approximately 50° F (23.5° C).

Normal exhaust temperatures are 650° to 670° F (343° to 354° C). Higher exhaust temperatures might indicate that the air/fuel ratio is too rich. Lower temperatures may mean that a cylinder is not firing.

**NOTE:** *Since air/fuel ratio, ambient air temperature and many other factors may affect exhaust gas temperatures, call the Waukesha Engine Division, Field Service Department, if additional information is required.*

Check engine exhaust temperatures for each cylinder daily. Monitor the exhaust temperatures when the engine is running at rated speed and load.

#### EXHAUST SYSTEM INSPECTION

1. Inspect the exhaust manifolds and exhaust piping for leaks.
2. Record the exhaust manifold temperatures for reference.

## EXHAUST SYSTEM MAINTENANCE

**Table 4.35-1. Maximum Allowable Exhaust Backpressure And Reductions For Speed And Load**

<b>NATURALLY ASPIRATED VHP G MODELS</b>
<p>The maximum allowable exhaust backpressure for a VHP G model is 18 in. (457.2 mm) of water column pressure (4.5 kPa) at the highest load at the highest speed that the engine will experience during operation. At reduced load and/or speed, the backpressure on the engine will decrease by the operating characteristic of the exhaust system.</p>
<b>STOICHIOMETRIC, TURBOCHARGED AND INTERCOOLED, VHP GSI* MODELS</b>
<p>The maximum allowable exhaust backpressure for a VHP GSI* model is 18 in. (457.2 mm) of water column pressure (4.5 kPa) at 180 BMEP at 1200 rpm. This pressure must be reduced by 1.5 in. (38 mm) of water column (0.37 kPa) for every 100 rpm that the maximum rated speed is below 1200 rpm and reduced by 1.5 in. (38 mm) of water column (0.37 kPa) for every 10 BMEP that the maximum rated load is below 180 BMEP. Allowable backpressure is not reduced below 4.0 in. (101.6 mm) of water column pressure (1 kPa). At reduced load and/or speed the backpressure on the engine will decrease by the operating characteristic of the exhaust system.</p> <p><b>Max Exhaust Backpressure = 18.0 - 1.5 x [(1200 - rpm)/100] - 1.5 x [(180 - BMEP)/10] in. H<sub>2</sub>O</b>                      * This applies only to VHP GSI engines with the ejector style breather system. For other models, contact the Waukesha Applications Engineering Department.</p>
<b>LEAN BURN, TURBOCHARGED AND INTERCOOLED, VHP GL MODELS (EXCEPT 5115GL)</b>
<p>The maximum allowable exhaust backpressure for a VHP GL model (except 5115GL) is 13.5 in. (342.9 mm) of water column pressure (3.4 kPa) at 160 BMEP at 1200 rpm. This pressure must be reduced by 1.0 in. (25.4 mm) of water column (0.25 kPa) for every 100 rpm that the maximum rated speed is below 1200 rpm and reduced by 1.0 in. (25.4 mm) of water column (0.25 kPa) for every 10 BMEP that the maximum rated load is below 160 BMEP. Allowable backpressure is not reduced below 4.0 in. (101.6 mm) of water column pressure (1 kPa). At reduced load and/or speed the backpressure on the engine will decrease by the operating characteristic of the exhaust system.</p> <p><b>Max Exhaust Backpressure = 13.5 - [(1200 - rpm)/100] - [(160 - BMEP)/10] in. H<sub>2</sub>O</b></p>
<b>VHP 5115GL MODELS</b>
<p>The maximum allowable exhaust backpressure for a VHP 5115GL model is 13.5 in. (342.9 mm) of water column pressure (3.4 kPa) at 165 BMEP at 1500 rpm. This pressure must be reduced by 1.0 in. (25.4 mm) of water column (0.25 kPa) for every 100 rpm that the maximum rated speed is below 1500 rpm and reduced by 1.0 in. (25.4 mm) of water column (0.25 kPa) for every 10 BMEP that the maximum rated load is below 165 BMEP. Allowable backpressure is not reduced below 4.0 in. (101.6 mm) of water column pressure (1 kPa). At reduced load and/or speed the backpressure on the engine will decrease by the operating characteristic of the exhaust system.</p> <p><b>Max Exhaust Backpressure = 13.5 - [(1500 - rpm)/100] - [(165 - BMEP)/10] in. H<sub>2</sub>O</b></p>

## SECTION 4.40

### CRANKCASE BREATHER SYSTEM MAINTENANCE

#### CRANKCASE BREATHER SYSTEM MAINTENANCE

**NOTE:** After cleaning, servicing or replacing any component of the crankcase breather system, recheck the crankcase pressure to verify that it is within specification and that all system components are functioning properly.

#### SEPARATOR SCREEN MAINTENANCE

6 and 12 cylinder engines have a crankcase separator screen. On six cylinder engines, the separator screen is located in the firing deck of the crankcase at the rear of the engine (see Figure 4.40-1). On 12 cylinder engines, the separator screen is located in the rear right side of the engine on the cylinder firing deck. 16 cylinder engines do not have separator screens.

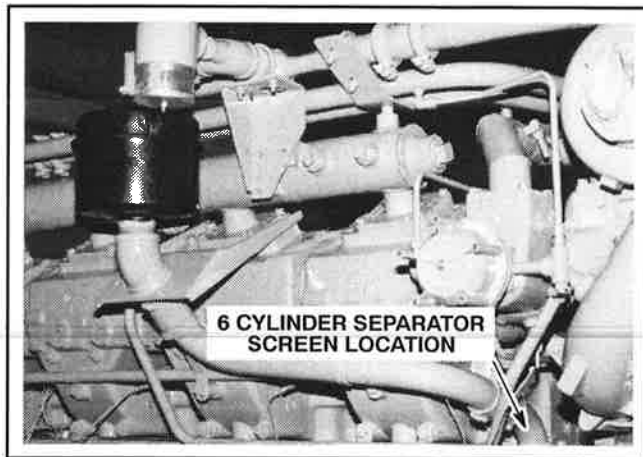


Figure 4.40-1. Crankcase Separator Screen - 6 Cylinder

#### Crankcase Separator Screen Removal

1. Disconnect the separator screen tubing from the oil separator (see Figure 4.40-1, Figure 4.40-2, Figure 4.40-3 and Figure 4.40-4).
2. Remove the capscrews, lock washers, and gaskets and the separator screen assembly from the top of the cylinder block.

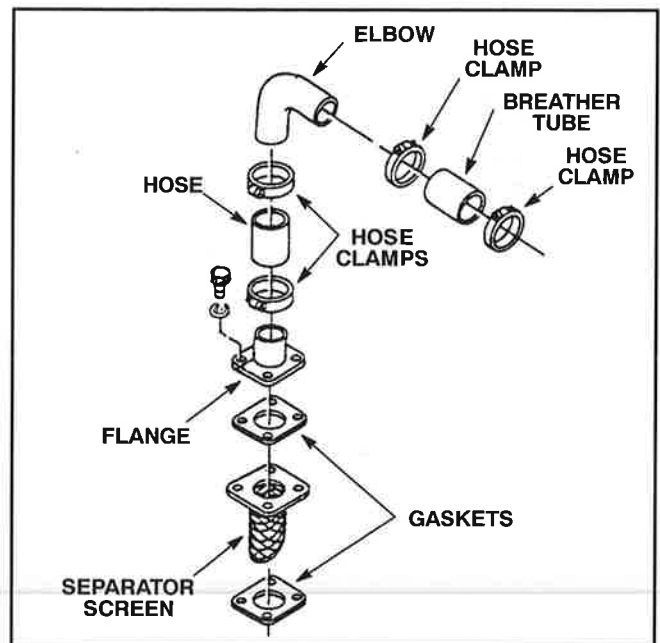


Figure 4.40-2. Crankcase Separator Screen - 6 Cylinder

## CRANKCASE BREATHER SYSTEM MAINTENANCE

### Crankcase Separator Screen Cleaning And Inspection

#### WARNING

Always use approved cleaning solvents in a well ventilated area. Avoid contact with skin. Disregarding this information could result in severe personal injury or death.

1. Wash the screen in a non-volatile cleaning solution or solvent, if necessary.
2. Remove the separator screen and breather transition assembly.

#### WARNING

Compressed air can pierce the skin and cause severe injury. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.

3. Dry the screening element from the inside out using low pressure compressed air.

### Crankcase Separator Screen Assembly

1. Position a new gasket over the rectangular hole on the top of the cylinder block (rear right corner) (see Figure 4.40-1, Figure 4.40-2, Figure 4.40-3 and Figure 4.40-4). Verify that the gasket surfaces are clean and completely free of grease and oil.
2. Install the separator screen in the cylinder block.
3. Install a new gasket on top of the separator screen.
4. Fasten the separator screen and breather transition assembly to the top of the cylinder block lock washers and capscrews.
5. Install the oil separator tubing.

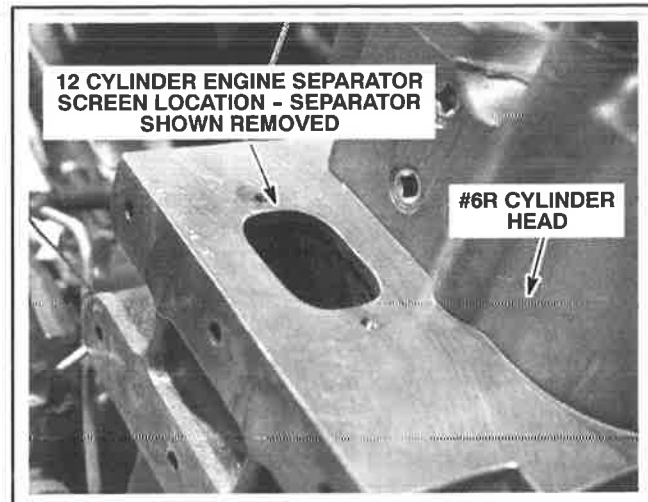


Figure 4.40-3. Crankcase - Rear Right

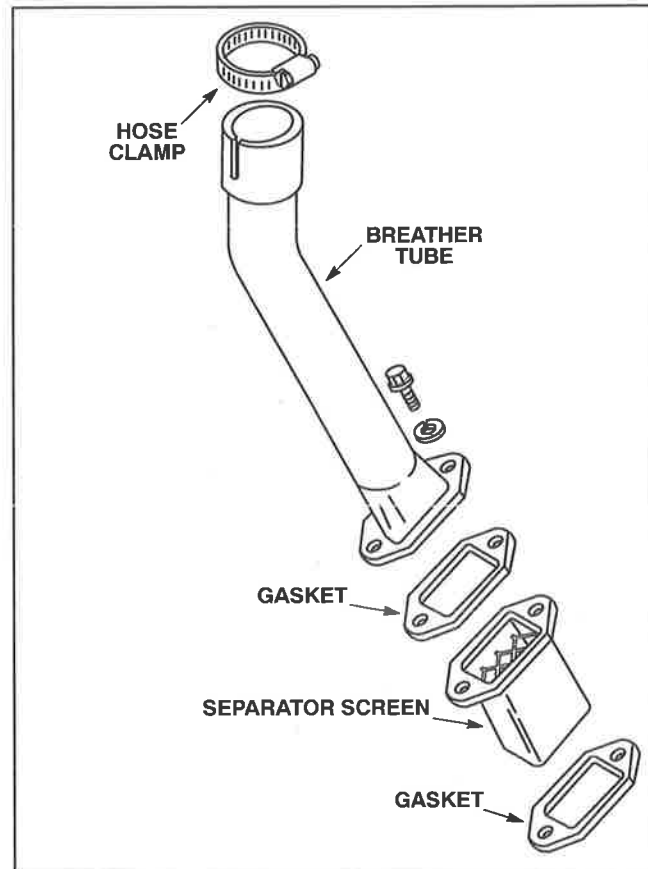


Figure 4.40-4. Crankcase Separator Screen Assembly - 12 Cylinder GL Shown



## OIL SEPARATOR(S) MAINTENANCE

6 cylinder and 12 cylinder G engines, have one oil separator located at the rear of the engine (see Figure 4.40-5).

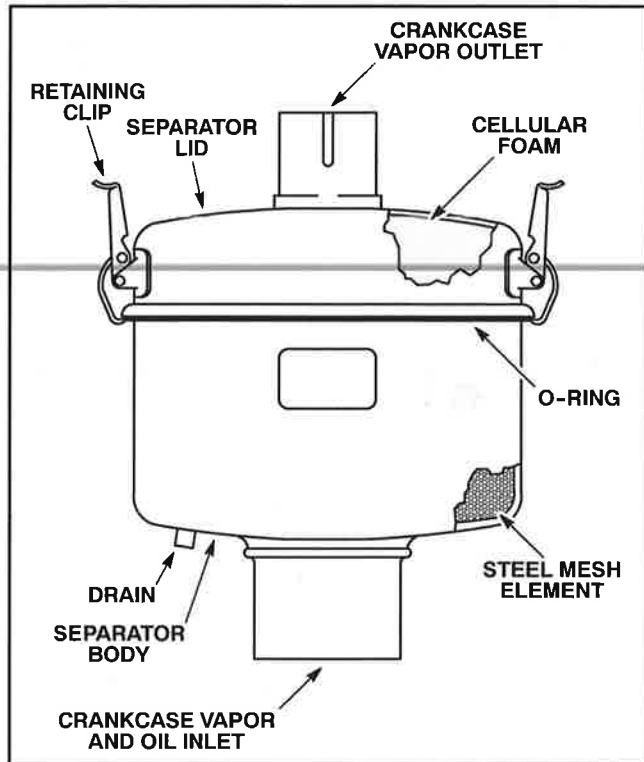


Figure 4.40-5. Oil Separator 6 And 12 Cylinder Engine

The 5115GL engine and 12 cylinder GSI and GL engines have two oil separators. One oil separator is connected by an elbow to the vent in the gear housing cover on the front left side of the engine. The second oil separator is mounted above the crankcase at the rear right side of the engine (see Figure 4.40-6). This oil separator is connected by a breather tube to the crankcase separator screen in the top of the crankcase.

16 cylinder engines have one oil separator located on the rear of the engine directly above the flywheel.

### Oil Separator Cleaning And Inspection - 6 And 12 Cylinder

Clean the oil separator at each oil change.

**NOTE:** Current production separators have elongated indentations along the circumference of the cover. This indicates that the upper foam filter is removable.

1. Disconnect the breather plumbing from the separator as required and remove the oil separator from the engine. Release the two latches on the separator and remove the cover (see Figure 4.40-5 and Figure 4.40-6).

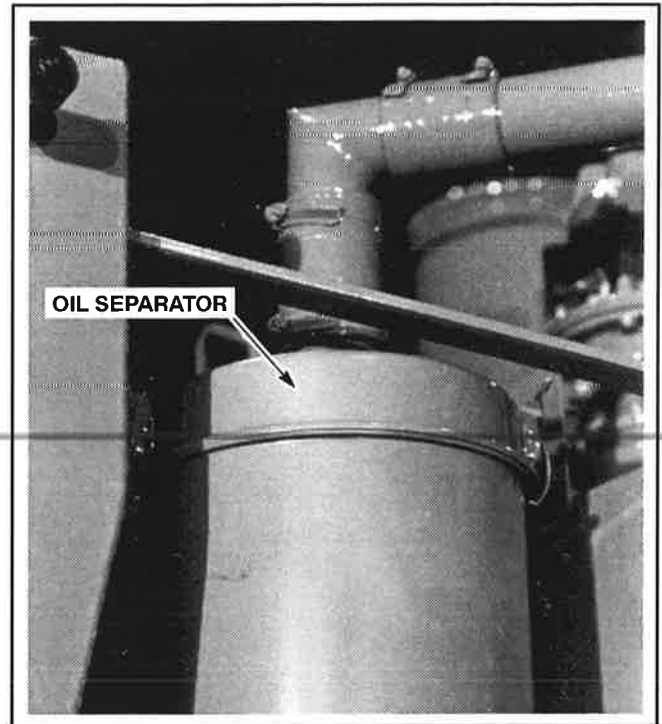


Figure 4.40-6. Oil Separator Assembly - 5115GL Engine Rear Right

2. Remove the O-ring from the cover.
3. Pry the screen out of the cover and remove the foam (see Figure 4.40-7). Remove the upper screen from the inside of the cover.

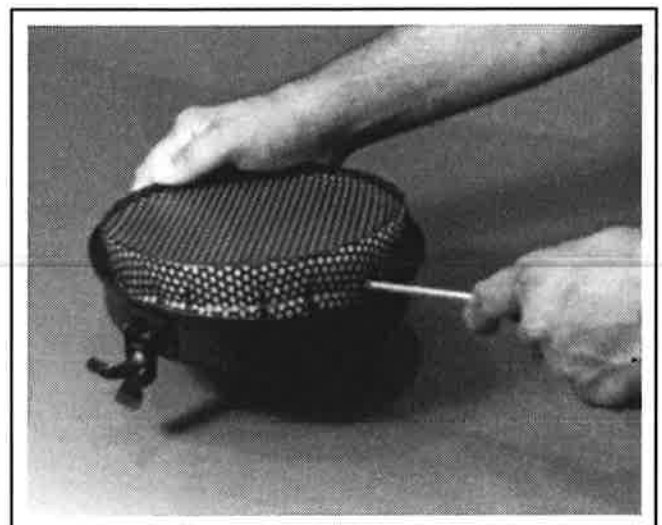
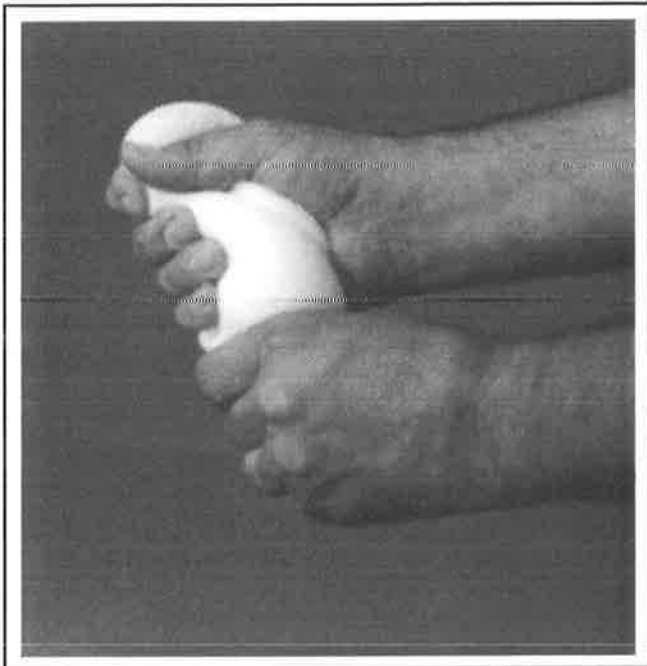


Figure 4.40-7. Pry Screen From Cover

## CRANKCASE BREATHER SYSTEM MAINTENANCE

4. Wash the foam in a detergent solution and wring dry by hand (see Figure 4.40-8). Do not use a mineral based solvent



**Figure 4.40-8. Wring Foam Dry**

5. Wipe the inside of the cover clean.

6. Install the upper screen to the inside of the cover.

7. Place the foam into place in the retaining screen (see Figure 4.40-9).



**Figure 4.40-9. Install Foam In Screen**

8. Press the retaining screen and foam into the cover (see Figure 4.40-10).



**Figure 4.40-10. Press Screen Into Cover**

9. Install the O-ring on the cover.

10. Clean the lower separator body in a solvent tank. Allow the separator to dry (see Figure 4.40-11).



**Figure 4.40-11. Wash Separator With Solvent**

11. Install the separator on the engine. Connect the drain tube to the separator (if equipped).

12. Install the cover on the separator. Install the breather plumbing as required.

## Oil Separator Cleaning And Inspection - 16 Cylinder

1. Remove the oil separator from the engine.
2. Loosen the retaining clamp and remove the lid from the body of the oil separator (see Figure 4.40-12 and Figure 4.40-13).

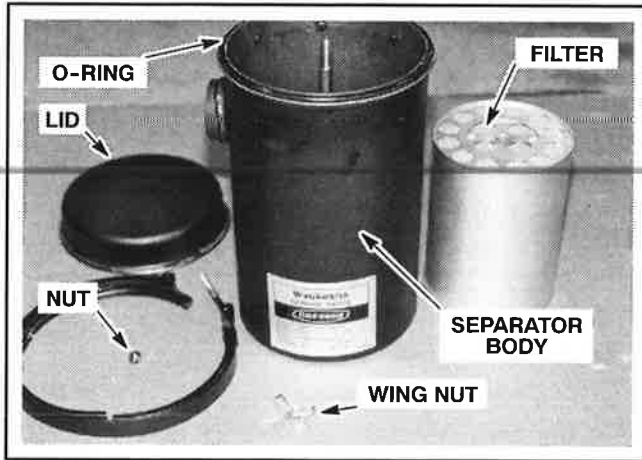


Figure 4.40-12. Oil Separator - 16 Cylinder Engine

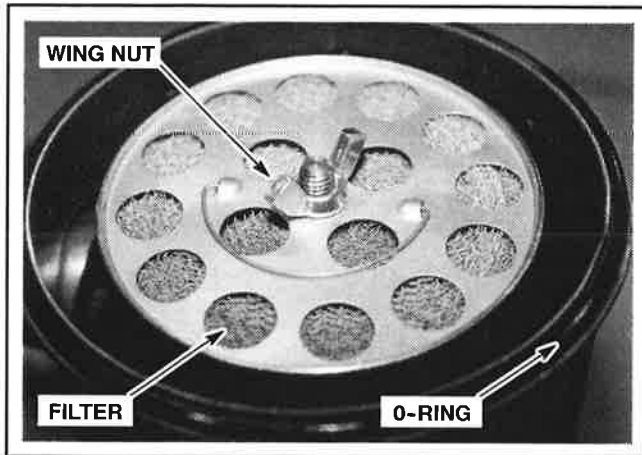


Figure 4.40-13. Oil Separator - 16 Cylinder Engine

3. Remove the rubber O-ring seal from the inside rim of the lid. Inspect the seal for cuts, tears or loss of elasticity. Replace when necessary.
4. Remove wing nut and lift the filter assembly from the separator body.
5. Thoroughly wash the body and filter element in a non-volatile cleaning solution or solvent.

## **⚠ WARNING**

Compressed air can pierce the skin and cause severe injury. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.

**⚠ CAUTION** High pressure compressed air can easily damage the light metal filter mesh element causing breather system restriction and the resultant excessive crankcase pressure condition.

6. Dry the lid, body, and filter element with low pressure compressed air.
7. Install the filter element in the separator body with the handle on the filter facing up, and hand tighten the wing nut.
8. Place the rubber O-ring seal on the inside rim of the lid.
9. Position the lid and clamp on the separator body and secure by tightening the nut on the clamp.

## CRANKCASE PRESSURE CHECK

A negative crankcase pressure of 0 - 1 in. (25.4 mm) H<sub>2</sub>O must be maintained.

**NOTE:** Measure the crankcase pressure at least once every 3 months (2160 hours).

Proceed as follows:

1. Remove the pipe plug from the oil level gauge support and install a tube connector in the hole (1/8 inch NPT) (see Figure 4.40-14).

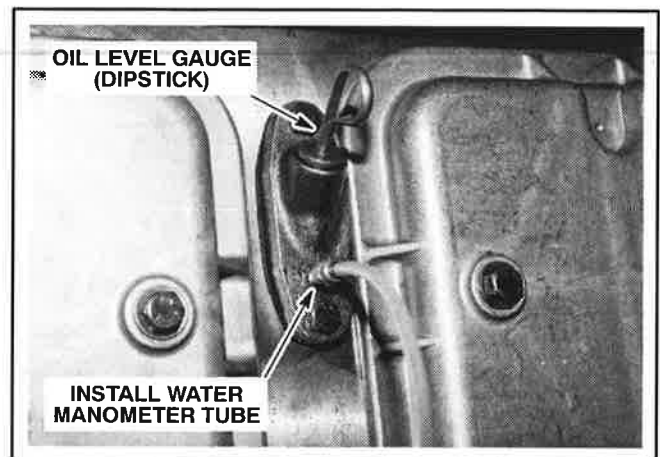


Figure 4.40-14. Install Water Manometer Tube Connector

## CRANKCASE BREATHER SYSTEM MAINTENANCE

2. Connect one end of a water manometer to the connector and vent the free end to the atmosphere; the manometer line must not protrude beyond the inner surface of the gauge support or an inaccurate reading may result (see Figure 4.40-15).

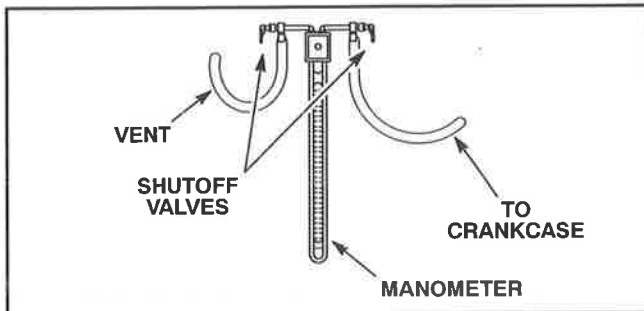


Figure 4.40-15. Water Manometer

3. Measure the crankcase pressure and perform all pressure adjustments while the engine is operating at rated speed and load (see *Crankcase Pressure Adjustment*)

4. Remove the manometer line and tube connector. Install the pipe plug.

### CRANKCASE PRESSURE ADJUSTMENT CONTROLS

All engines are provided with manual crankcase pressure adjustment. The adjustment is accomplished by admitting more or less outside air into the breather system. All manual adjustment devices are externally controlled and easily accessible.

#### 6 Cylinder Engine Crankcase Pressure Adjustment Controls

On 6 cylinder models, crankcase pressure is adjusted with either a venturi/adjusting screw assembly (see Figure 4.40-16), an ejector breather/adjusting valve assembly (see Figure 4.40-17) or vacuum valve (see Figure 4.40-18).

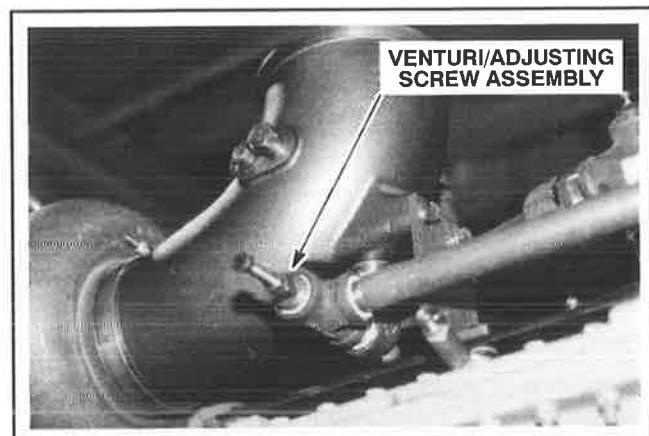


Figure 4.40-16. Venturi/Adjusting Screw Assembly - 6 Cylinder GSI Shown

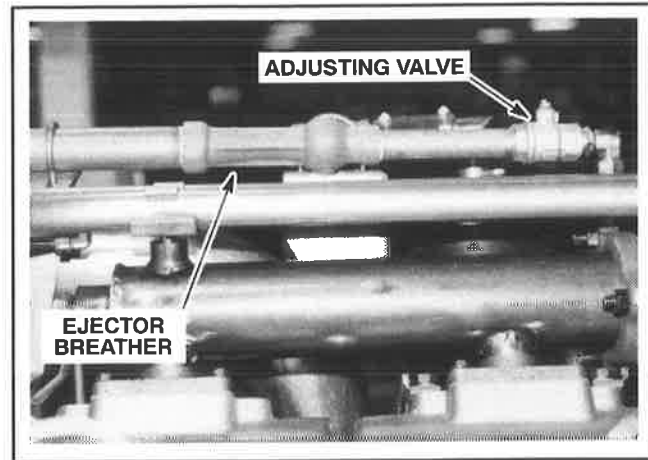


Figure 4.40-17. Ejector Breather/Adjusting Valve Assembly - 6 Cylinder Shown

#### 12 Cylinder Engine Crankcase Pressure Adjustment Controls

On 12 cylinder models that are not equipped with venturi extractor, the crankcase pressure is adjusted with a vacuum valve assembly of which there are different configurations. (see Figure 4.40-18 and Figure 4.40-19). On 12 cylinder models equipped with a venturi extractor, a choke valve is located on the end of the venturi extractor (see Figure 4.40-20).

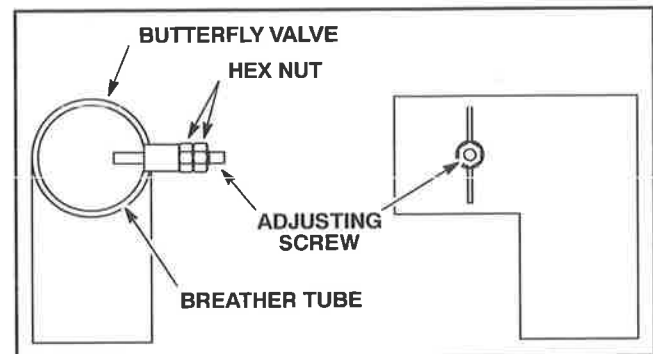


Figure 4.40-18. Vacuum Valve Assembly

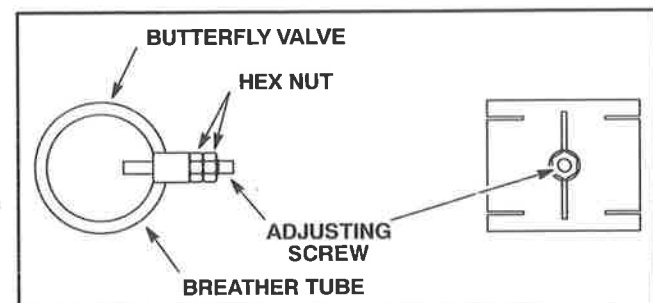


Figure 4.40-19. Vacuum Valve Assembly

## CRANKCASE BREATHER SYSTEM MAINTENANCE

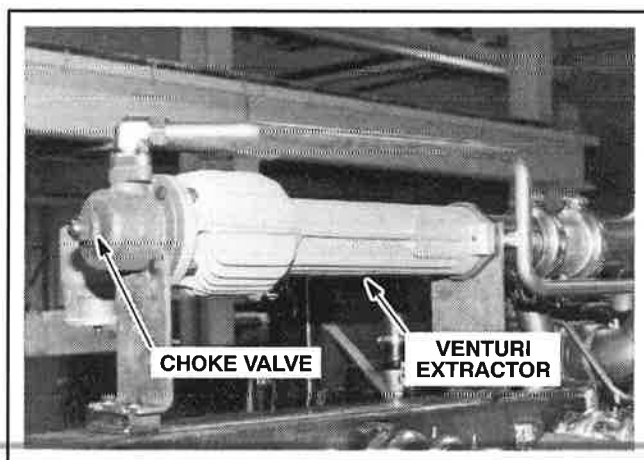


Figure 4.40-20. Venturi Extractor/Choke Valve Assembly - 12 Cylinder GL Shown

### 16 Cylinder Engine Crankcase Pressure Adjustment Controls

On 16 cylinder engines, the crankcase pressure is adjusted with a vacuum valve that is similar in appearance to the valve shown in Figure 4.40-16, or a venturi extractor/choke valve assembly similar to the one shown in Figure 4.40-20.

### CRANKCASE PRESSURE ADJUSTMENT

1. Run the engine at rated speed and load.

**NOTE:** A negative pressure of 0 - 1 in. (25.4 mm) H<sub>2</sub>O is desirable at all speeds and loads.

2. Refer to *Crankcase Pressure Check* and install a water manometer to monitor crankcase pressure.
3. Loosen the hex nut and turn the adjusting screw while monitoring the water manometer, until the recommended negative crankcase pressure is obtained.
4. Remove the engine load.
5. Measure the crankcase pressure again. Readjust if it is not within specification.
6. Retest at rated speed and load. If the crankcase pressure is within specification, tighten the hex nut to hold the setting.
7. If adjustment of manual control devices fails to properly regulate crankcase pressure:

- A. Clean the crankcase separator screen.
- B. Clean the crankcase oil separators.
- C. Clean all breather tubes.
- D. Clean and inspect the crankcase breather regulator assembly.

- E. Clean and inspect the venturi extractor assembly.
- F. Inspect the air cleaner prefilter pads and main filter elements. Clean or replace as necessary.
- G. Measure the exhaust backpressure. Excessive backpressure reduces breather system effectiveness.

**NOTE:** After cleaning, servicing or replacing any component of the crankcase breather system, recheck the crankcase pressure to verify that it is within specification and that all system components are functioning properly.

### CRANKCASE BREATHER REGULATOR MAINTENANCE

The crankcase breather regulator assembly is above the water manifold and connected to the venturi extractor through a tee and pipe nipple arrangement (see Figure 4.40-21).

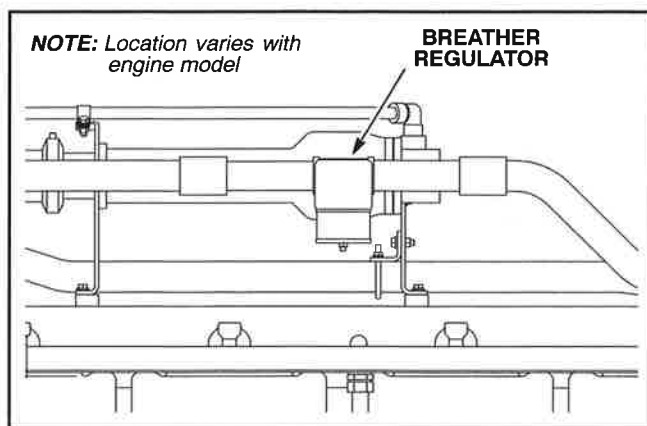


Figure 4.40-21. Breather Regulator

While there is no manual adjustment of the crankcase breather regulator, it should be inspected annually for an accumulation of dirt or grit. Harsh environments may dictate more frequent attention.

## CRANKCASE BREATHER SYSTEM MAINTENANCE

### CRANKCASE BREATHER REGULATOR - CLEANING AND INSPECTION

#### **⚠ WARNING**

Compressed air can pierce the skin and cause severe injury. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.

1. Thoroughly wash all parts in a non-volatile cleaning solution or solvent to remove accumulations of dust, dirt, grease and grit (see Figure 4.40-22). Dry with low pressure compressed air.

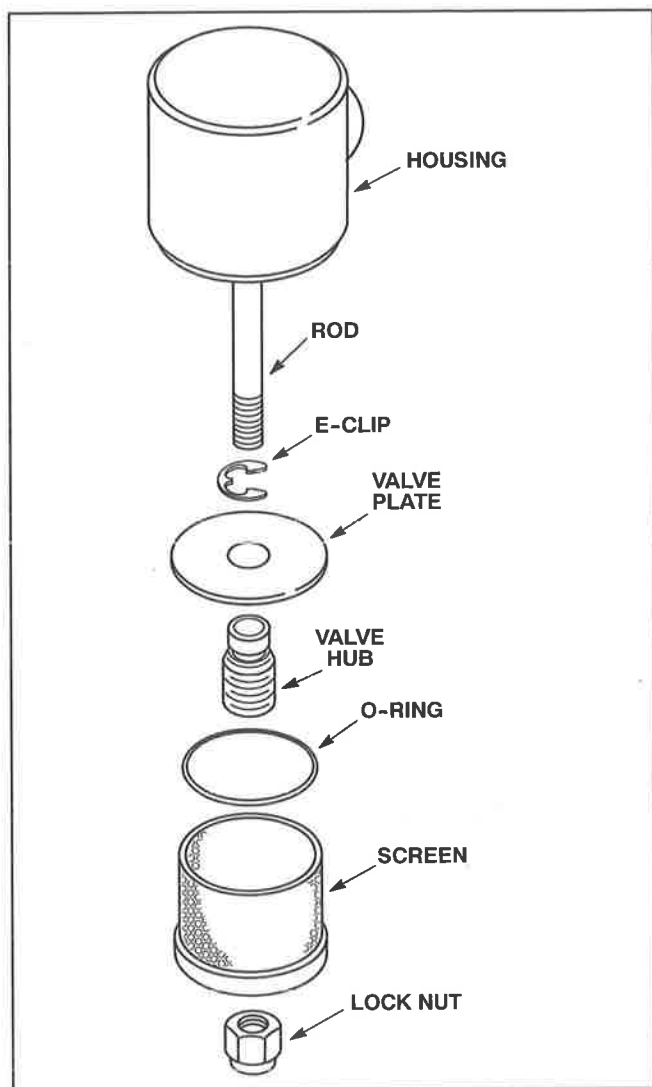


Figure 4.40-22. Breather Regulator Assembly

2. Inspect the regulator housing for cracks.
3. Inspect the regulator rod for scratches or burrs.
4. Inspect the O-ring for cuts, tears or loss of elasticity.

5. Inspect the valve plate for nicks, cracks or damage.

**⚠ CAUTION** If replacement of the breather regulator housing or valve assembly is necessary, be sure to order the correct part numbers. Since air flow requirements vary between engine models and applications, the housings and valves are sized or weighted differently and are not interchangeable. Disregarding this information could result in product damage.

6. Replace any parts of the assembly that are damaged or worn.

### CRANKCASE PRESSURE RELIEF VALVES MAINTENANCE

To ensure that they are in proper working condition, the crankcase pressure relief valves should be exercised and inspected annually (see Figure 4.40-23). If removed, replace crankcase pressure relief valves in the same positions as received from the factory.

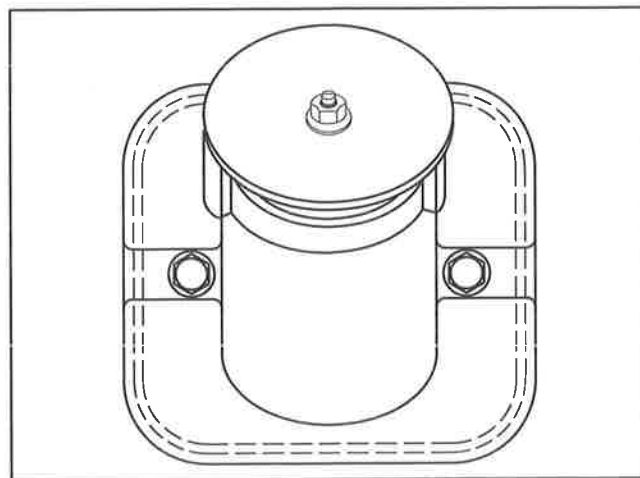


Figure 4.40-23. Crankcase Pressure Relief Valve

1. Shut down the engine and allow it to cool.
2. Lift the valve off its seat to verify that the plate is free to move.

#### **⚠ WARNING**

The number of pressure relief valves used on the engine depends on the volume of the crankcase. Never operate the engine without all valves on the engine. The ability of the system to function is dependent upon the proper number of relief valves. Operation without the proper type and number of relief valves, or if the relief valves are not properly maintained, can result in severe personal injury or death.

## SECTION 4.45

### PRELUBE AND STARTING SYSTEM MAINTENANCE

#### PRELUBE AND STARTING SYSTEM MAINTENANCE

##### **WARNING**

From the bulkhead, all gas vented from the system must be piped to a safe area in conformance with all applicable codes. Failure to comply could result in severe personal injury or death.

#### ELECTRIC STARTER SYSTEM MAINTENANCE

##### **WARNING**

Always disconnect electrical power during inspection of electrical components. Failure to comply could result in severe personal injury or death.

Inspect the starter motor and wiring for loose connections or frayed insulation (see Figure 4.45-1).

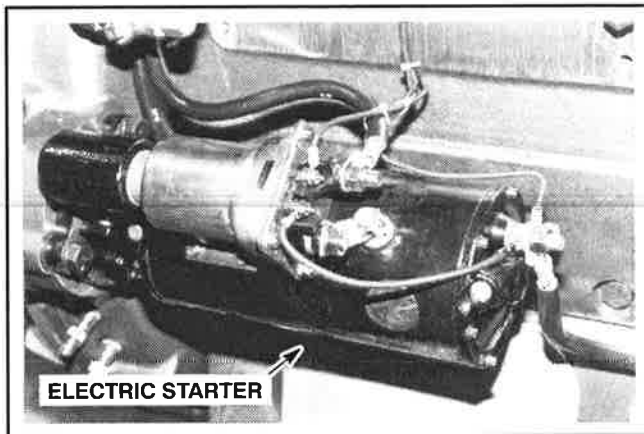


Figure 4.45-1. Electric Starter

#### AIR/GAS STARTER LUBRICATION RESERVOIR MAINTENANCE

1. Prior to each start check the air/gas starter reservoir for lubricant (see Figure 4.45-2 and Figure 4.45-3).

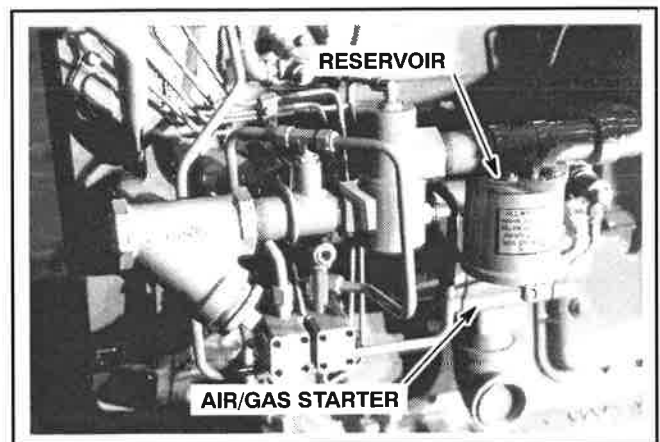


Figure 4.45-2. Air/Gas Starter

2. Remove the plug and fill the reservoir. DO NOT OVERFILL. Use the proper grade of oil. Add SAE 10W oil at 32° F (0° C) and above. Use No. 2 Diesel Oil when ambient temperatures fall below 32° F (0° C).

3. Replace the plug.



## PRELUBE AND STARTING SYSTEM MAINTENANCE



Figure 4.45-3. Air/Gas Starter Reservoir

### IN-LINE LUBRICATOR

#### **⚠ WARNING**

If high pressure gas is used to drive the air/gas prelude pump motor, vent the motor exhaust to a safe area in conformance with all applicable codes. Improper venting may result in severe personal injury or death.

**NOTE:** The air/gas starting system also has a lubrication reservoir. See Starting Systems for information.

The in-line lubricator injects oil into a stream of compressed air/gas to provide the internal lubrication of the air/gas operated prelude pump motor (see Figure 4.45-4).

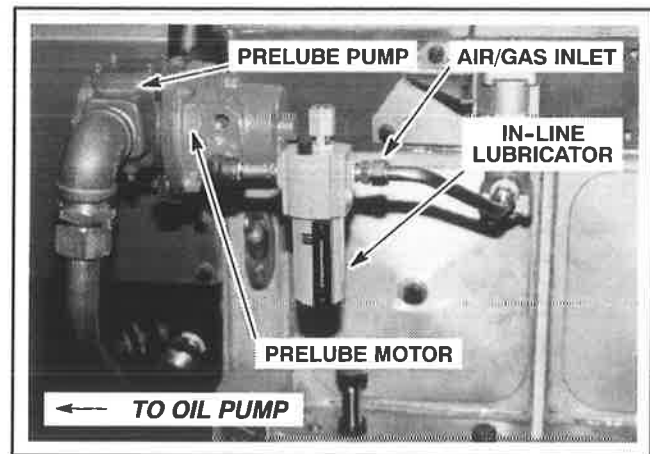


Figure 4.45-4. In-line Lubricator And Prelude Motor/Pump Assembly

**⚠ CAUTION** The lubricator is intended for systems using dry, clean natural gas. Any appreciable amount of hydrogen sulfide ( $H_2S$ ), particularly when combined with moisture, will cause corrosion and adversely effect the lubricator and its operation. Disregarding this information could result in product damage and/or personal injury.

**⚠ CAUTION** From the point of use, some oil mist may escape into the surrounding atmosphere. Users are referred to OSHA safety and health standards for limiting oil mist contamination and use of protecting equipment. Disregarding this information could result in product damage and/or personal injury.

**⚠ CAUTION** The maximum operating temperature of the lubricator is 175° F (79° C). Disregarding this information could result in product damage and/or personal injury.



## Oil Fill

Check the level of the in-line lubricator daily. The oil level must always be visible in the sight glass. Refill as follows:

1. With the inlet pressure shut off, slowly loosen the oil fill plug in the lubricator housing cover (see Figure 4.45-5). Loosening the plug exposes a bleed orifice that reduces pressure in the oil reservoir.

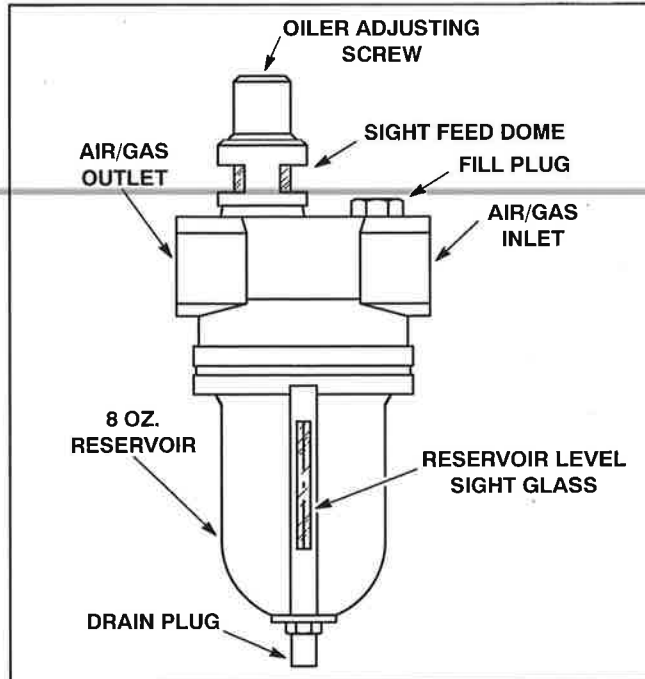


Figure 4.45-5. In-line Lubricator



**CAUTION** Insure that oil level of the in-line lubricator is always visible in the sight glass. **DO NOT OVERFILL** the reservoir. Failure to follow proper procedures could result in product damage and/or personal injury.

2. Remove the plug and fill the reservoir to the proper level. **DO NOT OVERFILL**. The oil level must always be visible in the sight glass. Use the proper grade of oil. Add SAE 10W oil at 32° F (0° C) and above. Use No. 2 Diesel Oil when ambient temperatures fall below 32° F (0° C).
3. Inspect the O-ring on the neck of the oil fill plug for tears, cuts or general deterioration. Replace as necessary.
4. Install the plug in the lubricator housing cover.

## Adjustments

Periodically check the lubricator drip rate. If the prelube pump motor exhaust is oil-free or contains an excessive amount of oil, manual adjustment is necessary.

1. Locate the oiler adjusting screw at the top of the sight feed dome on the lubricator housing cover.
2. Pull the lock ring on the adjusting screw upward to release the drip rate setting.
3. Adjust the drip rate only when there is a constant rate of air/gas flow through the lubricator. Oil drops are

atomized by the air/gas flowing through the lubricator throat. Monitor the drip rate through the sight feed dome. All of the drops visible in the dome are delivered to the prelube pump motor.

4. Adjust the lubricator to provide a light oil vapor at the prelube motor exhaust (about 4 to 5 drops per minute). Turn the adjusting screw clockwise to decrease the drip rate, turn the screw counterclockwise to increase it.
5. Push the lock ring on the adjusting screw downward to lock the drip rate setting.
6. Monitor the prelube pump motor for a few days following the adjustment. Readjust the drip rate if necessary.

## Cleaning

Clean the in-line lubricator monthly.

1. With the inlet pressure shut off, slowly loosen the oil fill plug in the lubricator housing cover. Loosening the plug exposes a bleed orifice that reduces pressure in the oil reservoir. Remove the oil fill plug.
2. Remove the drain plug at the bottom of the reservoir. Drain the oil.
3. Unthread the reservoir from the lubricator housing cover.
4. Inspect the O-ring on the upper lip of the reservoir for tears, cuts or general deterioration. Replace as necessary.



## WARNING

**Compressed air can pierce the skin and cause severe injury. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.**

5. Clean the reservoir using soap and water. Dry parts and blow out internal body passages using clean, dry compressed air.
6. Inspect all parts carefully. Replace any parts that appear damaged.
7. Install the reservoir onto the lubricator housing cover and fully tighten the reservoir until it stops (approximately 5 turns). Unscrew the reservoir no more than one full turn to position the sight glass for best visibility.
8. Inspect the O-ring on the neck of the oil fill plug for tears, cuts or general deterioration. Replace as necessary. Install the plug in the lubricator housing cover.
9. Install the drain plug at the bottom of the lubricator reservoir.
10. Fill the lubricator reservoir with the proper grade and amount of oil (see Table 4.30-1 and Table 4.30-2).
11. Periodically check the drip rate. Readjust if necessary (see *In-line Lubricator, Adjustments*).

# PRELUBE AND STARTING SYSTEM MAINTENANCE

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## SECTION 4.50

### ENGINE PROTECTION SYSTEM MAINTENANCE

#### ENGINE PROTECTION SHUTDOWN SYSTEM MAINTENANCE

Maintenance of the engine protection shutdown system is generally limited to visual inspection of components.

#### **⚠ WARNING**

Switches for alarms and automatic engine shutdown must be supplied by the customer. The sensors provided are for measuring and monitoring temperatures and WILL NOT shut the engine down if potentially harmful temperatures are reached. Waukesha will not be responsible for any property damage, severe personal injury or death, due to the failure to follow these instructions.

#### K-TYPE THERMOCOUPLES INSPECTION

**⚠ CAUTION** Thermocouples can be extremely hot. Allow engine to cool prior to handling thermocouple. Failure to follow these procedures could result in severe personal injury.

1. Inspect the thermocouples (see Figure 4.50-1) to insure they are securely seated.

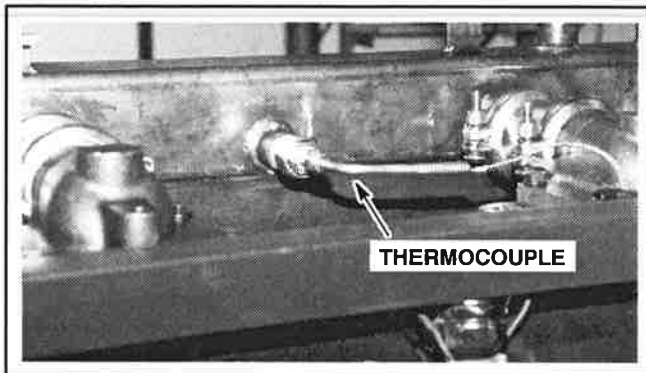


Figure 4.50-1. Jacket Water Temperature Sensor - 5115GL Engine Shown

2. Inspect connecting cables and wires for loose connections, broken wires or insulation.

#### MANUAL SHUTDOWN LEVER MAINTENANCE

#### **⚠ WARNING**

Always insure that the fuel gas valve(s) are closed after engine shutdown. Failure to close fuel gas valve(s) could cause severe personal injury or death.

1. Inspect the manual shutdown lever for proper operation (see Figure 4.50-2). With the engine running under no load, move the lever to the CLOSED position, the engine should return to idle speed.

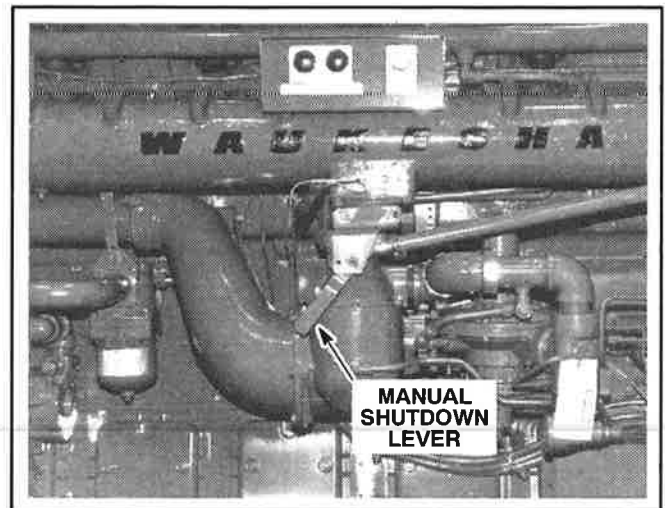


Figure 4.50-2. Manual Shutdown Lever - 12 Cylinder VHP GL Shown

#### PRESSURE AND TEMPERATURE SWITCHES CALIBRATION

Calibrating and testing pressure and temperature switches, should be performed by qualified service technicians every 90 days.

#### OPTIONAL INSTRUMENT PANEL

Inspect the instrument panel to insure the gauges are operating.

# VALVE ADJUSTMENT

---

# SECTION 4.60

## MAINTENANCE SCHEDULE

### MAINTENANCE SCHEDULE

**Table 4.60-1. Routine Maintenance Chart**

ITEM	SERVICE	DAILY OR AS REQUIRED	WEEKLY	MONTHLY	EVERY 3 MONTHS	EVERY 6 MONTHS	ANNUALLY	100 HRS.	250 HRS.	500 HRS.	720 HRS.	1,000 HRS.	1,500 HRS.	2,500 HRS.	4,000 HRS.	8,000 HRS.
Air Cleaner Filter Element	Check/Clean or Replace	•														
Air Starter Lubricator	Check/Fill	•														
Control Rod Ends and Linkage	Clean/Lubricate	•														
Cooling Systems Fluid Level (Jacket and Auxiliary)	Check/Fill	•														
Crankcase Oil Level	Check/Fill	•														
Governor Oil Level	Check/Fill	•														
Oil Filter	Release Trapped Air	•														
Precleaner Element	Check/Clean or Replace	•														
Prelube Motor Reservoir	Check/Fill	•														
Battery Electrolyte	Check/Fill		•													
Cooling Water Analysis	Check/Fill		•													
Belt Tension	Check		•													
Ignition Cables, Primary and Secondary Connect.	Inspect		•													
Water Temperature Gauge	Test				•											
Crankcase Pressure	Check				•											
Oil Pressure Safety	Test				•											
Safety Controls	Test				•											
Valve Clearance	Adjust				•											
Valve Cover Gasket	Replace				•											
Admission Valve Assembly	Clean or Replace					•										
Admission Valve O-Ring	Replace					•										
Electric Starter Bearings	Lubricate					•										

Continued

# MAINTENANCE SCHEDULE

ITEM	SERVICE	DAILY OR AS REQUIRED	WEEKLY	MONTHLY	EVERY 3 MONTHS	EVERY 6 MONTHS	ANNUALLY	100 HRS.	250 HRS.	500 HRS.	720 HRS.	1,000 HRS.	1,500 HRS.	2,500 HRS.	4,000 HRS.	8,000 HRS.
Governor-Synchronizer Motor Bearings	Lubricate					•										
Turbocharger	Clean and Inspect					•										
Cooling System (Jacket and Auxiliary)	Clean and Flush						•									
Crankcase Oil Pickup Screen	Clean						•									
Exhaust Back Pressure	Check						•									
Full Flow Filter Relief Valve	Inspect						•									
High Tension Wires	Replace						•									
Ignition Primary Terminals, Harness Plug	Inspect						•									
Governor-Synchronizer Motor Reduction Gears	Lubricate						•									
Jacket Water Hoses	Replace						•									
Oil Pan	Clean						•									
Engine Oil (Excess of Continuous Duty, See Table 4.30-11, Table 4.30-12, and Table 4.30-13)*	Change								•							
Control Linkage	Clean and Lubricate										•					
Engine Oil	Analysis										•					
Fan Hub And idler Pulley Bearings	Lubricate										•					
Auxiliary Water Pump	Inspect/Lubricate										•					
Spark Plugs (or as required)	Clean and Regap											•				
Engine Protection Devices	Inspect											•				
Engine Oil & Filter (Standby Service, See Table 4.30-11, Table 4.30-12, and Table 4.30-13)*	Change												•			
Engine Oil (Continuous Duty, See Table 4.30-11, Table 4.30-12, and Table 4.30-13)*	Change												•			
Governor Rod Ends	Lubricate												•			
Ignition Timing	Check												•			
Lube Oil Strainer Element	Clean												•			
Magnetic Plugs	Clean												•			
Oil Cooler (Oil Side)	Drain												•			
Oil Filter Elements	Replace												•			
Crankcase Breather	Clean												•			
Oil Separators	Clean												•			
Water Pump Idler Pulley Bearings	Lubricate												•			
Spark Plugs (2500 - 4000 hours or as required)	Replace													•		

Continued

## MAINTENANCE SCHEDULE

ITEM	SERVICE	DAILY OR AS REQUIRED	WEEKLY	MONTHLY	EVERY 3 MONTHS	EVERY 6 MONTHS	ANNUALLY	100 HRS.	250 HRS.	500 HRS.	720 HRS.	1,000 HRS.	1,500 HRS.	2,500 HRS.	4,000 HRS.	8,000 HRS.	
Oil Filter Seal	Replace														•		
Precleaner Element	Replace															•	
Cooling Water Analysis	Check																•
Hydraulic Governor Oil (or as required)	Change																•
Intercooler	Clean and Inspect																•
Belts	Replace																•
Ignition Coils	Inspect																•
Ignition Primary Terminals, Connections, Harness Plug, and Wires	Inspect																•
CEC Ignition	Inspect																•
Detonation Sensing Module	Inspect																•
Air/Fuel Module	Inspect																•

**NOTE:** \* See Section 4.30, Lubrication System Maintenance, Table 4.30-11, Table 4.30-12 for ebullient cooled engines, or hot water system with engine water temperature 200° F (93° C) or above (5115GL rated at 220° C (104° C). Table 4.30-12 details intervals for engines receiving normal maintenance and using gaseous fuel containing H<sub>2</sub>S in excess of published limits.


**WARNING**

**Failure to observe the above maintenance schedule could result in severe personal injury or death.**

## TROUBLESHOOTING

SYMPTOM	PROBABLE CAUSE	REMEDY
Excessive fuel consumption.	Leaks in fuel system.	Contact your Waukesha Engine Distributor for assistance.
	Retarded ignition timing.	Set timing to specifications.
	Engine overloaded.	Determine and correct cause.
TURBOCHARGER: Excessive noise or vibration.	Low lube oil pressure. Improper bearing lubrication. Load engine before warm oil is supplied to the turbocharger.	Contact your Waukesha Engine Distributor for assistance.
GOVERNOR: UG-8 Engine hunts or surges.	Dirty oil in governor.	Drain oil, clean governor and refill.
	Foamy oil in governor.	Drain oil and refill.
	Low oil level.	Add oil to correct level on gauge glass. Check for leaks, especially at drive shaft.
GOVERNOR: UG-8 Engine is slow to respond to speed or load changes	Engine overloaded.	Reduce load.
GOVERNOR: UG-8 Engine will not pick up rated load	Restricted fuel supply.	Clean fuel supply line and filters.
	Governor linkage binding or sticking.	Contact your Waukesha Engine Distributor for assistance.
	Governor linkage loose or sloppy.	Contact your Waukesha Engine Distributor for assistance.
	Governor rod length incorrect.	Contact your Waukesha Engine Distributor for assistance.
	Incorrect angle on governor terminal shaft.	Contact your Waukesha Engine Distributor for assistance.
	Governor compensation set too low.	Contact your Waukesha Engine Distributor for assistance.
	Fuel pressure unstable and "hunting".	Contact your Waukesha Engine Distributor for assistance.
	Governor drive gear dampers are worn out.	Contact your Waukesha Engine Distributor for assistance.



## ALPHABETICAL INDEX

## A

Air Intake System Description .....	2.15 - 1
Air Cleaner(s) .....	2.15 - 1
Carburetor(s) And Intake Manifold(s) .....	2.15 - 1
Intercooler(s) .....	2.15 - 2
Turbocharger(s) .....	2.15 - 2
Air Intake System Maintenance .....	4.15 - 1
Air Filter Maintenance .....	4.15 - 1

## B

Basic Engine Description .....	1.15 - 1
--------------------------------	----------

## C

Component Descriptions .....	1.15 - 2
Camshafts .....	1.15 - 2
Carburetor(s) .....	1.15 - 3
CEC Detonation Sensing Module .....	1.15 - 3
CEC Ignition Module .....	1.15 - 2
Connecting Rods .....	1.15 - 2
Crankcase .....	1.15 - 2
Crankshaft .....	1.15 - 2
Cylinder Head And Valves .....	1.15 - 2
Cylinder Liners .....	1.15 - 2
Exhaust Manifold(s) .....	1.15 - 2
Instrument Panel .....	1.15 - 3
Intake Manifold(s) .....	1.15 - 2
Intercooler(s) .....	1.15 - 3
Pistons .....	1.15 - 2
Serial Numbers And Engine Nameplate .....	1.15 - 3
Turbocharger(s) .....	1.15 - 2
Cooling System Description .....	2.25 - 1
Auxiliary Remote Heat Transfer Device .....	2.25 - 5
Auxiliary Water Pump .....	2.25 - 4
Cluster Thermostat Housing .....	2.25 - 3
Exhaust Manifold .....	2.25 - 1
Intercooler(s) .....	2.25 - 4
Jacket Water Header/Jacket Water .....	2.25 - 1
Jacket Water Pump .....	2.25 - 3
Oil Cooler .....	2.25 - 5
Remote Heat Transfer Device .....	2.25 - 4
Water Manifold .....	2.25 - 3
Cooling System Maintenance .....	4.25 - 1
Auxiliary Cooling Water Circuit - Initial Fill .....	4.25 - 4
Auxiliary Water Pump Bearings Lubrication .....	4.25 - 8
Auxiliary Water Pump Drive Belt Replacement .....	4.25 - 13
Auxiliary Water Pump Drive Belt Tension Adjustment .....	4.25 - 14
Cooling System Additives .....	4.25 - 1

Cooling System Specifications And Recommendations .....	4.25 - 2
Cooling Water Circuits - Drain And Flush .....	4.25 - 5
Cooling Water System - Air Bleed .....	4.25 - 4
Grease Recommendations .....	4.25 - 9
Idle Pulley Bearing Lubrication .....	4.25 - 8
Jacket Cooling Water Circuit - Initial Fill .....	4.25 - 3
Jacket Water Pump Belts Replacement .....	4.25 - 9
Jacket Water Pump Belts Tension Adjustment .....	4.25 - 11
Jacket/Auxiliary Water Pump Inspection .....	4.25 - 16

Crankcase Breather System Description .....	2.40 - 1
Breather Regulator .....	2.40 - 5
Choke Valve/Vacuum Valve Maintenance .....	2.40 - 4
Oil Separator(s) .....	2.40 - 2
Pressure Relief Valves .....	2.40 - 5
Separator Screen .....	2.40 - 1
Venturi Extractor .....	2.40 - 5
Crankcase Breather System Maintenance .....	4.40 - 1
Oil Separator(s) Maintenance .....	4.40 - 3
Pressure Adjustment .....	4.40 - 7
Pressure Adjustment Controls .....	4.40 - 6
Pressure Check .....	4.40 - 5
Pressure Relief Valves Maintenance .....	4.40 - 8
Regulator Cleaning And Inspection .....	4.40 - 8
Regulator Maintenance .....	4.40 - 7
Separator Screen Maintenance .....	4.40 - 1

## E

Engine During Operation Checks .....	3.00 - 6
Engine Identification Views .....	1.15 - 6
5115GL .....	1.15 - 9
Six Cylinder GL .....	1.15 - 6
Sixteen Cylinder GL .....	1.15 - 16
Twelve Cylinder GL .....	1.15 - 13
Engine Performance Record .....	3.00 - 11
Engine Protection Shutdown System Description Options .....	2.50 - 1
K-Type Thermocouples .....	2.50 - 1
Customer Supplied Control Switches .....	2.50 - 4
Detonation Module And Sensors .....	2.50 - 5
Manual Shutdown Lever And Governor Speed Control Lever .....	2.50 - 3
Manual Shutdown Switch/Switches .....	2.50 - 4
Optional Instrument Panel .....	2.50 - 4
Pressure And Temperature Switch Calibration .....	2.50 - 4
Thermocouple Junction Box .....	2.50 - 3
Engine Protection Shutdown System Maintenance .....	4.50 - 1
K-Type Thermocouples .....	4.50 - 1

## APPENDIX A

Delonation Module And Sensors .....	4.50 - 2
Manual Shutdown Lever .....	4.50 - 1
Optional Instrument Panel .....	4.50 - 1
Pressure And Temperature Switches Calibration .....	4.50 - 1
Engine Rigging And Lifting .....	1.10 - 1
Correct Method .....	1.10 - 1
Location Of The Lifting Eyes .....	1.10 - 1
Engine Shutdown Procedures .....	3.00 - 8
Emergency Shutdown .....	3.00 - 8
Routine Shutdown .....	3.00 - 8
Engine Specifications .....	1.15 - 19
Engine Startup Procedures .....	3.00 - 3
Engine Storage .....	4.65 - 1
Preservation Equipment And Material .....	4.65 - 1
Engine Storage - New .....	4.65 - 3
Non-Operational .....	4.65 - 3
Operational .....	4.65 - 3
External Component Protection .....	4.65 - 3
Internal Component Protection .....	4.65 - 3
Engine Storage - Used .....	4.65 - 4
Non-Operational .....	4.65 - 4
Operational .....	4.65 - 4
Engine Timing Data .....	1.15 - 24
Engines Returned To Service After Storage .....	4.65 - 4
Exhaust System Description .....	2.35 - 1
Exhaust Manifold .....	2.35 - 1
Turbochargers .....	2.35 - 2
Wastegates .....	2.35 - 2
Exhaust System Maintenance .....	4.35 - 1
Backpressure Measurement .....	4.35 - 1
Inspection .....	4.35 - 1
Temperature Monitoring .....	4.35 - 1

## F

Fuel System Description .....	2.05 - 1
Admission Valve Assemblies .....	2.05 - 3
Carburetor(s) .....	2.05 - 2
CEC Air/Fuel Module System .....	2.05 - 4
Draw-thru Engines .....	2.05 - 5
Main Fuel Gas Pressure Regulators .....	2.05 - 1
Prechamber Gas Safety Shutdown Valve .....	2.05 - 3
Prechamber Gas Valve .....	2.05 - 2
Prechamber Regulator .....	2.05 - 2
Prechambers And Spark Plug Carriers .....	2.05 - 4
Fuel System Maintenance .....	4.05 - 1
Admission Valve Maintenance .....	4.05 - 1

## G

General Information .....	1.15 - 1
Features And Benefits .....	1.15 - 1

## H

How To Use This Manual .....	vii
------------------------------	-----

## I

Ignition Maintenance .....	4.10 - 1
CEC Ignition Module Timing Adjustment - Dynamic .....	4.10 - 10
Ignition System General Maintenance And Inspection .....	4.10 - 11
Ignition Timing Adjustment - Dynamic (Magneto System) .....	4.10 - 8
Spark Plug Maintenance - CSA .....	4.10 - 5
Spark Plug Maintenance - Non-CSA .....	4.10 - 1
Ignition System Description .....	2.10 - 1, 2.10 - 2
CEC Detonation Sensing Module .....	2.10 - 5
CEC Ignition Module .....	2.10 - 2
CSA Ignition System .....	2.10 - 4
Magneto Ignition System .....	2.10 - 4
Spark Plug, Spark Plug Carriers, And Connectors .....	2.10 - 1

## L

Lubrication System Description .....	2.30 - 1
In-line Lubricator .....	2.30 - 8
Internal Oil Control .....	2.30 - 1
MICROSPIN™ Cleanable Lube Oil Filtering System .....	2.30 - 6
Oil Cooler .....	2.30 - 5
Oil Pan And Pickup Screen .....	2.30 - 4
Oil Pump .....	2.30 - 4
Oil Strainer .....	2.30 - 5
Prelube Pump/Motor .....	2.30 - 7
Prelube Pushbutton Valve .....	2.30 - 7
Prelube System Components .....	2.30 - 1
Prelube Valve .....	2.30 - 7
Lubrication System Maintenance .....	4.30 - 1
Catalyst Contaminants .....	4.30 - 19
Crankcase Oil Level Checking .....	4.30 - 3
In-line Lubricator .....	4.30 - 15
Low Ambient Temperature Operation .....	4.30 - 24
Lube Oil Condemning Limits .....	4.30 - 23
Lube Oil Consumption Rates .....	4.30 - 24
Lube Oil Filter Maintenance .....	4.30 - 11
Lube Oil Filter Relief Valve Maintenance .....	4.30 - 13
Lube Oil Pressure Adjustment .....	4.30 - 15
Lube Oil Strainer Maintenance .....	4.30 - 14
Lube Oil System Air Bleed .....	4.30 - 10

Lubricating Oil Performance ..... 4.30 - 19  
 Magnetic Plug Maintenance ..... 4.30 - 15  
 MICROSPIN™ Maintenance ..... 4.30 - 17  
 Multi-Viscosity Oils ..... 4.30 - 24  
 Oil Additives ..... 4.30 - 19  
 Oil Change ..... 4.30 - 3  
 Oil Consumption Rate Formulas ..... 4.30 - 24  
 Oil Cooler And Lube Oil Filter Installation  
     Requirements ..... 4.30 - 2  
 Oil Cooler Maintenance ..... 4.30 - 10  
 Oil Designations ..... 4.30 - 19  
 Oil Fill -Initial Procedure ..... 4.30 - 1  
 Oil Filtration Requirement ..... 4.30 - 19  
 Oil Pan Maintenance ..... 4.30 - 4  
 Oil Pickup Screen Maintenance ..... 4.30 - 5  
 Oil Recommendations ..... 4.30 - 19  
 Oil System Piping Purge ..... 4.30 - 2  
 Oil Viscosity Selection ..... 4.30 - 24  
 Prelube Y-Strainer Maintenance ..... 4.30 - 16  
 Recommendations For Fuel Gas Filtration  
     Of Solids And Liquids ..... 4.30 - 22  
 Recommended Lube Oils For Landfill Gas  
     Applications ..... 4.30 - 21  
 Recommended Oil Change Intervals .... 4.30 - 25  
 Sour Gas, Alternate Fuel Gas, And  
     Landfill Gas Recommendations ..... 4.30 - 21  
 Synthetic Oils ..... 4.30 - 24  
 Waukesha Cogeneration Installations -  
     Oil Recommendations ..... 4.30 - 20

**M**

Maintenance Of Standby Units ..... 3.00 - 11  
 Maintenance Schedule ..... 4.60 - 1

**P**

Prelube And Starting System Description ... 2.45 - 1  
     In-line Lubricator ..... 2.45 - 2  
     Prelube Pump And Motor ..... 2.45 - 1  
     Prelube Pushbutton Valve ..... 2.45 - 1  
     Start Pushbutton Valve ..... 2.45 - 2  
     Starter Motor - Air/Gas ..... 2.45 - 2  
     Starter Motor - Electric Start ..... 2.45 - 2  
 Prelube And Starting System Maintenance .. 4.45 - 1  
     Air/Gas Starter - Lubrication Reservoir ... 4.45 - 1  
     Electric Starter System ..... 4.45 - 1  
     In-line Lubricator ..... 4.45 - 2  
 Prestart Inspection ..... 3.00 - 1

**S**

Safety Introduction ..... 1.05 - 1  
 Acids ..... 1.05 - 2  
 Batteries ..... 1.05 - 2  
 Body Protection ..... 1.05 - 2  
 Chemicals ..... 1.05 - 2  
     Cleaning Solvents ..... 1.05 - 2  
     General ..... 1.05 - 2  
     Liquid Nitrogen/Dry Ice ..... 1.05 - 2  
 Components ..... 1.05 - 2  
     Heated Or Frozen ..... 1.05 - 2  
     Interference Fit ..... 1.05 - 2  
 Cooling System ..... 1.05 - 3  
 Electrical ..... 1.05 - 3  
     General ..... 1.05 - 3  
     Ignition ..... 1.05 - 3  
 Equipment Repair And Service ..... 1.05 - 1  
 Exhaust ..... 1.05 - 3  
 Fire Protection ..... 1.05 - 3  
 Fuels ..... 1.05 - 3  
     Gaseous ..... 1.05 - 4  
     General ..... 1.05 - 3  
     Liquid ..... 1.05 - 4  
 Intoxicants And Narcotics ..... 1.05 - 4  
 Pressurized Fluids/Gas/Air ..... 1.05 - 4  
 Protective Guards ..... 1.05 - 4  
 Safety Tags And Decals ..... 1.05 - 1  
 Springs ..... 1.05 - 4  
 Tools ..... 1.05 - 4  
     Electrical ..... 1.05 - 4  
     Hydraulic ..... 1.05 - 5  
     Pneumatic ..... 1.05 - 5  
     Weight ..... 1.05 - 5  
     Welding ..... 1.05 - 5  
         General ..... 1.05 - 5  
         On Engine ..... 1.05 - 5  
 Service Tools List ..... 1.15 - 24  
 Speed Governing System Description ..... 2.00 - 1  
     Control Panel ..... 2.00 - 4  
     Governor Linkage ..... 2.00 - 3  
     Magnetic Pickup ..... 2.00 - 3  
     Overspeed Governor ..... 2.00 - 2  
     Woodward EG-3P Electronic Governor ... 2.00 - 2  
     Woodward UG-8 Dial Governor ..... 2.00 - 1  
     Woodward UG-8 Governor ..... 2.00 - 1  
     Woodward UG-Actuator Governor ..... 2.00 - 1  
 Speed Governing System Maintenance ..... 4.00 - 1  
     Governor Maintenance ..... 4.00 - 1  
     Governor Rod Maintenance ..... 4.00 - 2

## APPENDIX A

---

### T

Torque Values .....	1.15 - 22
Troubleshooting .....	5.00 - 1
Turbocharger System Description .....	2.20 - 1
Turbochargers .....	2.20 - 1
Turbocharger System Maintenance .....	4.20 - 1
Inspection .....	4.20 - 1
Lubrication Check .....	4.20 - 2

### V

Valve Adjustment .....	4.55 - 1
Intake/Exhaust Valves - 5115GL Only .....	4.55 - 1
Intake/Exhaust Valves - 6, 12, And 16 Cylinder Gas - Excluding 5115GL .....	4.55 - 5

### W

Warning Tags And Decal Locations .....	1.00 - 1
VHP 12 Cylinder .....	1.00 - 4
VHP 16 Cylinder .....	1.00 - 7
VHP 6 Cylinder .....	1.00 - 2
Waukesha Engine Preservative Oil .....	4.65 - 2
Preservative Oil Usage .....	4.65 - 2
Use Of Other Preservative Oils And Materials .....	4.65 - 2

**WAUKESHA ENGINE DIVISION, DRESSER EQUIPMENT GROUP, INC.**  
**EXPRESS LIMITED WARRANTY FOR PRODUCTS USED IN CONTINUOUS DUTY APPLICATIONS**

---

**INTRODUCTION**

CONTINUOUS DUTY DEFINITION: The highest load and speed which can be applied, subject to Waukesha's approved ratings in effect at time of sale.

**I. TERMS OF EXPRESS LIMITED WARRANTY**

Waukesha Engine Division warrants that it will repair or replace, AT ITS ELECTION AND EXPENSE, any part of an engine, or Enginator®, or product (hereinafter referred to as "Products") manufactured by Waukesha, which proves to have had a defect in material or workmanship.

**II. TERM LIMITATIONS OF EXPRESS LIMITED WARRANTY**

- A. This coverage shall commence upon initial new Products start-up date and shall expire upon the earlier of the following:
1. 12 months after the initial new Products start-up date; or
  2. 24 months after the original shipment date of the covered products by Waukesha Engine Division.
- B. Notwithstanding the foregoing, Waukesha further warrants that the cylinder block casting, cylinder head castings, connecting rod forgings, and crankshaft forging will be free from defects in material or workmanship. This additional warranty only covers failures of the specific items noted within this subparagraph.

This coverage shall expire upon the earlier of the following:

1. 60 months after the initial new Products start-up date; or
2. 25,000 hours of operation of the covered Products; or
3. 72 months after the original shipment date of the covered Products by Waukesha Engine Division.

**NOTE:** No damage from other sources, such as damage from the loss of a crankshaft bearing, shall be considered as a forging defect.

**III. WAUKESHA'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY**

Waukesha shall be responsible for:

- A. The repair or replacement, at Waukesha's election, of covered defective parts and all reasonable labor required regarding a warranted failure during the express limited warranty term. All such labor shall be provided by Waukesha's authorized contractor or distributor.
- B. Reasonable and necessary travel and expenses incurred by Waukesha's authorized contractor or distributor.
- C. Replacement of lubricating oil, coolant, filter elements, or other normal maintenance items that are contaminated and/or damaged as a direct result of a warranted failure.

NOTWITHSTANDING THE FOREGOING, WAUKESHA SHALL NOT BE RESPONSIBLE FOR LABOR COSTS ASSOCIATED WITH WARRANTY CLAIMS BROUGHT PURSUANT TO SUBPARAGRAPH II(B).

**IV. OWNER'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY**

Owner shall be responsible for:

- A. The operation and maintenance of the Products within the guidelines established by Waukesha.
- B. Making the Products available to Waukesha or Waukesha's authorized contractors or distributors for any warranty repair, during normal business hours.
- C. All additional costs incurred for premium or overtime labor, should owner request that repairs be made on a premium or overtime schedule.
- D. All costs incurred as the result of removal or reinstallation of the Products as may be required to effect any warranted repair.
- E. All administrative costs and expenses resulting from a warranted failure.
- F. Any costs of transportation, towing, repair facilities, or associated costs.
- G. All labor, travel, mileage, and other related costs and expenses associated with a claim made pursuant to subparagraph II(B) above.
- H. Loss of revenue and loss of or damage to real and/or personal property.

**V. LIMITATION OF WAUKESHA'S OBLIGATIONS**

The obligations of Waukesha under this express limited warranty shall be waived and voided, and Waukesha shall not, thereafter, be responsible for:

- A. Any failure resulting from owner or operator abuse or neglect, including but not by way of limitation, any operation, installation, application, or maintenance practice not in accordance with guidelines or specifications established by Waukesha; or
- B. Any failure resulting from unauthorized modifications or repairs of the Products; or
- C. Any failure resulting from overload, overspeed, overheat, accident, improper storage; or
- D. Failure of owner to promptly provide notice of a claimed defect; or
- E. Failure of Products for which Waukesha did not receive properly completed start-up reports; or
- F. Repairs of a covered failure performed with non-genuine Waukesha parts; or
- G. Repairs of covered failure performed by non-authorized contractors or distributors; or
- H. Failure to make Products available to Waukesha or its authorized representatives; or
- I. Failure to supply documents such as drawings and specifications relating to the specific application of the Product.

**VI. APPLICATION AND EXPIRATION**

The warranties set out above are extended to all owners in the original chain of distribution. The warranties and obligations of Waukesha shall expire and be of no further effect upon the dates of expiration of the applicable warranty periods.

**THE FOREGOING SETS FORTH WAUKESHA'S ONLY OBLIGATIONS AND OWNERS' EXCLUSIVE REMEDY FOR BREACH OF WARRANTY, WHETHER SUCH CLAIMS ARE BASED ON BREACH OF CONTRACT, TORT (INCLUDING NEGLIGENCE AND STRICT LIABILITY), OR OTHER THEORIES, AND THE FOREGOING IS EXPRESSLY IN LIEU OF OTHER WARRANTIES WHATSOEVER EXPRESSED, IMPLIED, AND STATUTORY, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS.**

**Notwithstanding the preceding, in no event shall Waukesha be liable for any direct, special, incidental or consequential damages (whether denominated in contract, tort, strict liability, negligence or other theories) arising out of this Agreement or the use of any Products provided under this Agreement.**

**Any action arising hereunder or relating hereto, whether based on breach of contract, tort (including negligence and strict liability), or other theories must be commenced within two (2) years after the cause of action accrues or it shall be barred.**

**All disputes and claims between the parties which may arise out of or in connection with this Contract shall be settled by good faith negotiation between an executive level representative of each party. If the parties are nonetheless unable to reach agreement, such dispute shall be resolved by binding arbitration. The arbitration shall be administered by the American Arbitration Association according to its rules of Commercial Arbitration then in force. The arbitration shall take place in Milwaukee, Wisconsin, before one arbitrator. The language to be used in the arbitration shall be English. The law of Texas shall govern. Judgment upon the award of the arbitrators may be entered in any court of competent jurisdiction.**

**WAUKESHA ENGINE DIVISION, DRESSER EQUIPMENT GROUP, INC.**  
**EXPRESS LIMITED WARRANTY FOR PRODUCTS OPERATED IN EXCESS OF CONTINUOUS DUTY RATINGS**

---

**INTRODUCTION**

This warranty only applies to engines which Waukesha Engine Division has approved to operate in excess of the continuous duty rating.

**APPLICATIONS COVERED BY THIS WARRANTY**

**Standby Service Applications:** This rating applies to those systems used as a secondary or backup source of electrical power. This rating is the output the system will produce continuously (no overload), 24 hours per day for the duration of the prime power source outage.

**Intermittent Service Applications:** This rating is the highest load and speed that can be applied in variable speed mechanical system applications only (i.e., blowers, pumps, compressors, etc.). Operation at this rating is limited to a maximum of 3500 hours/year. For continuous operation for any length of time between the continuous and intermittent ratings see the Peak Shaving Application rating procedure.

**Peak Shaving Applications for VHP Natural Gas Engines:** The Rating for a Peak Shaving Application is based on the number of horsepower-hours available per year at site specific conditions. All applications using a Peak Shaving Rating require a signed Special Application Approval (SAA) from Waukesha's Application Engineering Department.

**I. TERMS OF EXPRESS LIMITED WARRANTY**

Waukesha Engine Division warrants that it will repair or replace, AT ITS ELECTION AND EXPENSE, any part of an engine, or engine powered Engineator® (hereinafter referred to as "Products") manufactured by Waukesha, which proves to have had a defect in material or workmanship.

**II. TERM LIMITATIONS OF EXPRESS LIMITED WARRANTY**

A. This coverage shall commence upon initial new Products start-up date and shall expire upon the earlier of the following:

1. 60 months or 3500 hours, whichever occurs first, after the initial new Products start-up date; or
2. 72 months after the original shipment date of the covered products by Waukesha Engine Division.

B. Notwithstanding the foregoing, Waukesha further warrants that the cylinder block casting, cylinder head castings, connecting rod forgings, and crankshaft forging will be free from defects in material or workmanship. This additional warranty only covers failure of the specific items noted within this subparagraph.

This coverage shall expire upon the earlier of the following:

1. 60 months after the initial new Products start-up date; or
2. 25,000 hours of operation of the covered Products; or
3. 72 months after the original shipment date of the covered Products by Waukesha Engine Division.

**NOTE:** No damage from other sources, such as damage from the loss of a crankshaft bearing, shall be considered as a forging defect.

**III. WAUKESHA'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY**

Waukesha shall be responsible for:

- A. The repair or replacement, at Waukesha's election, of covered defective parts and all reasonable labor required regarding a warranted failure during the express limited warranty term. All such labor shall be provided by Waukesha's authorized contractor or distributor.
- B. Reasonable and necessary travel and expenses incurred by Waukesha's authorized contractors or distributor.
- C. Replacement of lubricating oil, coolant, filter elements, or other normal maintenance items that are contaminated and/or damaged as a direct result of a warranted failure.

NOTWITHSTANDING THE FOREGOING, WAUKESHA SHALL NOT BE RESPONSIBLE FOR LABOR COSTS ASSOCIATED WITH WARRANTY CLAIMS BROUGHT PURSUANT TO SUBPARAGRAPH II (B).

**IV. OWNER'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY**

Owner shall be responsible for:

- A. The operation of the product within the allowable HP-HR/YR rating granted by the specific Special Application Approval for the Product.
- B. The operation and maintenance of the Products within the guidelines established by Waukesha.
- C. Making the Products available to Waukesha or Waukesha's authorized contractors or distributors for any warranty repair, during normal business hours.
- D. All additional costs incurred for premium or overtime labor, should owner request that repairs be made on a premium or overtime schedule.
- E. All costs incurred as the result of removal or reinstallation of the Products as may be required to effect any warranted repair.
- F. All administrative costs and expenses resulting from a warranted failure.
- G. Any costs of transportation, towing, repair facilities, or associated costs.
- H. All labor, travel, mileage, and other related costs and expenses associated with a claim made pursuant to subparagraph II (B) above.
- I. Loss of revenue and loss of or damage to real and/or personal property.

**V. LIMITATION OF WAUKESHA'S OBLIGATIONS**

The obligations of Waukesha under this express limited warranty shall be waived and voided, and Waukesha shall not, thereafter, be responsible for:

- A. Any failure resulting from owner or operator abuse or neglect, including but not by way of limitation, any operation, installation, application, or maintenance practice not in accordance with guidelines or specifications established by Waukesha; or
- B. Any failure resulting from unauthorized modifications or repairs of the Products; or
- C. Any failure resulting from overload, overspeed, overheat, accident, improper storage; or
- D. Failure of owner to promptly provide notice of a claimed defect; or
- E. Failure of Products for which Waukesha did not receive properly completed start-up reports; or
- F. Repairs of a covered failure performed with non-genuine Waukesha parts; or
- G. Repairs of a covered failure performed by non-authorized contractors or distributors; or
- H. Failure to make Products available to Waukesha or its authorized representatives; or
- I. Failure to supply documents such as drawings and specifications relating to the specific application of the Products.

**VI. APPLICABILITY AND EXPIRATION**

The warranties set out above are extended to all owners in the original chain of distribution. The warranties and obligations of Waukesha shall expire and be of no further effect upon the dates of expiration of the applicable warranty periods.

**THE FOREGOING SETS FORTH WAUKESHA'S ONLY OBLIGATIONS AND OWNERS' EXCLUSIVE REMEDY FOR BREACH OF WARRANTY, WHETHER SUCH CLAIMS ARE BASED ON BREACH OF CONTRACT, TORT (INCLUDING NEGLIGENCE AND STRICT LIABILITY), OR OTHER THEORIES, AND THE FOREGOING IS EXPRESSLY IN LIEU OF OTHER WARRANTIES WHATSOEVER EXPRESSED, IMPLIED, AND STATUTORY, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS.**

Notwithstanding the preceding, in no event shall Waukesha be liable for any direct, special, incidental or consequential damages (whether denominated in contract, tort, strict liability, negligence or other theories) arising out of this Agreement or the use of any Products provided under this Agreement.

Any action arising hereunder or relating hereto, whether based on breach of contract, tort (including negligence and strict liability), or other theories must be commenced within two (2) years after the cause of action accrues or it shall be barred.

All disputes and claims between the parties which may arise out of or in connection with this Contract shall be settled by good faith negotiation between an executive level representative of each party. If the parties are nonetheless unable to reach agreement, such dispute shall be resolved by binding arbitration. The arbitration shall be administered by the American Arbitration Association according to its rules of Commercial Arbitration then in force. The arbitration shall take place in Milwaukee, Wisconsin, before one arbitrator. The language to be used in the arbitration shall be English. The law of Texas shall govern. Judgment upon the award of the arbitrators may be entered in any court of competent jurisdiction.

M-761 Effective November 1, 1994

**WAUKESHA ENGINE DIVISION, DRESSER EQUIPMENT GROUP, INC.  
EXPRESS LIMITED WARRANTY FOR GENUINE WAUKESHA SERVICE PARTS**

---

**INTRODUCTION**

This warranty only applies to Genuine Waukesha Service Parts (to include assemblies and short blocks) sold by Waukesha Engine Division and used for repair, maintenance, or overhaul of Waukesha Products.

**I. TERMS OF EXPRESS LIMITED WARRANTY**

Waukesha Engine Division warrants that it will repair or replace, AT ITS ELECTION AND EXPENSE, any Genuine Waukesha Service Part installed on an engine, or Engine<sup>®</sup>, or product (hereinafter referred to as "Products") manufactured by Waukesha, which proves to have had a defect in material or workmanship.

**II. TERM LIMITATIONS OF EXPRESS LIMITED WARRANTY**

This coverage will begin on the purchase date from an authorized Waukesha Distributor and will expire twelve (12) months after the purchase date.

**III. WAUKESHA'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY**

Waukesha shall be responsible for:

- A. The repair or replacement, at Waukesha's election, of covered defective Service Parts.
- B. Labor time to repair or replace the defective part as established by the Waukesha Labor Guide Manual. All reimbursable labor costs shall be provided by Waukesha's authorized distributor.
- C. The reimbursement of documented Distributor expenses covering Freight, Customs, Brokers Fees, and Import Duties to obtain the replacement Service Part from Waukesha.

**IV. OWNER'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY**

Owner shall be responsible for:

- A. The operation and maintenance of the Products/Service Parts within the guidelines established by Waukesha.
- B. Making the Products/Service Parts available to Waukesha or Waukesha's authorized distributors for any warranty repair, during normal business hours.
- C. All additional costs incurred for premium or overtime labor, should owner request that repairs be made on a premium or overtime schedule.
- D. All costs incurred as the result of removal or reinstallation of the Products as may be required to effect any warranted repair.
- E. All administrative costs and expenses resulting from a warranted failure.
- F. Any costs of transportation, towing, repair facilities, or associated costs.
- G. All travel, mileage, and other related Distributor costs and expenses associated with repair under the terms of this Service Parts Warranty.
- H. All additional labor time in excess of Waukesha's Labor Guide for the warrantable repair.
- I. Loss of revenue and loss of/for damage to real and/or personal property.

**V. LIMITATION OF WAUKESHA'S OBLIGATIONS**

The obligations of Waukesha under this express limited warranty shall be waived and voided, and Waukesha shall not, thereafter, be responsible for:

- A. Any failure resulting from owner or operator abuse or neglect, including but not by way of limitation, any operation, installation, application, maintenance, or assembly practice not in accordance with guidelines or specifications established by Waukesha; or
- B. Any failure resulting from unauthorized modifications or repairs of the Products or Service Parts; or
- C. Any failure resulting from overload, overspeed, overheat, accident; or
- D. Failure of owner to promptly provide notice of a claimed defect; or
- E. Failure of Service Parts for which Waukesha did not receive proper documentation concerning the Service Parts purchase date from an Authorized Waukesha Engine Division Distributor; or
- F. Repairs of a covered failure performed with non-genuine Waukesha parts; or
- G. Repairs of a covered failure performed by non-authorized Contractors or Distributors; or
- H. Failure to make Products and Service Parts available to Waukesha or its authorized representatives; or
- I. Failure to supply documents such as drawings and specifications relating to the specific application of the Products; or
- J. Any failure of Service Parts resulting from misapplication or improper repair procedures; or
- K. Any failure or damage resulting from the improper or extended storage of a Service Part; or
- L. Freight, Customs, Brokers Fees, and Import Duties if appropriate documentation is not provided.

**VI. APPLICABILITY AND EXPIRATION**

The warranty set out above is extended to the original purchaser of the Genuine Waukesha Service Parts. The warranty and obligations of Waukesha shall expire and be of no further effect upon the dates of expiration of the applicable warranty period.

**VII. WARRANTY ADMINISTRATION**

This warranty is administered exclusively by an Authorized Waukesha Distributor. The invoice for the failed Service Parts must be provided to the Distributor to determine whether the warranty is applicable.

Contact the nearest Authorized Waukesha Distributor for assistance with warranty matters or questions. The location of the nearest Authorized Distributor is available by contacting Waukesha Engine Division at (414) 547-3311.

**THE FOREGOING SETS FORTH WAUKESHA'S ONLY OBLIGATIONS AND OWNERS' EXCLUSIVE REMEDY FOR BREACH OF WARRANTY, WHETHER SUCH CLAIMS ARE BASED ON BREACH OF CONTRACT, TORT (INCLUDING NEGLIGENCE AND STRICT LIABILITY), OR OTHER THEORIES, AND THE FOREGOING IS EXPRESSLY IN LIEU OF OTHER WARRANTIES WHATSOEVER EXPRESSED, IMPLIED, AND STATUTORY, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS.**

**Notwithstanding the preceding, in no event shall Waukesha be liable for any direct, special, incidental, or consequential damages (whether denominated in contract, tort strict liability, negligence, or other theories) arising out of this Agreement or the use of any Products provided under this Agreement.**

**Any action arising hereunder or relating hereto, whether based on breach of contract, tort (including negligence and strict liability), or other theories must be commenced within two (2) years after the cause of action accrues or it shall be barred.**

**All disputes and claims between the parties which may arise out of or in connection with this Contract shall be settled by good faith negotiation between an executive level representative of each party. If the parties are nonetheless unable to reach agreement, such dispute shall be resolved by binding arbitration. The arbitration shall be administered by the American Arbitration Association according to its rules of Commercial Arbitration then in force. The arbitration shall take place in Milwaukee, Wisconsin, before one arbitrator. The language to be used in the arbitration shall be English. The law of Texas shall govern. Judgment upon the award of the arbitrators may be entered in any court of competent jurisdiction.**



**WAUKESHA ENGINE DIVISION, DRESSER EQUIPMENT GROUP, INC.**  
**EXPRESS LIMITED WARRANTY FOR CUSTOM ENGINE CONTROL®**

**INTRODUCTION**

Custom Engine Control® (CEC) are sold as standard, or as options on new Engines or as Genuine Waukesha Service Parts, and include the Detonation Sensing Module (DSM), Air Fuel Module (AFM), Turbocharger Control Management System (TCMS), and Ignition Module (IM), or any other control device identified as a CEC product.

**I. TERMS OF EXPRESS LIMITED WARRANTY**

Waukesha Engine Division warrants that it will repair or replace, AT ITS ELECTION AND EXPENSE, any CEC installed on an engine, or Enginator® or product (hereinafter referred to as "Products") manufactured by Waukesha, or purchased as a Genuine Service Part, which proves to have had a defect in material or workmanship.

**II. TERM LIMITATIONS OF EXPRESS LIMITED WARRANTY**

- A. This coverage shall commence upon initial new Products start-up date or the purchase date, in the case of service parts sales, and shall expire upon the earlier of the following:
1. New Products
    - A. 12 months after the initial new Products start-up date; or
    - B. 24 months after the original shipment date of the covered Products by Waukesha Engine Division.
  2. Genuine Service Parts
    - A. 12 months from the date the CEC is put into service; or
    - B. 18 months from the purchase date.
- B. Notwithstanding the foregoing, Waukesha further warrants that it will repair or replace, AT ITS ELECTION AND EXPENSE, any component of the Waukesha Product damaged as the direct result of a warrantable defect in a CEC product.

**III. WAUKESHA'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY**

Waukesha shall be responsible for:

- A. The repair or replacement, at Waukesha's election, of covered defective parts and all reasonable labor required regarding a warranted failure during the express limited warranty term. All such labor shall be provided by Waukesha's authorized contractor or distributor.
- B. For the repair of CEC's installed on Products shipped from Waukesha, reasonable and necessary travel and expenses incurred by Waukesha's authorized contractor or distributor.
- C. Replacement of lubricating oil, coolant, filter elements, Waukesha supplied engine components, or other normal maintenance items that are contaminated and/or damaged as a direct result of a warranted failure.

**IV. OWNER'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY**

Owner shall be responsible for:

- A. The operation and maintenance of the Products within the guidelines established by Waukesha.
- B. Making the Products available to Waukesha or Waukesha's authorized contractors or distributors for any warranty repair, during normal business hours.
- C. All additional costs incurred for premium or overtime labor, should owner request that repairs be made on a premium or overtime schedule.
- D. All costs incurred as the result of removal or reinstallation of the Products as may be required to effect any warranted repair.
- E. All administrative costs and expenses resulting from a warranted failure.
- F. Any costs of transportation, towing, repair facilities, or associated costs.
- G. All travel, mileage, and other related Distributor costs and expenses associated with repair under the terms of the Service Parts Warranty.
- H. All additional labor time in excess of Waukesha's Labor Guide for the warrantable repair.
- I. Loss of revenue and loss of or damage to real and/or personal property.

**V. LIMITATION OF WAUKESHA'S OBLIGATIONS**

The obligations of Waukesha under this express limited warranty shall be waived and voided, and Waukesha shall not, thereafter, be responsible for:

- A. Any failure resulting from owner or operator abuse or neglect, including but not by way of limitation, any operation, installation, application, or maintenance practice not in accordance with guidelines or specifications established by Waukesha; or
- B. Any failure resulting from unauthorized modifications or repairs of the Products; or
- C. Any failure resulting from overload, overspeed, overheat, accident, improper storage; or
- D. Failure of owner to promptly provide notice of a claimed defect; or
- E. Failure of Products for which Waukesha did not receive properly completed start-up reports; or
- F. Repairs of a covered failure performed with non-genuine Waukesha parts; or
- G. Repairs of a covered failure performed by non-authorized contractors or distributors; or
- H. Failure to make Products available to Waukesha or its authorized representatives; or
- I. Failure to supply documents such as drawings and specifications relating to the specific application of the Products; or
- J. Improper diagnosis of a Product problem for which a CEC product is replaced.
- K. Failure of Service Parts for which Waukesha did not receive proper documentation concerning the Service Parts purchase date from an Authorized Waukesha Engine Division Distributor; or
- L. Any failure of a Service Part resulting from misapplication or improper repair procedures; or
- M. Any failure or damage resulting from the improper or extended storage of a Service Part; or
- N. Freight, Customs, Brokers Fees, and Import Duties if appropriate documentation is not provided.

**VI. APPLICABILITY AND EXPIRATION**

The warranties set out above are extended to all owners in the original chain of distribution. The warranties and obligations of Waukesha shall expire and be of no further effect upon the dates of expiration of the applicable warranty periods.

**VII. WARRANTY ADMINISTRATION**

This warranty is administered exclusively by an Authorized Waukesha Distributor. The invoice for the failed Service Part must be provided to the Distributor to determine whether the warranty is applicable. Contact the nearest Authorized Waukesha Distributor for assistance with warranty matters or questions. The location of the nearest Authorized Distributor is available by contacting Waukesha Engine Division at (414) 547-3311.

**THE FOREGOING SETS FORTH WAUKESHA'S ONLY OBLIGATIONS AND OWNERS' EXCLUSIVE REMEDY FOR BREACH OF WARRANTY, WHETHER SUCH CLAIMS ARE BASED ON BREACH OF CONTRACT, TORT (INCLUDING NEGLIGENCE AND STRICT LIABILITY), OR OTHER THEORIES, AND THE FOREGOING IS EXPRESSLY IN LIEU OF OTHER WARRANTIES WHATSOEVER EXPRESSED, IMPLIED, AND STATUTORY, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS.**

Notwithstanding the preceding, in no event shall Waukesha be liable for any direct, special, incidental, or consequential damages (whether denominated in contract, tort strict liability, negligence, or other theories) arising out of this Agreement or the use of any Products provided under this Agreement.

Any action arising hereunder or relating hereto, whether based on breach of contract, tort (including negligence and strict liability), or other theories must be commenced within two (2) years after the cause of action accrues or it shall be barred.

All disputes and claims between the parties which may arise out of or in connection with this Contract shall be settled by good faith negotiation between an executive level representative of each party. If the parties are nonetheless unable to reach agreement, such dispute shall be resolved by binding arbitration. The arbitration shall be administered by the American Arbitration Association according to its rules of Commercial Arbitration then in force. The arbitration shall take place in Milwaukee, Wisconsin, before one arbitrator. The language to be used in the arbitration shall be English. The law of Texas shall govern. Judgment upon the award of the arbitrators may be entered in any court of competent jurisdiction.

M-763 Effective March 1, 1995





# Waukesha Engine Division Welcomes Your Comments

In order to continue bringing you the BEST in Waukesha product information, we ask that you take a moment to let us know about any errors or omissions in this publication. Comments and suggestions are also welcome. Please use one of the self-addressed, postage paid cards attached below.

Thank you for your comments!

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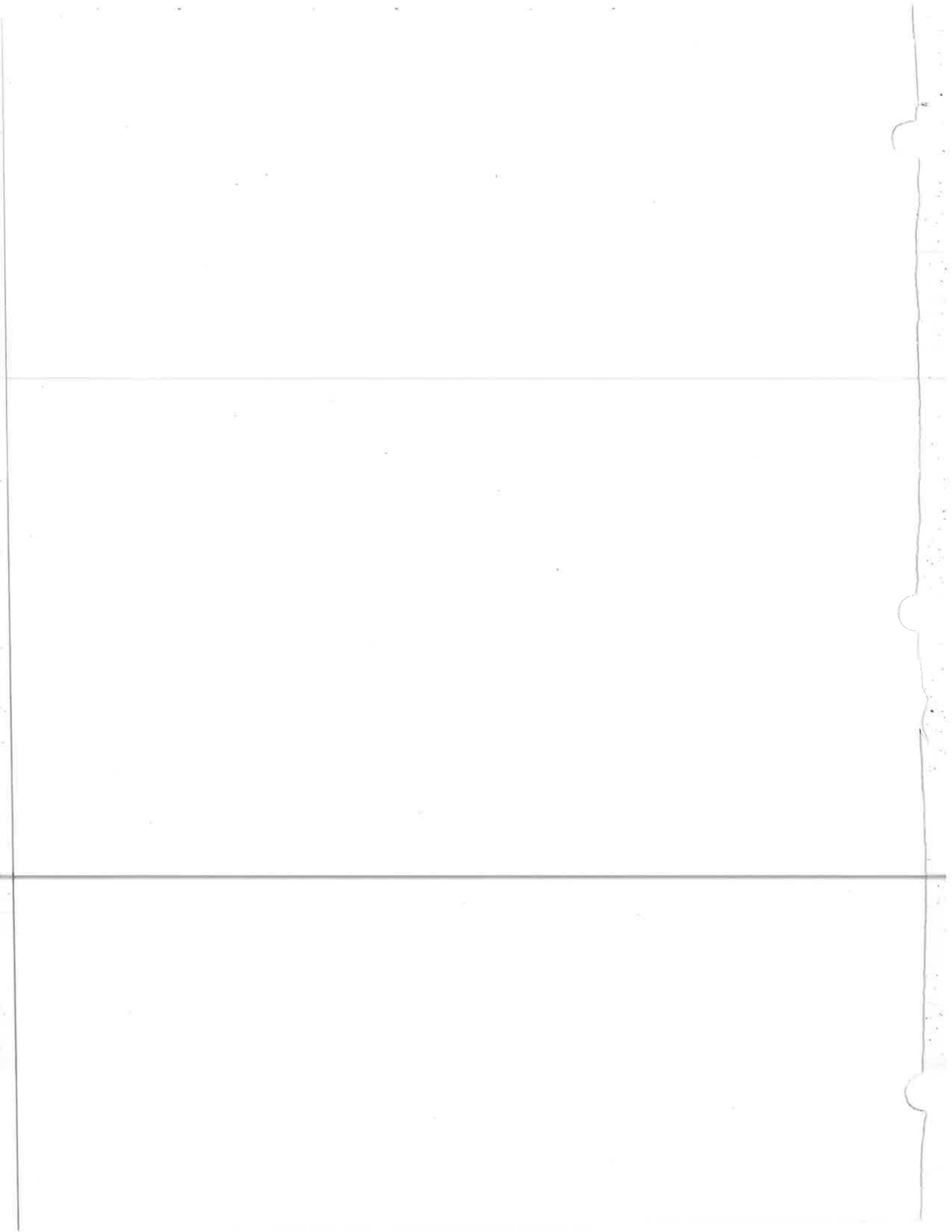


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DRESSER EQUIPMENT GROUP, INC.  
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<http://waukeshaengine.com>

WAUKESHA ENGINE  
A DIVISION OF DRESSER INDUSTRIAL PRODUCTS, B.V.  
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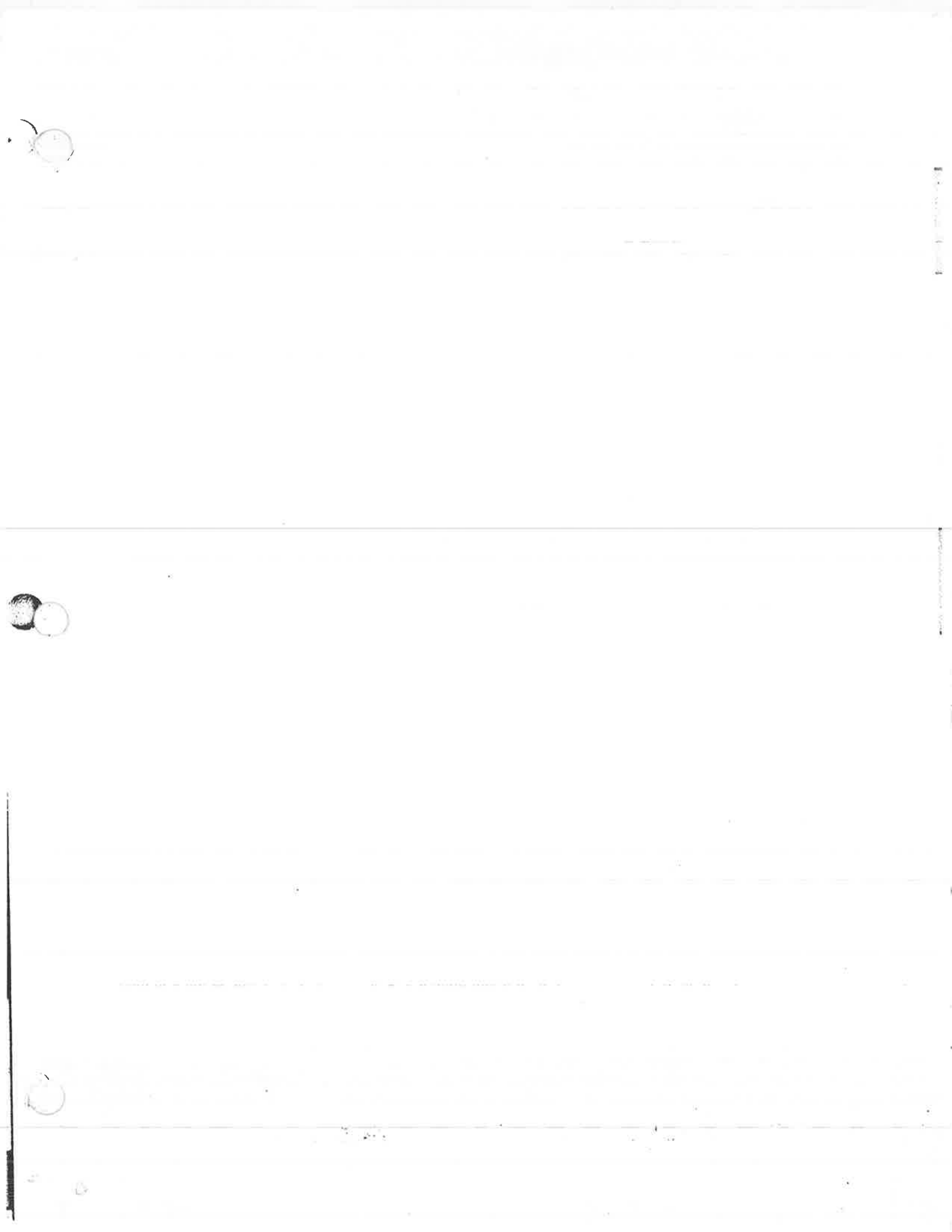
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G-G22-5939

C-13178

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Form 6272





- List Of Illustrations
- List Of Tables
- How To Use This Manual

**CHAPTER 1 - SAFETY AND GENERAL**

**Section 1.00 - Safety**

Safety Introduction	1.00 - 1
Safety Tags And Decals	1.00 - 1
Equipment Repair And Service	1.00 - 1
Acids	1.00 - 2
Batteries	1.00 - 2
Body Protection	1.00 - 2
Chemicals	1.00 - 2
General	1.00 - 2
Cleaning Solvents	1.00 - 2
Liquid Nitrogen/Dry Ice	1.00 - 2
Components	1.00 - 2
Heated Or Frozen	1.00 - 2
Interference Fit	1.00 - 2
Cooling System	1.00 - 3
Electrical	1.00 - 3
General	1.00 - 3
Ignition	1.00 - 3
Exhaust	1.00 - 3
Fire Protection	1.00 - 3
Fuels	1.00 - 4
General	1.00 - 4
Gaseous	1.00 - 4
Liquid	1.00 - 4
Intoxicants And Narcotics	1.00 - 4
Pressurized Fluids/Gas/Air	1.00 - 4
Protective Guards	1.00 - 4
Springs	1.00 - 4
Tools	1.00 - 5
Electrical	1.00 - 5
Hydraulic	1.00 - 5
Pneumatic	1.00 - 5
Weight	1.00 - 5
Welding	1.00 - 5
General	1.00 - 5
On Engine	1.00 - 5

**Section 1.05 - General Information**

Wiring	1.05 - 2
Power Requirements For Custom Engine Control® Products	1.05 - 3
Capacitive Discharge And Grounding	1.05 - 3

**Section 1.10 - Description Of Operation**

Waukesha Custom Engine Control®	
Ignition Module	1.10 - 1
System Description	1.10 - 1
Interface With CFC Detonation Sensing Module	1.10 - 2
Components	1.10 - 3
Engines Served	1.10 - 3
Operator Interface	1.10 - 3
Theory Of Operation	1.10 - 4
Ignition Module Operation	1.10 - 4
Hall-effect Pickup Verses Magnetic Pickup	1.10 - 4
Definitions	1.10 - 5

**CHAPTER 2 - VHP IGNITION MODULE INSTALLATION AND OPERATION**

**Section 2.00 - Ignition Module Operation On VHP Engines**

Ignition Module Operation On VHP Engines	2.00 - 1
VHP 6 And 12 Cylinder Timing Disc Alignment	2.00 - 1
VHP 5115GL And 16 Cylinder Timing Disc Alignment	2.00 - 4

**Section 2.05 - VHP Ignition Module Electrical Connections**

Mounting The Ignition Module	2.05 - 1
Electrical Connections	2.05 - 2
Ignition Module Power Requirements	2.05 - 2
Power Source Wiring Sizing And Grounding	2.05 - 2
Wiring Harness Connections	2.05 - 2
Completing Ignition Module Wiring	2.05 - 4

**Section 2.10 - VHP Ignition Module Timing Adjustments**

Prestart Checklist	2.10 - 1
VHP Ignition Timing Set	2.10 - 1
Steps Required To Adjust Ignition Module Timing	2.10 - 2
Discharging The Storage Capacitor	2.10 - 3

# CONTENTS

## CHAPTER 3 - ATGL IGNITION MODULE INSTALLATION AND OPERATION

### Section 3.00 - Ignition Module Operation On ATGL Engines

Ignition Module Operation On ATGL Engines	3.00 - 1
8L-AT273L Engines	3.00 - 1
12V-AT27GL Engines	3.00 - 2
12V-AT25GL Engines	3.00 - 3

### Section 3.05 - ATGL Ignition Module Electrical Connections

Mounting The Ignition Module	3.05 - 1
Electrical Connections	3.05 - 2
Ignition Module Power Requirements	3.05 - 2
Power Source Wiring Sizing And Grounding	3.05 - 2
AT Engine Wiring Harness Connections	3.05 - 2
Completing Ignition Module Wiring	3.05 - 4

### Section 3.10 - ATGL Ignition Module Timing Adjustments

Prestart Checklist	3.10 - 1
ATGL Ignition Timing Set	3.10 - 1
Steps Required To Adjust Ignition Module Timing	3.10 - 2
Discharging The Storage Capacitor	3.10 - 3

## CHAPTER 4 - VGF IGNITION MODULE INSTALLATION AND OPERATION

### Section 4.00 - Ignition Module Operation On VGF Engines

Ignition Module Operation On VGF Engines	4.00 - 1
VGF 6 And 8 Cylinder Engines	4.00 - 1
VGF 12 And 16 Cylinder Engines	4.00 - 1

### Section 4.05 - VGF Ignition Module Electrical Connections

Mounting The Ignition Module	4.05 - 1
Electrical Connections	4.05 - 2
Ignition Module Power Requirements	4.05 - 2
Power Source Wiring Sizing And Grounding	4.05 - 2
Wiring Harness Connections	4.05 - 2
Completing Ignition Module Wiring	4.05 - 4

### Section 4.10 - VGF Ignition Module Timing Adjustments

Prestart Checklist	4.10 - 1
VGF Ignition Timing Set	4.10 - 1
Steps Required To Adjust Ignition Module Timing	4.10 - 2
Discharging The Storage Capacitor	4.10 - 3

## CHAPTER 5 - DIAGNOSTICS AND TROUBLESHOOTING

### Section 5.00 - Ignition Module Diagnostics And Troubleshooting

Ignition Module Diagnostics And Troubleshooting	5.00 - 1
Diagnostics Chart	5.00 - 1
Troubleshooting Chart	5.00 - 1
Testing Ignition Module Components	5.00 - 4
Ignition Module Testing	5.00 - 8
Ignition Module Testing - On Engine	5.00 - 8
Ignition Module Testing - Bench Test	5.00 - 16
Hall-effect Pickup Testing	5.00 - 19
Ignition Coils Testing	5.00 - 21
Ignition Module Repair	5.00 - 21
Ignition Module Disassembly	5.00 - 22
Ignition Module Assembly	5.00 - 24
Tool Definitions	5.00 - 25

### Alphabetical Index

A - 1

## WARRANTY

Waukesha Engine Division - Dresser Industries, Inc.

Express Limited Warranty For Custom Engine Control®



LIST OF ILLUSTRATIONS

**Section 1.10 - Description Of Operation**

Figure 1.10-1. CEC Ignition Module ..... 1.10 - 1  
 Figure 1.10-2. Ignition Module 16 Position  
 Timing Switches ..... 1.10 - 1  
 Figure 1.10-3. Ignition Module Harness  
 Connections ..... 1.10 - 2  
 Figure 1.10-4. CEC Detonation Sensing  
 Module ..... 1.10 - 3  
 Figure 1.10-5. IM Diagnostic LEDs ..... 1.10 - 3  
 Figure 1.10-6. Sinking Type Hall-effect  
 Pickup ..... 1.10 - 4  
 Figure 1.10-7. Magnetic Pickup ..... 1.10 - 4

**Section 2.00 - Ignition Module Operation  
 On VHP Engines**

Figure 2.00-1. Governor Drive Housing ..... 2.00 - 1  
 Figure 2.00-2. Hall-effect Pickup Installed On  
 Governor Drive Gear Hub ..... 2.00 - 1  
 Figure 2.00-3. Governor Drive Gear ..... 2.00 - 1  
 Figure 2.00-4. Flywheel Timing Opening ..... 2.00 - 2  
 Figure 2.00-5. Engine Firing Order -  
 6 And 12 Cylinder VHP Engines ..... 2.00 - 2  
 Figure 2.00-6. Ignition Timing Disc ..... 2.00 - 3  
 Figure 2.00-7. Governor Drive Housing ..... 2.00 - 3  
 Figure 2.00-8. Flywheel Timing Opening ..... 2.00 - 4  
 Figure 2.00-9. Engine Firing Order -  
 12 And 16 Cylinder VHP Engines ..... 2.00 - 4  
 Figure 2.00-10. Magneto Drive Gear And  
 Timing Disc ..... 2.00 - 5

**Section 2.05 - VHP Ignition Module  
 Electrical Connections**

Figure 2.05-1. Mounting The Ignition Module -  
 VHP Engines ..... 2.05 - 1  
 Figure 2.05-2. Ignition Module Wiring  
 Harness Connections ..... 2.05 - 2  
 Figure 2.05-3. Waukesha CEC Products  
 Power Wiring Requirements ..... 2.05 - 3  
 Figure 2.05-4. CEC Ignition Module  
 Power Supply ..... 2.05 - 5  
 Figure 2.05-5. VHP 6 Cylinder  
 (With Murphy Gas Valves)  
 Ignition Module Wiring Diagram ..... 2.05 - 6  
 Figure 2.05-6. VHP 6 Cylinder  
 (Without Murphy Gas Valves)  
 Ignition Module Wiring Diagram ..... 2.05 - 7  
 Figure 2.05-7. VHP 12 Cylinder  
 (With Murphy Gas Valves)  
 Ignition Module Wiring Diagram ..... 2.05 - 8

Figure 2.05-8. VHP 12 Cylinder  
 (Without Murphy Gas Valves)  
 Ignition Module Wiring Diagram ..... 2.05 - 9  
 Figure 2.05-9. VHP 5115GL  
 Ignition Module Wiring Diagram ..... 2.05 - 10  
 Figure 2.05-10. VHP 16 Cylinder  
 (With Murphy Gas Valves)  
 Ignition Module Wiring Diagram ..... 2.05 - 11  
 Figure 2.05-11. VHP 16 Cylinder  
 (Without Murphy Gas Valves)  
 Ignition Module Wiring Diagram ..... 2.05 - 12

**Section 2.10 - VHP Ignition Module  
 Timing Adjustments**

Figure 2.10-1. Ignition Module Timing  
 Switches ..... 2.10 - 1  
 Figure 2.10-2. Timing Switches "A" And "B" .. 2.10 - 2  
 Figure 2.10-3. Flywheel Timing Opening ..... 2.10 - 3

**Section 3.00 - Ignition Module Operation  
 On ATGL Engines**

Figure 3.00-1. AT27GL Hall-effect Pickup ... 3.00 - 1  
 Figure 3.00-2. AT27GL Hall-effect Pickup ... 3.00 - 1  
 Figure 3.00-3. Camshaft Hall-effect Pickup .. 3.00 - 2  
 Figure 3.00-4. Hall-effect Pickup Installed ... 3.00 - 2  
 Figure 3.00-5. AT27GL Flywheel Hall-effect  
 Pickup ..... 3.00 - 3  
 Figure 3.00-6. 12V-AT25GL Timing Disc .... 3.00 - 3

**Section 3.05 - ATGL Ignition Module  
 Electrical Connections**

Figure 3.05-1. Mounting The Ignition Module -  
 AT Engines ..... 3.05 - 1  
 Figure 3.05-2. Ignition Module Wiring  
 Harness Connections ..... 3.05 - 2  
 Figure 3.05-3. Waukesha CEC Products  
 Power Wiring Requirements ..... 3.05 - 3  
 Figure 3.05-4. CEC Ignition Module  
 Power Supply ..... 3.05 - 5  
 Figure 3.05-5. 8L-AT27GL Hall-effect  
 Pickups And Harness Connections ..... 3.05 - 6  
 Figure 3.05-6. 12V-AT27GL Hall-effect  
 Pickups And Harness Connections ..... 3.05 - 7  
 Figure 3.05-7. 12V-AT25GL Hall-effect  
 Pickup And Harness Connections ..... 3.05 - 8  
 Figure 3.05-8. 8L-AT27GL IM  
 Wiring Diagram ..... 3.05 - 9  
 Figure 3.05-9. 12V-AT27GL IM  
 Wiring Diagram ..... 3.05 - 10  
 Figure 3.05-10. 12V-AT25GL IM  
 Wiring Diagram ..... 3.05 - 11

**Section 3.10 - ATGL Ignition Module  
Timing Adjustments**

Figure 3.10-1. Ignition Module Timing  
Switches ..... 3.10 - 1  
Figure 3.10-2. Timing Switches "A" And "B" .. 3.10 - 2

**Section 4.00 - Ignition Module Operation  
On VGF Engines**

Figure 4.00-1. Hall-effect Pickup Location ... 4.00 - 1  
Figure 4.00-2. Hall-effect Pickup ..... 4.00 - 2  
Figure 4.00-3. CEC Ignition Timing Magnets . 4.00 - 2

**Section 4.05 - VGF Ignition Module  
Electrical Connections**

Figure 4.05-1. Mounting The Ignition  
Module - VGF Engines ..... 4.05 - 1  
Figure 4.05-2. Ignition Module Wiring  
Harness Connections ..... 4.05 - 2  
Figure 4.05-3. Waukesha CEC Products  
Power Wiring Requirements ..... 4.05 - 3  
Figure 4.05-4. CEC Ignition Module  
Power Supply ..... 4.05 - 5  
Figure 4.05-5. VGF 6 Cylinder  
(With Murphy Gas Valves-Retrofit Only)  
Ignition Module Wiring Diagram ..... 4.05 - 6  
Figure 4.05-6. VGF 6 Cylinder (Without  
Murphy Gas Valves-Retrofit Or Production)  
Ignition Module Wiring Diagram ..... 4.05 - 7  
Figure 4.05-7. VGF 8 Cylinder (With  
Murphy Gas Valves-Retrofit Only)  
Ignition Module Wiring Diagram ..... 4.05 - 8  
Figure 4.05-8. VGF 8 Cylinder (Without  
Murphy Gas Valves-Retrofit or Production)  
Ignition Module Wiring Diagram ..... 4.05 - 9  
Figure 4.05-9. VGF 12 Cylinder  
(Without Murphy Gas Valves)  
Ignition Module Wiring Diagram ..... 4.05 - 10  
Figure 4.05-10. VGF 12 Cylinder Ignition  
Module Wiring Diagram ..... 4.05 - 11  
Figure 4.05-11. VGF 16 Cylinder Ignition  
Module Wiring Diagram ..... 4.05 - 12

**Section 4.10 - VGF Ignition Module  
Timing Adjustments**

Figure 4.10-1. Ignition Module Timing  
Switches ..... 4.10 - 1  
Figure 4.10-2. Timing Switches "A" And "B" .. 4.10 - 2

**Section 5.00 - Ignition Module  
Diagnostics And  
Troubleshooting**

Figure 5.00-1. Ignition Module  
Diagnostic LEDs ..... 5.00 - 1  
Figure 5.00-2. Ignition Module System ..... 5.00 - 4  
Figure 5.00-3. Ignition Module Components .. 5.00 - 5  
Figure 5.00-4. CEC Ignition Tester ..... 5.00 - 8  
Figure 5.00-5. Ignition Module  
Power Supply ..... 5.00 - 11  
Figure 5.00-6. The 7 Pin And 3 Pin  
Connectors ..... 5.00 - 12  
Figure 5.00-7. Oscilloscope Test Pattern  
(6 Cylinder Shown) ..... 5.00 - 13  
Figure 5.00-8. Oscilloscope Patterns ..... 5.00 - 15  
Figure 5.00-9. Ignition System Wiring  
Diagram For Test Stand ..... 5.00 - 16  
Figure 5.00-10. CEC Ignition Tester ..... 5.00 - 19  
Figure 5.00-11. Hall-effect Pickup Test  
With Ohmmeter ..... 5.00 - 20  
Figure 5.00-12. View Of Circuit Board  
Assemblies Inside Ignition Module ..... 5.00 - 21  
Figure 5.00-13. Ignition Module -  
Side View ..... 5.00 - 22  
Figure 5.00-14. Backplate Of  
Ignition Module ..... 5.00 - 22  
Figure 5.00-15. Backplate Of  
Ignition Module ..... 5.00 - 23  
Figure 5.00-16. Power Board Assembly  
Inside Ignition Module ..... 5.00 - 23  
Figure 5.00-17. Remaining Installed Screws  
And Standoffs On Backplate ..... 5.00 - 23  
Figure 5.00-18. Logic Board Assembly ..... 5.00 - 23  
Figure 5.00-19. Ignition Module -  
Side View ..... 5.00 - 24  
Figure 5.00-20. Ignition Module -  
Side View ..... 5.00 - 25

LIST OF TABLES

**Section 1.05 - General Information**

Table 1.05-1. English To Metric Formula Conversion Table ..... 1.05 - 1  
 Table 1.05-2. Metric To English Formula Conversion Table ..... 1.05 - 1  
 Table 1.05-3. Power Requirements For Waukesha Custom Engine Control® Products ..... 1.05 - 3

**Section 1.10 - Description Of Operation**

Table 1.10-1. Ignition Module Applications ... 1.10 - 3

**Section 2.05 - VHP Ignition Module Electrical Connections**

Table 2.05-1. Power Requirements For The Ignition Module ..... 2.05 - 3  
 Table 2.05-2. Page Locations Of VHP Wiring Diagrams ..... 2.05 - 4

**Section 2.10 - VHP Ignition Module Timing Adjustments**

Table 2.10-1. Firing Order For VHP 6 Cylinder Engines ..... 2.10 - 1  
 Table 2.10-2. Firing Order For VHP 12 Cylinder Engines ..... 2.10 - 1  
 Table 2.10-3. Firing Order For VHP 16 Cylinder Engines ..... 2.10 - 1  
 Table 2.10-4. Ignition Module Selector Switch Settings ..... 2.10 - 2

**Section 3.05 - ATGL Ignition Module Electrical Connections**

Table 3.05-1. Power Requirements For The Ignition Module ..... 3.05 - 3  
 Table 3.05-2. Page Locations Of AT Wiring Diagrams ..... 3.05 - 4

**Section 3.10 - ATGL Ignition Module Timing Adjustments**

Table 3.10-1. Firing Order For 8L-ATGL Cylinder Engines ..... 3.10 - 1  
 Table 3.10-2. Firing Order For 12V-ATGL Cylinder Engines ..... 3.10 - 1  
 Table 3.10-3. Firing Order For VGF 16 Cylinder Engines ..... 3.10 - 1  
 Table 3.10-4. Ignition Module Selector Switch Settings ..... 3.10 - 2

**Section 4.05 - VGF Ignition Module Electrical Connections**

Table 4.05-1. Power Requirements For The Ignition Module ..... 4.05 - 3  
 Table 4.05-2. Page Locations Of VGF Wiring Diagrams ..... 4.05 - 4

**Section 4.10 - VGF Ignition Module Timing Adjustments**

Table 4.10-1. Firing Order For VGF 6 Cylinder Engines ..... 4.10 - 1  
 Table 4.10-2. Firing Order For VGF 8 Cylinder Engines ..... 4.10 - 1  
 Table 4.10-3. Firing Order For VGF 12 Cylinder Engines ..... 4.10 - 1  
 Table 4.10-4. Firing Order For VGF 16 Cylinder Engines ..... 4.10 - 1  
 Table 4.10-5. Ignition Module Selector Switch Settings ..... 4.10 - 2

**Section 5.00 - Ignition Module Diagnostics And Troubleshooting**

Table 5.00-1. Ignition Module Diagnostics Chart ..... 5.00 - 2  
 Table 5.00-2. Ignition Module Troubleshooting Chart ..... 5.00 - 3  
 Table 5.00-3. Ignition Module Components Part Numbers ..... 5.00 - 6  
 Table 5.00-4. Wiring Harnesses Part Numbers ..... 5.00 - 6  
 Table 5.00-5. Ignition Module Internal Parts List ..... 5.00 - 7  
 Table 5.00-6. Ignition Module Specifications .. 5.00 - 7  
 Table 5.00-7. Ignition Module Selector Switch Settings ..... 5.00 - 8  
 Table 5.00-8. Triggering Magnet ..... 5.00 - 8  
 Table 5.00-9. Hall-effect Pickup Part Numbers ..... 5.00 - 8  
 Table 5.00-10. Ohmmeter Tests ..... 5.00 - 10  
 Table 5.00-11. Testing The 7 Pin And 3 Pin Connectors ..... 5.00 - 12  
 Table 5.00-12. VGF Engine "G" Lead Test Pigtail Adaptors ..... 5.00 - 13  
 Table 5.00-13. Bench Testing Voltage Output ..... 5.00 - 17  
 Table 5.00-14. Hall-effect Pickup Air Gap ... 5.00 - 20  
 Table 5.00-15. Coil Resistance ..... 5.00 - 21

**TABLES**

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## HOW TO USE THIS MANUAL

Your purchase of a Custom Engine Control® Ignition Module was a wise investment. In the industrial engine field the name, Waukesha Engine, stands for quality and durability. With normal care and maintenance this equipment will provide many years of reliable service.

Before placing the Ignition Module in service read Chapter 1 very carefully. This chapter covers Safety and General Information.

Section 1.00 - Safety Section - Provides a list of warnings and cautions to make you aware of the dangers present during operation and maintenance of the engine. - **READ THEM CAREFULLY AND FOLLOW THEM COMPLETELY** -

Section 1.05 - General Information - Provides conversion tables, wiring information, power requirements for Custom Engine Control® products, and capacitive discharge and grounding information.

Section 1.10 - Description of Operation - Provides basic data on the Ignition Module such as: system description, theory of operation, and definitions.

**ALWAYS BE ALERT FOR THE SPECIAL WARNINGS WITHIN THE MANUAL TEXT. THESE WARNINGS PRECEDE INFORMATION THAT IS CRUCIAL TO YOUR SAFETY AS WELL AS OTHER PERSONNEL WORKING ON OR NEAR THE ENGINE. CAUTIONS OR NOTES IN THE MANUAL CONTAIN INFORMATION THAT RELATES TO POSSIBLE DAMAGE TO THE ENGINE OR ITS COMPONENTS DURING ENGINE OPERATION OR MAINTENANCE PROCEDURES.**

This manual contains installation, operation, and maintenance instructions for the CEC Ignition Module. There are five chapters within the manual and each chapter contains one or more sections. The title of each chapter or section appears at the top of each page. To locate information on a specific topic, refer to the Table of Contents at the front of the manual or the Index at the back of the manual.

Recommendations and data contained in the manual are the latest information available at the time of this printing and are subject to change without notice. Since engine accessories may vary due to customer specifications consult your local Distributor or Waukesha Engine Division Service Operations Department for any information on subjects beyond the scope of this manual.

# HOW TO USE THIS MANUAL

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# **CHAPTER 1 - SAFETY AND GENERAL**

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## **CONTENTS**

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**SECTION 1.00 - SAFETY**

**SECTION 1.05 - GENERAL INFORMATION**

**SECTION 1.10 - DESCRIPTION OF OPERATION**

\_\_\_\_\_

124

124

124

124



## SECTION 1.00

### SAFETY

#### SAFETY INTRODUCTION

The following safety precautions are published for your information. Waukesha Engine Division, Dresser Industries, Inc., does not, by the publication of these precautions, imply or in any way represent that they are the sum of all dangers present near industrial engines or fuel rating test units. If you are installing, operating, or servicing a Waukesha product, it is your responsibility to ensure full compliance with all applicable safety codes and requirements. All requirements of the Federal Occupational Safety and Health Act must be met when Waukesha products are operated in areas that are under the jurisdiction of the United States of America. Waukesha products operated in other countries must be installed, operated and serviced in compliance with any and all applicable safety requirements of that country.

For details on safety rules and regulations in the United States, contact your local office of the Occupational Safety and Health Administration (OSHA).

The words "danger," "warning," "caution," and "note" are used throughout this manual to highlight important information. Be certain that the meanings of these alerts are known to all who work on or near the equipment.

**NOTE:** This symbol identifies information which is **NECESSARY TO THE PROPER OPERATION, MAINTENANCE OR REPAIR OF THE EQUIPMENT.**



**CAUTION** This symbol identifies information about hazards or unsafe practices. Disregarding this information could result in **PRODUCT DAMAGE AND/OR PERSONAL INJURY.**



**WARNING**

This symbol identifies information about hazards or unsafe practices. Disregarding this information could result in **SEVERE PERSONAL INJURY OR DEATH.**



**DANGER**

This symbol identifies information about immediate hazards. Disregarding this information will result in **SEVERE PERSONAL INJURY OR DEATH.**

#### SAFETY TAGS AND DECALS



**WARNING**

To avoid severe personal injury or death, all warning tags and decals must be visible and legible to the operator while the equipment is operating.

#### EQUIPMENT REPAIR AND SERVICE

Proper maintenance, service, and repair are important to the safe, reliable operation of the unit and related equipment. Do not use any procedure not recommended in the Waukesha Engine manuals for this equipment.



**WARNING**

To prevent severe personal injury or death, always stop the unit before cleaning, servicing, or repairing the unit or any driven equipment.

Place all controls in the OFF position and disconnect or lock out starters to prevent accidental restarting. If possible, lock all controls in the OFF position and take the key. Put a sign on the control panel warning that the unit is being serviced.

Close all manual control valves, disconnect and lock out all energy sources to the unit, including all fuel, electric, hydraulic, and pneumatic connections.

Disconnect or lock out driven equipment to prevent the possibility of the driven equipment rotating the disabled engine.

## SAFETY

### WARNING

To avoid severe personal injury or death, ensure that all tools and other objects are removed from the unit and any driven equipment before restarting the unit.

### WARNING

Allow the engine to cool to room temperature before cleaning, servicing, or repairing the unit. Hot components or fluids can cause severe personal injury or death.

Some engine components and fluids are extremely hot even after the engine has been shut down. Allow sufficient time for all engine components and fluids to cool to room temperature before attempting any service procedure.

## ACIDS

### WARNING

Comply with the acid manufacturer's recommendations for proper use and handling of acids. Improper handling or misuse could result in severe personal injury or death.

## BATTERIES

### WARNING

Comply with the battery manufacturer's recommendations for procedures concerning proper battery use and maintenance. Improper maintenance or misuse could result in severe personal injury or death.

## BODY PROTECTION

### WARNING

Always wear OSHA approved body, sight, hearing and respiratory system protection. Never wear loose clothing, jewelry, or long hair around an engine. The use of improper attire or failure to use protective equipment may result in severe personal injury or death.

## CHEMICALS

### GENERAL

### WARNING

Always read and comply with safety labels on all containers. Do not remove or deface the container labels. Improper handling or misuse could result in severe personal injury or death.

### CLEANING SOLVENTS

### WARNING

Comply with the solvent manufacturer's recommendations for proper use and handling of solvents. Improper handling or misuse could result in severe personal injury or death. Do not use gasoline, paint thinners or other highly volatile fluids for cleaning.

### LIQUID NITROGEN/DRY ICE

### WARNING

Comply with the liquid nitrogen/dry ice manufacturer's recommendations for proper use and handling of liquid nitrogen/dry ice. Improper handling or use could result in severe personal injury or death.

## COMPONENTS

### HEATED OR FROZEN

### WARNING

Always wear protective equipment when installing or removing heated or frozen components. Some components are heated or cooled to extreme temperatures for proper installation or removal. Direct contact with these parts could cause severe personal injury or death.

### INTERFERENCE FIT

### WARNING

Always wear protective equipment when installing or removing components with an interference fit. Installation or removal of interference components may cause flying debris. Failure to use protective equipment may result in severe personal injury or death.

## COOLING SYSTEM

**⚠ WARNING**

Always wear protective clothing when venting, flushing or blowing down the cooling system. Operational coolant temperatures can range from 180 - 250° F (82 - 121° C). Contact with hot coolant or coolant vapor can cause severe personal injury or death.

**⚠ WARNING**

Do not service the cooling system while the engine is operating or when the coolant is hot. Operational coolant temperatures can range from 180° - 250° F (82° - 121° C). Contact with hot coolant or vapor can cause severe personal injury or death.

## ELECTRICAL

## GENERAL

**⚠ WARNING**

Do not install, set up, maintain or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

**⚠ WARNING**

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

## IGNITION

**⚠ WARNING**

Avoid contact with ignition units and wiring. Ignition system components can store electrical energy and if contacted can cause electrical shocks. Electrical shock can cause severe personal injury or death.

**⚠ WARNING**

Properly discharge any electrical component that has the capability to store electrical energy before connecting or servicing that component. Electrical shock can cause severe personal injury or death.

## EXHAUST

**⚠ WARNING**

Do not inhale engine exhaust gases. Exhaust gases are highly toxic and could cause severe personal injury or death.

Ensure exhaust systems are leak free and that all exhaust gases are properly vented.

**⚠ WARNING**

Do not touch or service any heated exhaust components. Allow sufficient time for exhaust components to cool to room temperature before attempting any service procedure. Contact with hot exhaust system components can cause severe personal injury or death.

## FIRE PROTECTION

**⚠ WARNING**

Refer to local and federal fire regulations for guidelines for proper site fire protection. Fires can cause severe personal injury or death.

## SAFETY

### FUELS

#### GENERAL

#### WARNING

Ensure that there are no leaks in the fuel supply. Engine fuels are highly combustible and can ignite or explode causing severe personal injury or death.

#### GASEOUS

#### WARNING

Do not inhale gaseous fuels. Some components of fuel gas are odorless, tasteless, and highly toxic. Inhalation of gaseous fuels can cause severe personal injury or death.

#### WARNING

Shut off the fuel supply if a gaseous engine has been cranked excessively without starting. Crank the engine to purge the cylinders and exhaust system of accumulated unburned fuel. Failure to purge accumulated unburned fuel in the engine and exhaust system can result in an explosion resulting in severe personal injury or death.

#### LIQUID

#### WARNING

Do not ingest liquid fuels or breathe in their vapors. Liquid fuels may be highly toxic and can result in severe personal injury or death.

#### WARNING

Use protective equipment when working with liquid fuels and related components. Liquid fuel can be absorbed into the body resulting in severe personal injury or death.

### INTOXICANTS AND NARCOTICS

#### WARNING

Do not allow anyone under the influence of intoxicants and/or narcotics to work on or around industrial engines. Workers under the influence of intoxicants and/or narcotics are a hazard both to themselves and other employees and can cause severe personal injury or death to themselves or others.

### PRESSURIZED FLUIDS/GAS/AIR

#### WARNING

Never use pressurized fluids/gas/air to clean clothing or body parts. Never use body parts to check for leaks or flow rates. Pressurized fluids/gas/air injected into the body can cause severe personal injury or death.

Observe all applicable local and federal regulations relating to pressurized fluid/gas/air.

### PROTECTIVE GUARDS

#### WARNING

Provide guarding to protect persons or structures from rotating or heated parts. Contact with rotating or heated parts can result in severe personal injury or death.

It is the responsibility of the engine owner to specify and provide guarding.

### SPRINGS

#### WARNING

Use appropriate equipment and protective gear when servicing or using products that contains springs. Springs, under tension or compression, can eject if improper equipment or procedures are used. Failure to take adequate precautions can result in serious personal injury or death.

## TOOLS

## ELECTRICAL

**⚠ WARNING**

Do not install, set up, maintain, or operate any electrical tools unless you are a technically qualified individual who is familiar with them. Electrical tools use electricity and if used improperly could cause severe personal injury or death.

## HYDRAULIC

**⚠ WARNING**

Do not install, set up, maintain, or operate any hydraulic tools unless you are a technically qualified individual who is familiar with them. Hydraulic tools use extremely high hydraulic pressure and if used improperly could cause severe personal injury or death.

**⚠ CAUTION**

Always follow recommended procedures when using hydraulic tensioning devices. Improper use of hydraulic tensioning tools can cause severe engine damage.

## PNEUMATIC

**⚠ WARNING**

Do not install, set up, maintain, or operate any pneumatic tools unless you are a technically qualified individual who is familiar with them. Pneumatic tools use pressurized air and if used improperly could cause severe personal injury or death.

## WEIGH.

**⚠ WARNING**

Always consider the weight of the item being lifted and use only properly rated lifting equipment and approved lifting methods. Failure to take adequate precautions can result in serious personal injury or death.

**⚠ WARNING**

Never work or stand under an engine or component while it is suspended. Failure to adhere to this could result in severe personal injury or death.

## WELDING

## GENERAL

**⚠ WARNING**

Comply with the welder manufacturer's recommendations for procedures concerning proper use of the welder. Improper welder use can result in severe personal injury or death.

## ON ENGINE

**⚠ CAUTION**

Ensure that the welder is properly grounded before attempting to weld on or near an engine. Failure to properly ground the welder could result in severe engine damage.

**⚠ CAUTION**

Disconnect the ignition harness before welding on or near an engine to eliminate charging of an ignition system capacitor. Failure to disconnect the ignition harness could result in severe engine damage.

**SAFETY**

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# SECTION 1.05

## GENERAL INFORMATION

**Table 1.05-1. English To Metric Formula Conversion Table**

CONVERSION	FORMULA	EXAMPLE
Inches to Millimeters	Inches and any fraction in decimal equivalent multiplied by 25.4 equals millimeters.	$2\text{-}5/8 \text{ in.} = 2.625 \times 25.4 = 66.7 \text{ mm}$
Cubic Inches to Litres	Cubic inches multiplied by 0.01639 equals litres.	$9388 \text{ cu. in.} = 9388 \times 0.01639 = 153.9 \text{ L}$
Ounces to Grams	Ounces multiplied by 28.35 equals grams.	$21 \text{ oz.} = 21 \times 28.35 = 595 \text{ g}$
Pounds to Kilograms	Pounds multiplied by 0.4536 equals kilograms.	$22,550 \text{ lb.} = 22,550 \times 0.4536 = 10,229 \text{ kg}$
Inch Pounds to Newton-meters	Inch pounds multiplied by 0.113 equals Newton-meters.	$360 \text{ in-lb} = 360 \times 0.113 = 40.7 \text{ N-m}$
Foot Pounds to Newton-meters	Foot pounds multiplied by 1.3558 equals Newton-meters.	$145 \text{ ft-lb} = 145 \times 1.3558 = 197 \text{ N-m}$
Pounds per Square Inch to Bars	Pounds per square inch multiplied by 0.0690 equals bars.	$9933 \text{ psi} = 9933 \times 0.0690 = 685 \text{ Bar}$
Pounds per Square Inch to Kilograms per Square Centimeter	Pounds per square inch multiplied by 0.0703 equals kilograms per square centimeter.	$45 \text{ psi} = 45 \times 0.0703 = 3.2 \text{ kg/cm}^2$
Pounds per Square Inch to Kilopascals	Pounds per square inch multiplied by 6.8947 equals kilopascals.	$45 \text{ psi} = 45 \times 6.8947 = 310 \text{ kPa}$
Fluid Ounces to Cubic Centimeters	Fluid ounces multiplied by 29.57 equals cubic centimeters.	$8 \text{ oz.} = 8 \times 29.57 = 237 \text{ cc}$
Gallons to Litres	Gallons multiplied by 3.7853 equals litres.	$148 \text{ gal.} = 148 \times 3.7853 = 560 \text{ L}$
Degrees Fahrenheit to Degrees Centigrade	Degrees Fahrenheit minus 32 divided by 1.8 equals degrees Centigrade.	$212^\circ \text{ F} - 32 + 1.8 = 100^\circ \text{ C}$

**Table 1.05-2. Metric To English Formula Conversion Table**

CONVERSION	FORMULA	EXAMPLE
Millimeters to Inches	Millimeters multiplied by 0.03937 equals inches.	$67 \text{ mm} = 67 \times 0.03937 = 2.6 \text{ in.}$
Litres to Cubic Inches	Litres multiplied by 61.02 equals cubic inches.	$153.8 \text{ L} = 153.8 \times 61.02 = 9385 \text{ cu. in.}$
Grams to Ounces	Grams multiplied by 0.03527 equals ounces.	$595 \text{ g} = 595 \times 0.03527 = 21.0 \text{ oz.}$
Kilograms to Pounds	Kilograms multiplied by 2.205 equals pounds.	$10,228 \text{ kg} = 10,228 \times 2.205 = 22,553 \text{ lb.}$
Newton-meters to Inch Pounds	Newton-meters multiplied by 8.85 equals inch pounds.	$40.7 \text{ N-m} = 40.7 \times 8.85 = 360 \text{ in-lb}$
Newton-meters to Foot Pounds	Newton-meters multiplied by 0.7375 equals foot pounds.	$197 \text{ N-m} = 197 \times 0.7375 = 145 \text{ ft-lb}$
Bars to Pounds per Square Inch	Bars multiplied by 14.5 equals pounds per square inch.	$685 \text{ Bar} = 685 \times 14.5 = 9933 \text{ psi}$
Kilograms per Square Centimeter to Pounds per Square Inch (psi)	Kilograms per square centimeter multiplied by 14.22 equals pounds per square inch.	$3.2 \text{ kg/cm}^2 = 3.2 \times 14.22 = 46 \text{ psi}$
Kilopascals to Pounds per Square Inch (psi)	Kilopascals multiplied by 0.145 equals pounds per square inch.	$310 \text{ kPa} = 310 \times 0.145 = 45.0 \text{ psi}$
Cubic Centimeters to Fluid Ounces	Cubic centimeters multiplied by 0.0338 equals fluid ounces.	$236 \text{ cc} = 236 \times 0.0338 = 7.98 \text{ oz.}$
Litres to Gallons	Litres multiplied by 0.264 equals gallons.	$560 \text{ L} = 560 \times 0.264 = 148 \text{ gal.}$
Degrees Centigrade to Degrees Fahrenheit	Degrees Centigrade multiplied by 1.8 plus 32 equals Degrees Fahrenheit.	$100^\circ \text{ C} = 100 \times 1.8 + 32 = 212^\circ \text{ F}$



## GENERAL INFORMATION

### WIRING

All electrical equipment and wiring shall comply with applicable local codes. This Waukesha standard defines additional requirements for Waukesha engines.

#### WARNING

**Do not install, set up, maintain, or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.**

#### WARNING

**Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.**

1. Whenever two or more wires run together, they should be fastened together at no more than four (4) to six (6) inch intervals, closer where necessary, with "cable ties." Power wires (24 volts or greater) should never be run together with any other instrument or control wires. Spacing for these types of wires should be six (6) inches minimum to eliminate electrical "noise" problems in the instrument or control wires.

2. All wires should be mounted off hot areas of the engine with insulated clips, at intervals of no more than twelve (12) inches, closer where necessary. Wires must never be run closer than six (6) inches to exhaust manifolds, turbochargers, or exhaust pipes.

3. In cases where wires do not run over the engine, they should be fastened to rigid, non-moving bodies with insulated clips when possible or "cable-ties." Fasteners should be spaced at no more than twelve (12) inch intervals.

4. When wires run through holes, rubber grommets should be installed in holes to protect the wires. Wires should never be run over rough surfaces or sharp edges without protection (see Item 11).

 **CAUTION** Do not use non-electrical grade RTVs. Non-electrical RTVs can emit corrosive gases that can damage electrical connectors.

5. An electrical grade RTV should be applied around the wires entering all electrical devices such as Murphy Junction Boxes and gas valves, Syncro Start speed switches, microswitch boxes used in conjunction with safety equipment, solenoids, etc. An electrical grade RTV is to be applied immediately after wire installation and prior to the engine entering the test room.

6. A small "drip loop" should be formed in all wires before entering the electrical devices. This drip loop will reduce the amount of moisture entering electrical device via the wires if an electrical grade RTV does not seal completely.

7. The following procedures should be followed for wires entering engine junction boxes:

- Bottom entrance best and side entrance second best.
- Insert grommet in opening to protect wires.
- Wires to contain "drip loop" before entering box, except where using bottom entrance.
- When installing flexible conduit, use straight connector for side entrance. If top entrance is required, use elbow connector.

8. If wire harness has a covering, clamp harness so openings of covering are downward.

9. The routing of wires should be determined for reliability and appearance and not by shortest distance.

10. Installation connection wire must be coiled and secured to provide protection during shipment.

11. Each end of flexible metal conduit *must* have an insulating sleeve to protect wires from chafing.

#### WARNING

**Always label "HIGH VOLTAGE" on engine mounted equipment over 24 volts. Failure to adhere to this warning could result in personal injury or death.**

12. All engine mounted electrical equipment over 24 volts shall have "HIGH VOLTAGE" warning decal. Decal to be attached to all the equipment and junction boxes on visible surface (vertical surface whenever possible).

13. Wiring that is routed in rigid or flexible conduit shall have all wire splices made only in junction boxes, outlet boxes or equipment boxes. Wire splices shall not be located in the run of any conduit.



**POWER REQUIREMENTS FOR CUSTOM ENGINE CONTROL® PRODUCTS**

Table 1.05-3 provides you with the power requirements for Waukesha's Custom Engine Control® (CEC) products. An oscilloscope must be used to verify ripple limitations. All power connections must be in accordance with the applicable electrical codes.

**NOTE:** To power the CEC Ignition Module, a nominal supply of 24 VDC with less than a 2 volt peak-to-peak ripple is recommended for compatibility with other CEC products.

**CAPACITIVE DISCHARGE AND GROUNDING**

A Capacitive Discharge (CD) ignition system, such as the CEC Ignition Module, requires an external power source and special wiring requirements.

This ignition system contains several large energy storage capacitors. When firing a spark plug, the energy stored in one of these capacitors is rapidly discharged into an ignition coil which converts it to the high tension ignition voltage. Having been discharged, the energy storage capacitor must then be recharged to be ready to fire again. The storage capacitor is typically recharged by drawing

energy from the power supply as quickly as possible, resulting in a high current flow (typically 30 amps or more) in the power supply wiring for a short period of time.

The average ignition system current remains low (1 or 2 amps depending on the number of cylinders, engine speed, and supply voltage) since the high current only flows for the short period of time and virtually no current flows the rest of the time. However, the wiring must be sized for the high instantaneous currents. In addition, the grounding, particularly where the ground is "referenced," becomes more critical when electronic controls are used on engines having this type of CD ignition system.

With ignition power supply currents of approximately 30 amps, the resistive voltage drop of the wiring can easily reach a volt or two. As a result, it is necessary to reference all of the grounds to the same point. Since many electronic sensors are internally grounded, the engine crankcase has been chosen as THE GROUND reference to minimize problems with sensor signals. By following the recommended wiring and grounding procedures, the concerns associated with the ignition power supply wiring voltage drops can be greatly reduced or eliminated.

**Table 1.05-3. Power Requirements For Waukesha Custom Engine Control® Products**

CEC PRODUCT	NOMINAL VOLTAGE (volts DC)	TOLERANCE	OPERATING RANGE (volts DC)	PEAK-TO-PEAK RIPPLE (volts AC)	OPERATING CURRENT (amps)
Ignition Module (IM)	24	+33%, -58%	10.0 - 32.0*	less than 2*	2 (typical)
Detonation Sensing Module (DSM) System	24	+25%, -10%	21.6 - 30.0	less than 2	1.5
Air/Fuel Module (AFM) System	24	+25%, -10%	21.6 - 30.0	less than 2	2.5 (all rich burn applications) 18.0 (lean burn applications on VHP 6 cylinder and all VGF engines) 32.0 (lean burn applications on all AT and VHP 12 & 16 cylinder engines)
Turbocharger Control Module (TCM) System	24	+25%, -10%	21.6 - 30.0	less than 2	1.5

**NOTE:** \*For compatibility with other CEC products, a nominal supply of 24 VDC with less than a 2 volt peak-to-peak ripple is recommended to power the IM.

# GENERAL INFORMATION

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## SECTION 1.10

### DESCRIPTION OF OPERATION

#### WAUKESHA CUSTOM ENGINE CONTROL<sup>®</sup> IGNITION MODULE

##### SYSTEM DESCRIPTION

The Custom Engine Control<sup>®</sup> (CEC) Ignition Module (IM) is a microcircuit-based, digital ignition system (see Figure 1.10-1). The IM is designed to enhance the performance and cost-effectiveness of your Waukesha engine. The IM provides accurate and reliable ignition timing resulting in optimum stationary engine operation. The IM system has no wearing parts and uses the capacitor discharge principle providing high energy, precision timed spark for maximum engine performance. The IM's technology also provides full output at cranking speeds for better engine startup. With the IM installed, your engine will perform better and more powerful, emit lower emissions, decrease downtime, and increase spark plug life.

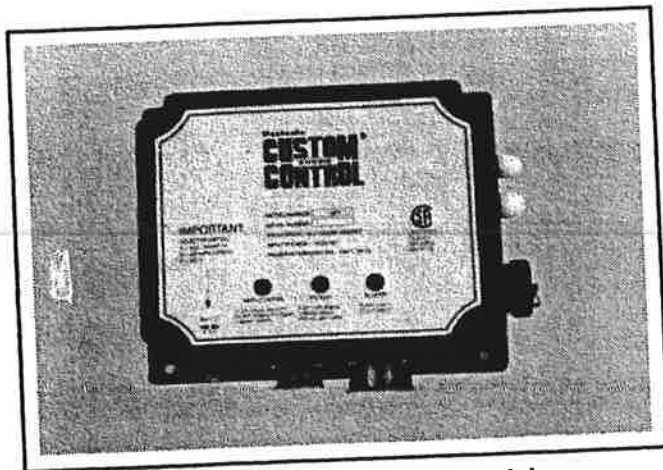


Figure 1.10-1. CEC Ignition Module

With the engine running, an electronic Hall-effect pickup reads magnetic reference marks mounted on a gear or timing disc to determine the exact position of the crankshaft. The Hall-effect pickup sends an electrical signal to the IM. Electronically the IM interprets the Hall-effect pickup's electrical signal based on an index

magnet so the IM knows exactly which cylinder is supposed to fire. Then the IM directs a charge of voltage to the appropriate ignition coil for spark plug firing to achieve accurate timing.

Ignition timing is changed with the two 16 position (0 - 15) timing switches on the right side of the IM (see Figure 1.10-2). With the two 16 position timing switches, the engine can be set up for dual fuel applications, two distinct fuel gases or load conditions.

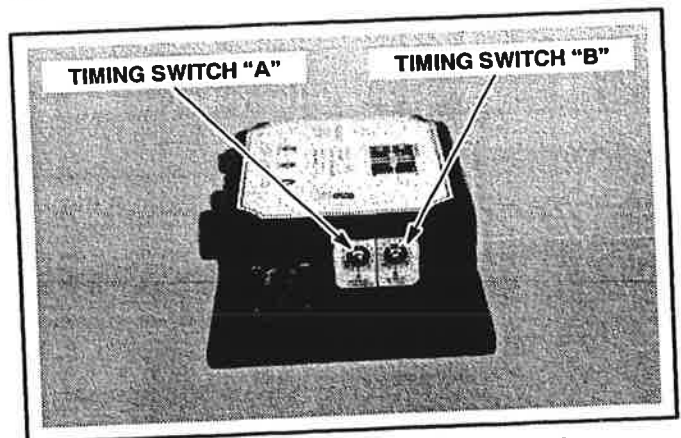


Figure 1.10-2. Ignition Module 16 Position Timing Switches

*For example:* On dual fuel applications, you can set timing switch "A" for one fuel and the timing on switch "B" for the other fuel. This allows you to switch from one timing setting to the other when you switch fuels and have the proper ignition timing for both fuels.

Switch position 15 gives the most advanced timing on the active timing switch, either switch "A" or "B." Switch "A" has a more advanced timing range than switch "B." The timing retards/advances 1.0 degree between each switch position. Although there are two timing switches on the IM, only one is active at any one time. The switch that is active is determined by the status of the "D" lead in the Power Pickup Harness (7 pin connector). If the "D" lead is grounded, switch "A" is active; if the "D" lead is not grounded, switch "B" is active.

## DESCRIPTION OF OPERATION

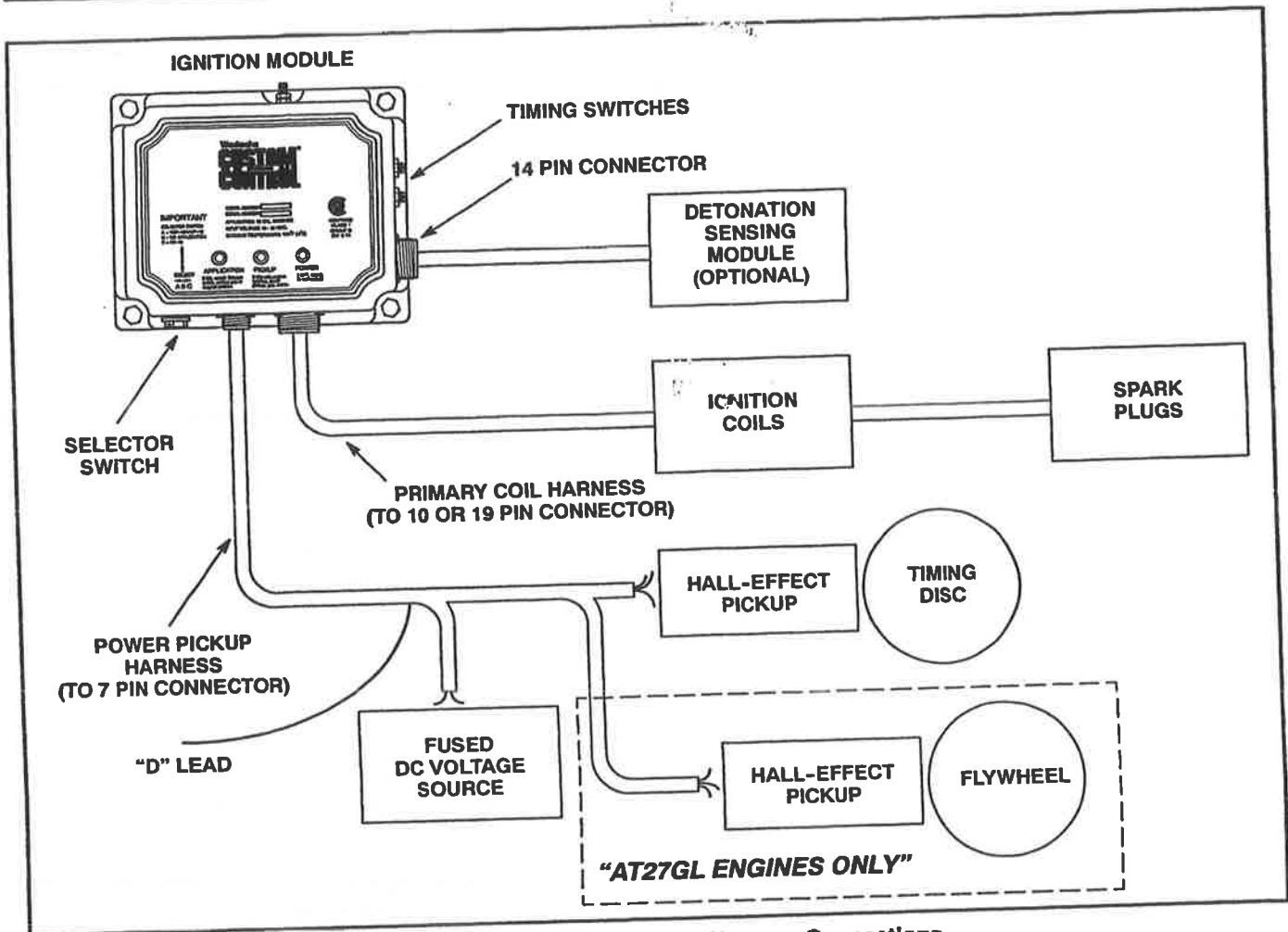


Figure 1.10-3. Ignition Module Harness Connections

The IM has three external cable connectors (see Figure 1.10-3). The Power Pickup Harness connects to the 7 pin connector and includes leads for DC power, the Hall-effect pickup, and the "D" lead which determines which timing switch is used. The Primary Coil Harness connects to the IM and includes leads to the ignition coils. The third connector (14 pin) is used to interface with the CEC Detonation Sensing Module (see next section, "Interface With CEC Detonation Sensing Module").

**NOTE:** The 14 pin connector on the IM is not used unless the Detonation Sensing Module is in operation on the engine.

The IM also features a three position Selector Switch for setting the engine model (see Figure 1.10-3). The Selector Switch programs the IM for a specific engine model—6 versus 8 cylinder, AT versus VHP. If the magnet pattern sensed by the Hall-effect pickup is not correct for the application selected on the Selector Switch (such as an 8 cylinder application selected on a 6 cylinder engine), an LED will light on the IM and the ignition will not fire.

### INTERFACE WITH CEC DETONATION SENSING MODULE

The IM interfaces with the CEC Detonation Sensing Module (DSM) system (see Figure 1.10-4). The DSM system is designed to protect Waukesha spark-ignited gas engines from damage due to detonation. The DSM system functions with the IM and connects to the IM's 14 pin connector. The two CEC systems, when connected together, provide defense against engine detonation which can lead to severe engine damage.

With the DSM system connected, the timing switches on the IM become non-functional and timing varies individually among the cylinders from a range of preset values. This individual cylinder timing allows maximum advance for cylinders that are not experiencing detonation to a predetermined setting.

Detonation is the autoignition of end gas during combustion in an engine's combustion chamber. Avoiding detonation conditions is critical since detonation is detrimental to engine components.

**NOTE:** Refer to the Custom Engine Control® Detonation Sensing Module Installation, Operation, and Maintenance Manual (Form 6268) for information on DSM system installation and programming.

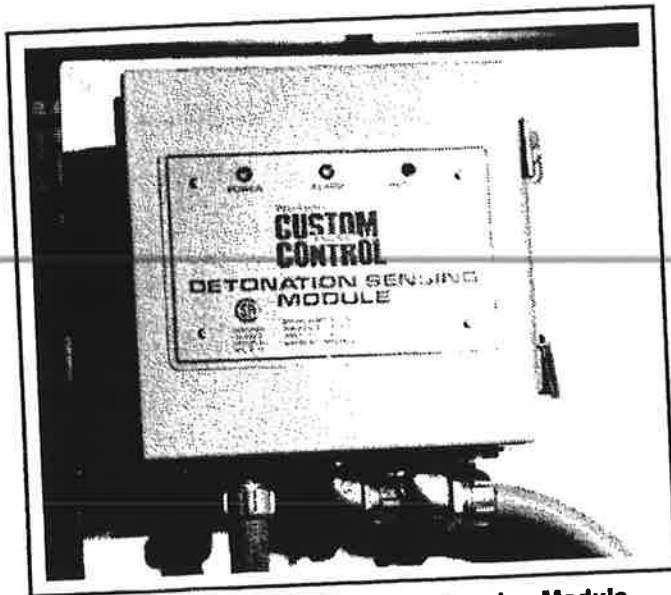


Figure 1.10-4. CEC Detonation Sensing Module

## COMPONENTS

The IM system consists of an electronic module (IM), wiring harnesses, timing disc or gear, ignition coils, high tension leads, and a Hall-effect pickup (two for AT27GL engines).

A diagram of the IM system's inputs and outputs is shown in Figure 1.10-3.

## ENGINES SERVED

The IM is designed to function with Waukesha's gaseous fueled AT, VHP, and VGF engines. The IM can also be installed as a retrofit on engines in the field. Retrofit kits include all the required IM components, mounting hardware, and installation instructions.

All Waukesha Engine models are covered by three IM control boxes. Table 1.10-1 lists the IM models and their engine applications.

Table 1.10-1. Ignition Module Applications

IGNITION MODULE MODELS		
Model 811	Model 1211	Model 1611
VHP 6 Cylinder Engines	VHP 12 Cylinder Engines	VHP 16 Cylinder Engines
VGF 6 and 8 Cylinder Engines	VGF 12 Cylinder Engines	VGF 16 Cylinder Engines
AT 8 Cylinder Engines	AT 12 Cylinder Engines	AT 16 Cylinder Engines

## OPERATOR INTERFACE

The IM is equipped with three diagnostic LEDs on front of the IM housing: "Power," "Pickup," and "Application" (see Figure 1.10-5). These LEDs give operators visual confirmation on (1) incoming power, (2) Hall-effect pickup signal, and (3) proper application settings.

- The green "Power" LED is lit any time power is applied to the IM. The power LED confirms to the operator that connection has been made to the IM from the VDC power supply.
- The red "Pickup" LED is lit when there is no Hall-effect pickup signal being detected by the IM due to a failed pickup, an incorrect air gap setting, and/or incorrect (bad) wiring. The pickup LED will also be lit when the engine is at rest.
- The red "Application" LED is lit whenever the IM detects a magnet pattern that does not match the application for which the IM Selector Switch is set (6 versus 8 cylinder) or when the incorrect IM model is installed (inline IM model versus vee engine IM model). Additionally, this LED will light when one Hall-effect pickup is lost (disconnected or failed) on a two pickup system (AT engines), or if a magnet is lost or is very weak. The application LED will also light when the Selector Switch is in the "B" position (no application).

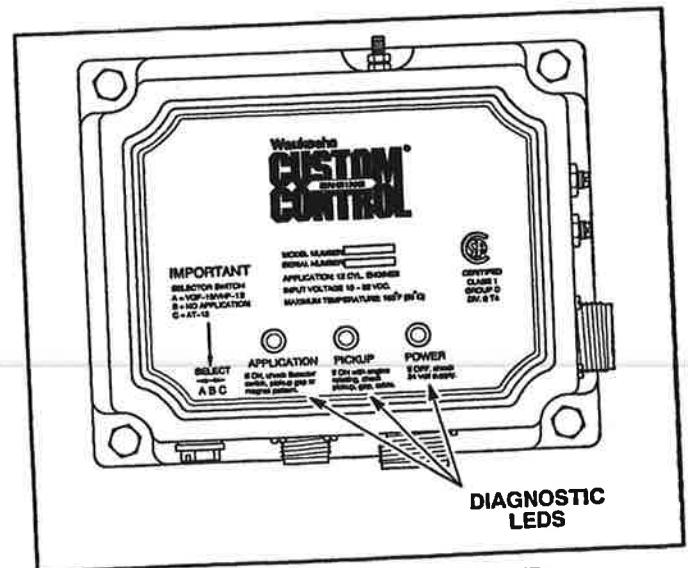


Figure 1.10-5. IM Diagnostic LEDs



# DESCRIPTION OF OPERATION

## THEORY OF OPERATION

### IGNITION MODULE OPERATION

The IM operates as a high energy capacitor discharge solid state ignition system. The IM first steps up the input voltage from 10 - 32 volts to approximately 160 volts. This voltage is then used to charge up energy storage capacitors.

A gear or aluminum disc rotates at 1/2 engine speed. Several magnets are imbedded in this gear or disc. These magnets signal the position of the engine crankshaft to the logic circuit in the IM through the use of a Hall-effect pickup.

When the IM and its internal microcircuits receive the signal from the Hall-effect pickup, the IM triggers SCRs (silicon controlled rectifiers) to release the energy stored in the capacitors. The voltage is then stepped up by the ignition coils to fire the spark plugs. The IM releases this energy in a programmed, timed sequence that varies with the application.

**NOTE:** For AT27GL engines, the two Hall-effect pickup system operates similar to the single pickup system, except one pickup is signalled by magnets in the flywheel and the other by a single magnet in a disc on the camshaft.

Timing is changed with two 16 position (0 - 15) timing switches located on the side of the IM. Each switch can be set to separate ignition timing settings for different applications. Switch position 15 gives the most advanced timing on the active timing switch, either switch "A" or "B." Switch "A" has a more advanced timing than switch "B." The timing advances/retards 1.0 degree between each switch position. Grounding lead "D" in the Power Pickup Harness (7-pin connector) activates the timing selected by switch "A." Ungrounded lead "D" will activate the timing selected by switch "B."

On dual fuel applications, it is possible to set the timing switch "A" for one fuel and the timing on switch "B" for the other fuel. This allows you to switch from one control to the other when you switch fuels and have the proper ignition timing in place automatically for each fuel.

### HALL-EFFECT PICKUP VERSUS MAGNETIC PICKUP

The Hall-effect pickup is a three wire solid state electronic device that requires the sensing of a magnet to trigger the pickup (see Figure 1.10-6). A magnetic pickup is a two wire electrical device that produces a voltage with the aid of a magnet as steel teeth move by. A magnetic pickup can look identical to a Hall-effect pickup but is self-powered and only has two connections (see Figure 1.10-7). Magnetic pickup devices do not work with the IM.

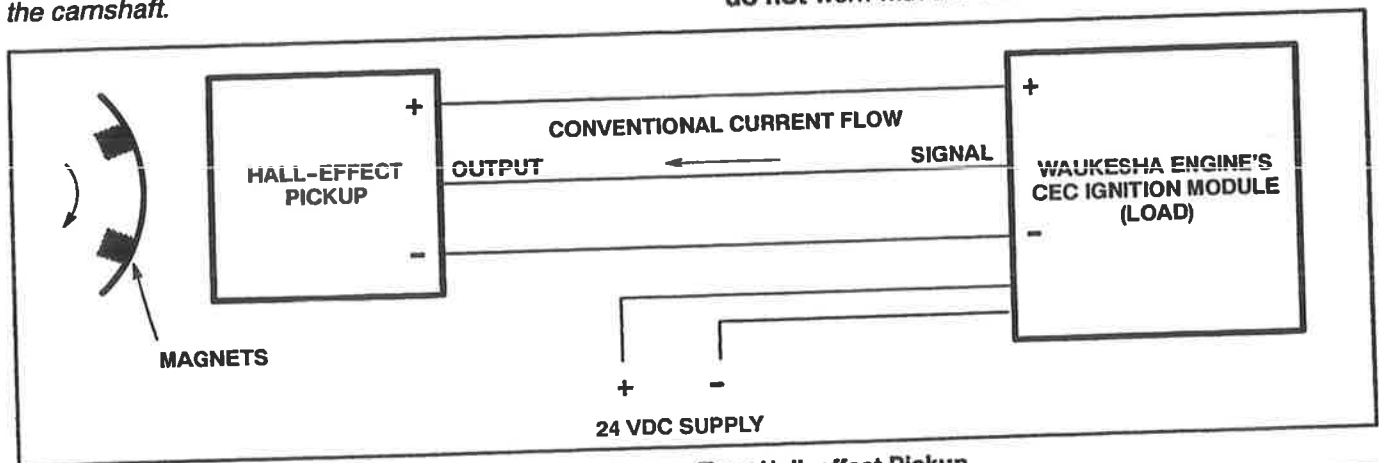


Figure 1.10-6. Sinking Type Hall-effect Pickup

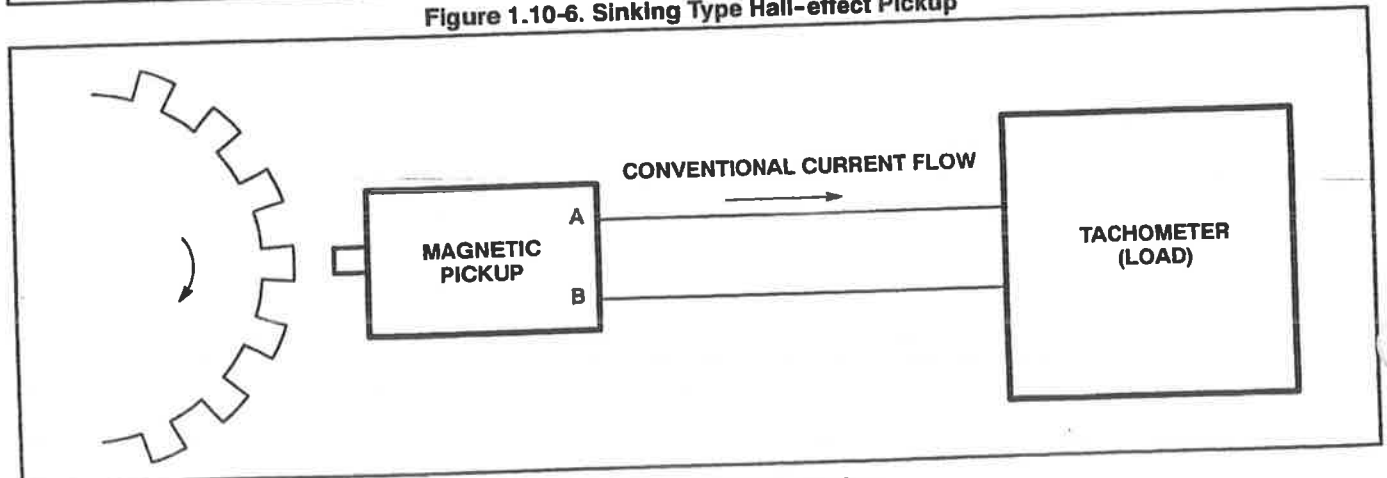


Figure 1.10-7. Magnetic Pickup

## DEFINITIONS

**Commercial Quality Natural Gas:** Natural gas that has been processed to remove heavy hydrocarbon components. The heat value normally ranges from 900 - 1000 Btu/ft<sup>3</sup> SLHV (33.54 - 37.26 J/cm<sup>3</sup>). Holland's pipeline gas has a heat value of 820 Btu/ft<sup>3</sup> SLHV (30.5 J/cm<sup>3</sup>).

**Detonation:** Detonation occurs when part of the air/fuel charge cannot wait for the normal flame-front, which was started by the spark plug, to pass completely through the combustion chamber. The advancing flame-front heats and squeezes the unburned mixture until it ignites on its own. A good comparison is a grass fire. Normal combustion is similar to a grass fire. It begins at one end of a field, and the flame-front progresses in an orderly manner through the field. When all of the grass is burned, the combustion stops. During "grass-detonation," the grass would begin burning normally, but before the flames could sweep through the length of the field, some portion of the unburned grass would burst into flames. When this happens in the combustion chamber of an engine, two pressure waves, associated with the two flame-fronts, slam together and cause an audible "ping" or "knock."

**Digester Gas:** A fuel gas formed by the decomposition of organic matter in a digester. It is composed primarily of methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>). The heat value normally ranges from 500 - 600 Btu/ft<sup>3</sup> SLHV (18.63 - 22.36 J/cm<sup>3</sup>). Hydrogen sulfide (H<sub>2</sub>S) is a typical trace component.

**Field Gas:** Raw or partially processed natural gas as taken from an extracting well. The heat value normally ranges from 900 - 1500 Btu/ft<sup>3</sup> SLHV (33.54 - 55.898 J/cm<sup>3</sup>).

**Hall-effect Pickup:** A three wire solid state electronic device that requires the sensing of a magnet to trigger it.

**HD-5:** A commercial quality propane with the following minimum requirements: 90 percent by liquid volume propane.

**Landfill Gas:** A fuel gas formed by the decomposition of landfill refuse. It is composed primarily of methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>). The heat value normally ranges from 450 - 550 Btu/ft<sup>3</sup> SLHV (16.77 - 20.39 J/cm<sup>3</sup>). Chlorine and fluorine bearing compounds are typical trace components.

**LED:** Light Emitting Diode. A semiconductor that emits light (not a light bulb) and is used as power and alarm indicators, located on the front of the IM.

**Low Btu Fuel:** Fuel having less than 700 Btu/ft<sup>3</sup> (26.08 J/cm<sup>3</sup>), such as landfill gas.

**Magnetic Pickup:** A two-wire electrical device that produces a voltage and current flow as steel teeth move by the pickup. Magnetic pickup devices **do not** work with the IM.

**Natural Gas:** A naturally occurring mixture of hydrocarbon and other gases found beneath the earth's surface, often in connection with liquid petroleum. The principle component is usually methane (CH<sub>4</sub>). Minor components are heavier hydrocarbons and other gases such as nitrogen (N<sub>2</sub>), carbon dioxide (CO<sub>2</sub>), helium (He), argon (Ar), oxygen (O<sub>2</sub>), and hydrogen sulfide (H<sub>2</sub>S). Seldom used in its raw state and normally processed to commercial quality natural gas.

**Propane:** A fuel gas made of carbon (C<sub>3</sub>) and hydrogen (H<sub>8</sub>). Often used as a backup fuel.

**Sinking Output:** In a sinking output device, the output signal (current) flows from the control to the pickup.

**Sourcing Output:** In a sourcing output device, the output signal (current) flows from the pickup to the control.

**WKI:** Waukesha Knock Index. Waukesha Engine's procedure for reading the knock resistance or detonation resistance of gaseous fuels.

# DESCRIPTION OF OPERATION

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# **CHAPTER 2 - VHP IGNITION MODULE INSTALLATION AND OPERATION**

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## **CONTENTS**

**SECTION 2.00 - IGNITION MODULE OPERATION ON  
VHP ENGINES**

**SECTION 2.05 - VHP IGNITION MODULE  
ELECTRICAL CONNECTIONS**

**SECTION 2.10 - VHP IGNITION MODULE TIMING ADJUSTMENTS**



## SECTION 2.00

# IGNITION MODULE OPERATION ON VHP ENGINES

### IGNITION MODULE OPERATION ON VHP ENGINES

The purpose of this section is to describe IM operation on VHP engines, location of the Hall-effect pickup, timing disc alignment, and air gap setting.

#### VHP 6 AND 12 CYLINDER TIMING DISC ALIGNMENT

The IM uses a Hall-effect pickup, a magnetic switching device, to read magnetic reference marks on a disc attached to the governor drive gear hub. This method of timing determines the exact position of the crankshaft. The microcircuit-based, digital IM interprets the pickup's impulses to set optimum ignition timing. The IM then directs a precisely timed voltage to the appropriate ignition coil.

#### Location Of Hall-effect Pickup

The Hall-effect pickup is located on the governor drive gear hub (see Figure 2.00-1, Figure 2.00-2, and Figure 2.00-3). The pickup senses each magnet as it passes and trips the logic circuit of the IM to fire.

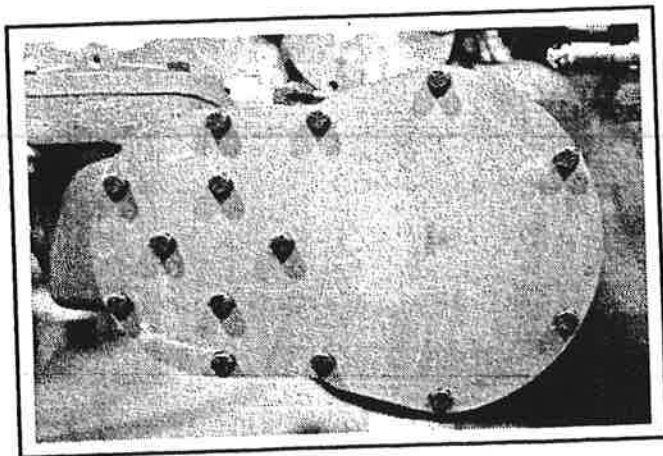


Figure 2.00-1. Governor Drive Housing

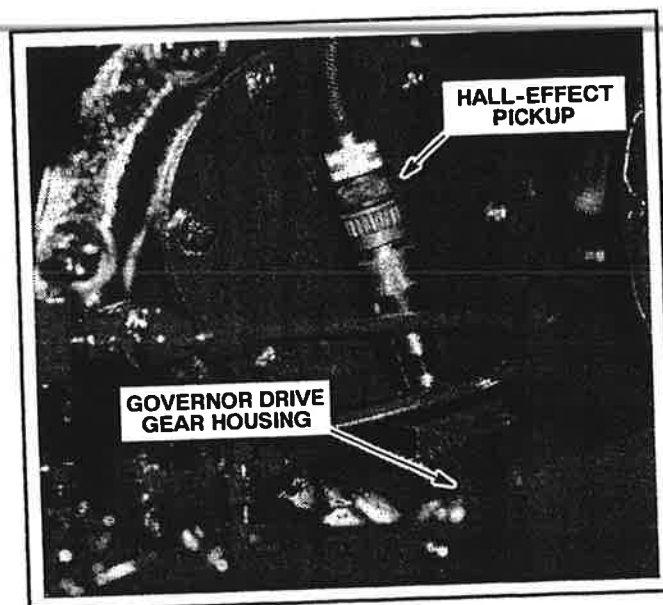


Figure 2.00-2. Hall-effect Pickup Installed On Governor Drive Gear Hub

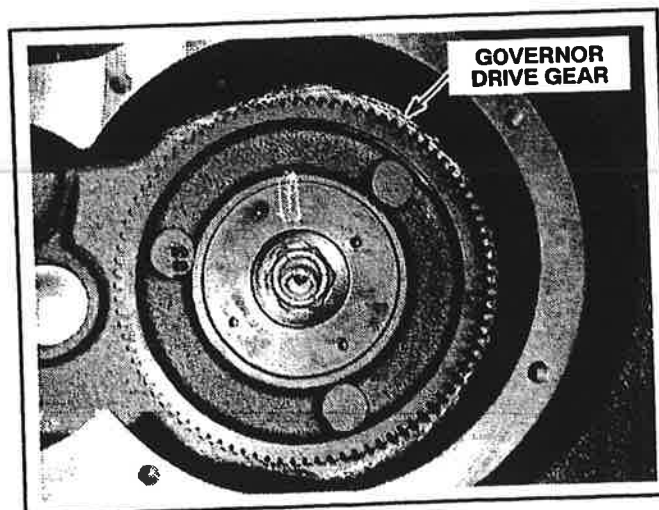


Figure 2.00-3. Governor Drive Gear

# IGNITION MODULE OPERATION ON VHP ENGINES

## Timing Disc Alignment And Air Gap Setting

1. Locate the first cylinder in the firing order sequence. Refer to the engine's nameplate for firing order sequence.

2. Check the engine's nameplate to determine the exact timing for the primary fuel.

3. Bar the engine over in a counterclockwise direction (facing the flywheel) until the valves of the first cylinder in the firing order, which is the #1R cylinder (12 cylinder engines), #1 cylinder (6 cylinder engines) are at top dead center (compression stroke) (see Figure 2.00-5).

To determine when this condition exists, watch the rocker arms and valves on its mating cylinder (see Figure 2.00-5). As the exhaust valves on the mating cylinder are closing, the intake valves begin to open. At this point, the mating cylinder is in valve overlap (all four valves partially open). This means that all four valves on the #1R cylinder (12 cylinder engines), #1 cylinder (6 cylinder engines) are fully closed. The cylinder is now at top dead center (compression stroke).

**NOTE:** Timing marks on the flywheel timing tape should be visible through the timing opening located in the flywheel housing when approaching top dead center (TDC) of the first firing cylinder on the compression stroke (see Figure 2.00-4).

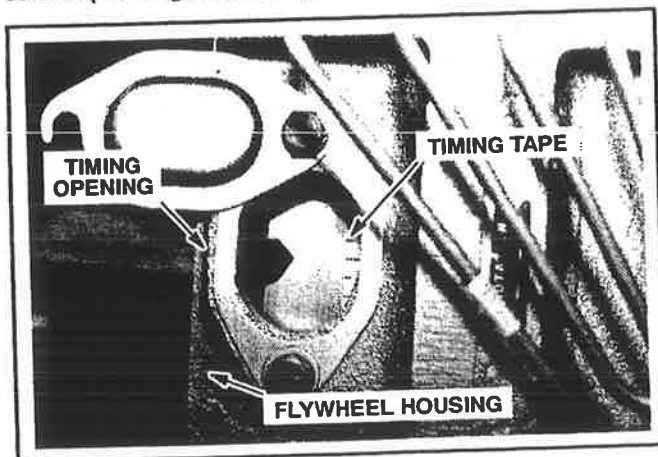


Figure 2.00-4. Flywheel Timing Opening

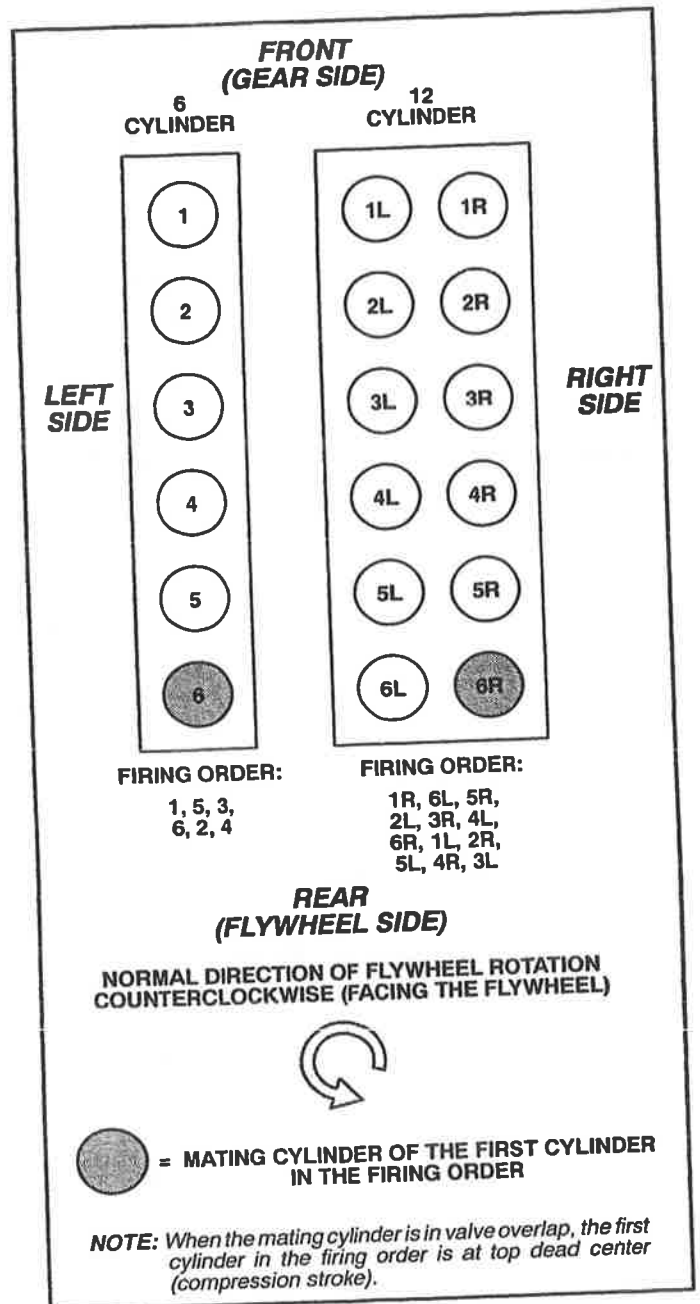


Figure 2.00-5. Engine Firing Order - 6 And 12 Cylinder VHP Engines

## IGNITION MODULE OPERATION ON VHP ENGINES

4. Bar the engine over in a clockwise direction (facing the flywheel), to a point at least 30 degrees prior to the point of desired timing.

5. Slowly bar the engine over in a counterclockwise direction (facing the flywheel), carefully observing the flywheel timing tape and pointer. Stop rotating the flywheel exactly at the correct timing desired.

**CAUTION** By rotating the crankshaft past the desired timing, and then backing up to the desired timing, the disc drive gear backlash will be on the wrong side of the gear teeth. The timing could therefore be incorrect by several degrees.

6. Thread the timing disc alignment tool (P/N 474022) into the governor drive housing (see Figure 2.00-6).

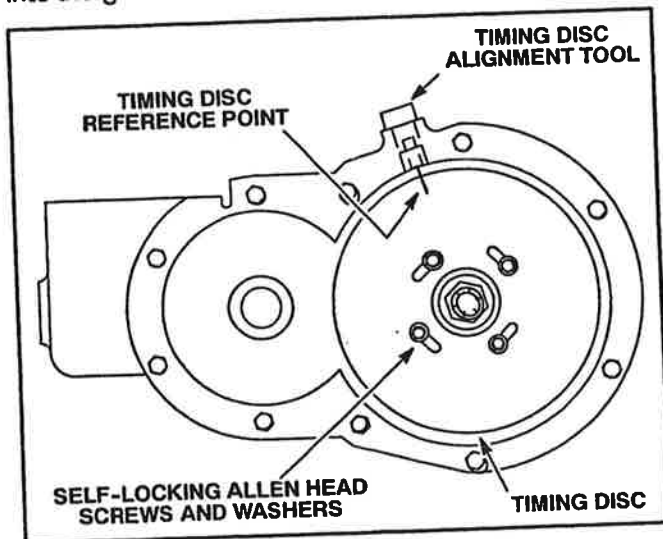


Figure 2.00-6. Ignition Timing Disc

7. Loosen the self-locking allen head screws, and rotate the timing disc so the timing disc reference point aligns with the point of the alignment tool.

8. Once aligned, torque the self-locking allen head screws on the timing disc to 43 - 45 in-lb (4.86 - 5.08 N-m) oiled.

9. Remove the alignment tool and install the Hall-effect pickup. Refer to the following steps to set the gap between the pickup and the timing disc.

A. Thread the Hall-effect pickup into the governor drive housing until the pickup comes in contact with the timing disc.

B. Scribe a reference mark on the Hall-effect pickup and at the same point mark the governor drive housing.

C. Using the reference mark on the pickup as the starting point, rotate the Hall-effect pickup  $3/4$  of a turn ( $\pm 1/16$  of a turn) counterclockwise to set the pickup to timing disc clearance.

D. After the clearance is set, snug the locking nut.

**CAUTION** DO NOT turn on the fuel until the ignition timing is verified to be at an acceptable setting, to prevent possible engine damage. Use a timing light to check the ignition timing while the engine is cranking in a NO-FUEL state.

10. Apply a fast setting contact-type gasket shellac, such as 3M Weather Strip Cement, Permatex® High-Tac or equivalent, on the gasket surfaces of the governor drive cover plate. Install a new governor drive cover gasket.

**NOTE:** During Step 11, the governor drive cover must first be installed on the ball bearing retainer, four capscrews, and lockwashers to prevent the gaskets from sliding during installation of the governor drive assembly. Allow the gasket shellac to cure following the manufacturer's recommendations.

11. With the WED part number facing outside, install the governor drive cover to the ball bearing retainer (4 capscrews,  $3/8 \times 3/4$  inch, with lockwashers). Install the remaining fasteners (10 capscrews,  $3/8 \times 1$  inch, with lockwashers) (see Figure 2.00-7).

12. Refer to Section 2.10, VHP Ignition Module Timing Adjustments, to set engine ignition timing.

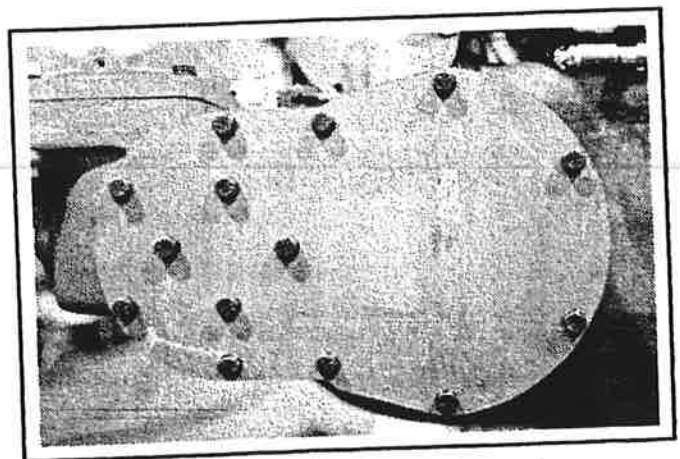


Figure 2.00-7. Governor Drive Housing

# IGNITION MODULE OPERATION ON VHP ENGINES

## VHP 5115GL AND 16 CYLINDER TIMING DISC ALIGNMENT

### Location Of Hall-effect Pickup

The Hall-effect pickup is located on the governor drive gear. The pickup senses each magnet as it passes and trips the logic circuit of the IM to fire.

### Timing Disc Alignment And Air Gap Setting

1. Locate the first cylinder to fire in the firing order sequence. Refer to the engine's nameplate and Figure 2.00-9 for firing order sequence.
2. Check the engine's nameplate to determine the exact timing (or most advanced) for the primary fuel.
3. Bar the engine crankshaft over in a counterclockwise (facing the flywheel) direction until the valves of the first cylinder in the firing order, which is the #1R cylinder, are at top dead center (compression stroke).

To determine when this condition exists, watch the rocker arms and valves on its mating cylinder (see Figure 2.00-5). As the exhaust valves on the mating cylinder are closing, the intake valves begin to open. At this point, the mating cylinder is in valve overlap (all four valves partially open). This means that all four valves on the #1R cylinder (12 cylinder engines), #1R cylinder (for 16 cylinder engines) are fully closed. The cylinder is now at top dead center (compression stroke).

**NOTE:** Timing marks on the flywheel timing tape should be visible through the timing opening located in the flywheel guard on 16 cylinder engines, or flywheel housing on 5115GL engines (see Figure 2.00-8) when approaching top dead center (TDC) of the first firing cylinder on the compression stroke.

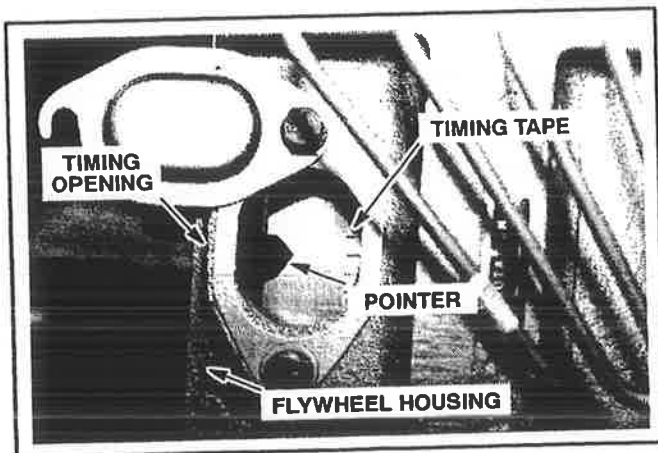


Figure 2.00-8. Flywheel Timing Opening

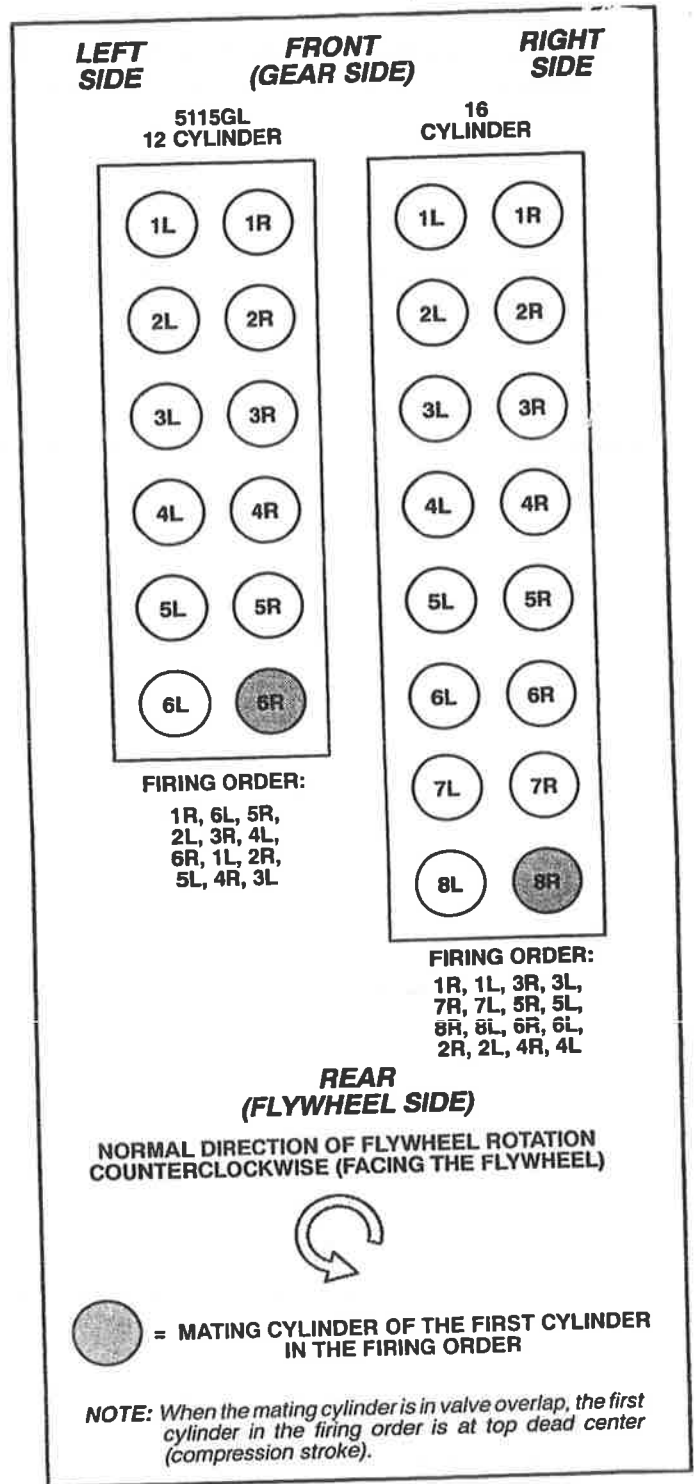


Figure 2.00-9. Engine Firing Order - 12 And 16 Cylinder VHP Engines

4. Bar the engine over in a clockwise direction (facing the flywheel) to a point at least 30 degrees prior to the point of desired timing.

5. Slowly bar the engine over in a counterclockwise direction (facing the flywheel), carefully observing the flywheel timing tape and pointer. Stop rotating the flywheel exactly at the correct timing desired.

**CAUTION** By rotating the crankshaft past the desired timing, and then backing up to the desired timing, the disc drive gear backlash will be on the wrong side of the gear teeth. The timing could therefore be incorrect by several degrees. Disregarding this information could result in product damage and/or personal injury.

6. Remove the Hall-effect pickup from the magneto housing (see Figure 2.00-10).

7. Thread the timing disc alignment tool (P/N 474022) into the magneto housing.

8. Loosen the self-locking allen head screws, and rotate the timing disc so the timing disc reference point aligns with the point of the alignment tool.

9. Once aligned, torque the self-locking allen head screws to 43 - 45 in-lb (4.86 - 5.08 N-m) to secure disc in place.

10. Remove the alignment tool and install the Hall-effect pickup. Refer to the following steps to set the the gap between the pickup and the timing disc.

A. Thread the Hall-effect pickup into the governor drive housing until the pickup comes in contact with the timing disc.

B. Scribe a reference mark on the Hall-effect pickup and at the same point mark the governor drive housing.

C. Using the reference mark on the pickup as the starting point, rotate the Hall-effect pickup  $\frac{3}{4}$  of a turn ( $\pm \frac{1}{16}$  of a turn) counterclockwise to set the pickup to timing disc clearance.

D. After the clearance is set, snug the locking nut.

11. Replace the magneto drive cover.

12. Refer to Section 2.10, *VHP Ignition Module Timing Adjustments*, to set engine ignition timing.

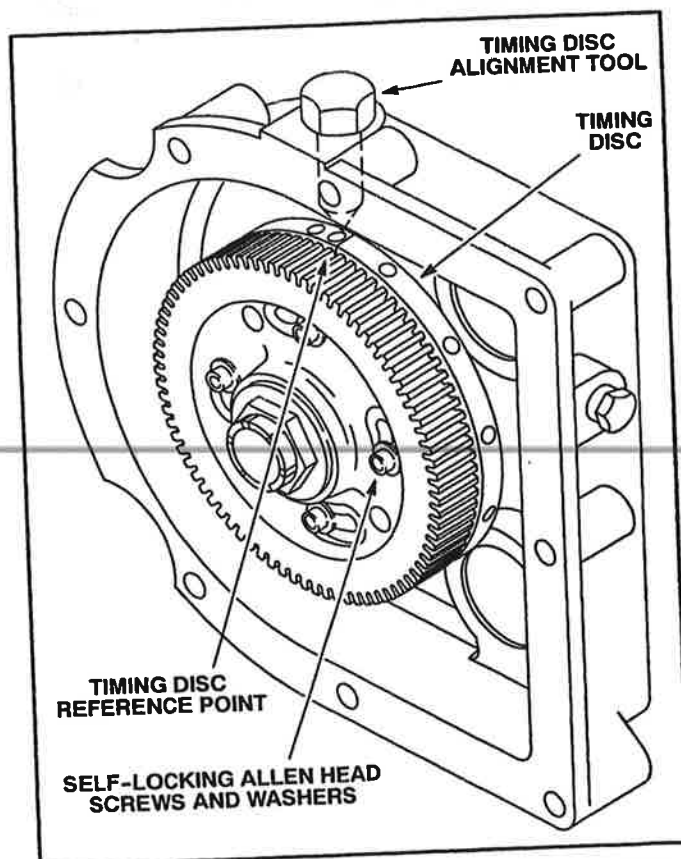


Figure 2.00-10. Magneto Drive Gear And Timing Disc

# IGNITION MODULE OPERATION ON VHP ENGINES

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## SECTION 2.05

# VHP IGNITION MODULE ELECTRICAL CONNECTIONS

### MOUNTING THE IGNITION MODULE

Mount the IM using the vibration isolators supplied with the IM (see Figure 2.05-1). Note the following:

- The outside temperature of IM casing should not exceed 150° F (65° C) in operation.

**CAUTION** Do not weld on or around engine unless the Ignition Module has been unplugged. Failure to do so may damage the Ignition Module.

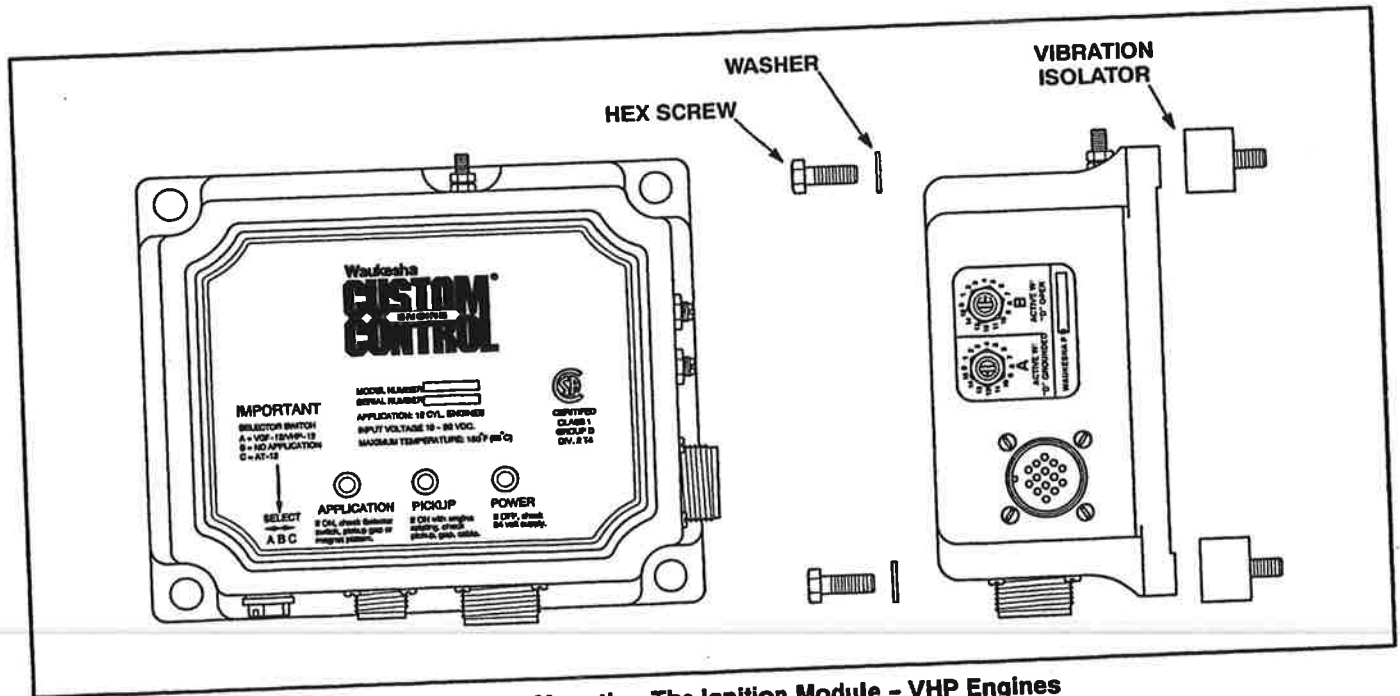


Figure 2.05-1. Mounting The Ignition Module - VHP Engines

# VHP IGNITION MODULE ELECTRICAL CONNECTIONS

## ELECTRICAL CONNECTIONS

### IGNITION MODULE POWER REQUIREMENTS

The power connections made for the IM must be in accordance with the applicable local electrical codes. The IM is suitable for installation in Canadian Standards Association (CSA) Class I, Group D, Division 2 locations. All power sizing must be in accordance with Figure 2.05-3, "Waukesha CEC Products Power Wiring Requirements."

See Table 2.05-1 for IM power requirements.

**NOTE:** An AC to DC power supply is not preferred unless care is taken to eliminate the possibility of a momentary loss of AC power which will result in an engine shutdown. A DC voltage filter (battery) is recommended to eliminate voltage fluctuations.

**NOTE:** For compatibility with other CEC products, a nominal supply of 24 VDC with less than a 2 volt peak-to-peak ripple is recommended to power the IM.

**NOTE:** Refer to Section 1.05, General Information, "Power Requirements for Custom Engine Control® Products," for the power requirements of all Waukesha Engine CEC products.

### POWER SOURCE WIRING SIZING AND GROUNDING

The IM, a capacitive discharge (CD) ignition system, requires an external power source which presents special wiring requirements. The IM will function properly with a power source as defined in Table 2.05-1. However, if the supply is capable of providing a pulse current (higher current level for a shorter period of time such that the average current is the same), the IM will utilize that pulse capability. In this case, the voltage fluctuations on the supply wiring, including the ground return to the power source, may interfere with the operation of other electrical devices. For this reason, it is recommended that the IM power source wiring, specifically the ground return, be sized for at least 30 amps even though the average current will be less than 2 amps (typical).

In addition, the grounding, particularly where the ground is "referenced," is critical. It is necessary to reference all of the grounds to the same point. The engine crankcase has been chosen as THE GROUND reference to minimize interference with sensor signals. By following the recommended wiring and grounding procedures, the concerns associated with the ignition power supply wiring voltage drops can be greatly reduced or eliminated.

**NOTE:** For additional information on capacitive discharge and grounding, see Section 1.05, General Information, "Capacitive Discharge And Grounding."

### WIRING HARNESS CONNECTIONS

The IM has three external wiring harness connectors (see Figure 2.05-2). The Power Pickup Harness connects to the 7 pin connector on the IM and includes leads for DC power, the Hall-effect pickup, and the "D" lead which determines which timing switch is used. The Primary Coil Harness connects to the IM and includes leads to the ignition coils. The 14 pin connector is used to interface with the CEC Detonation Sensing Module (DSM). The 14 pin connector is only used when the DSM is installed on the engine.

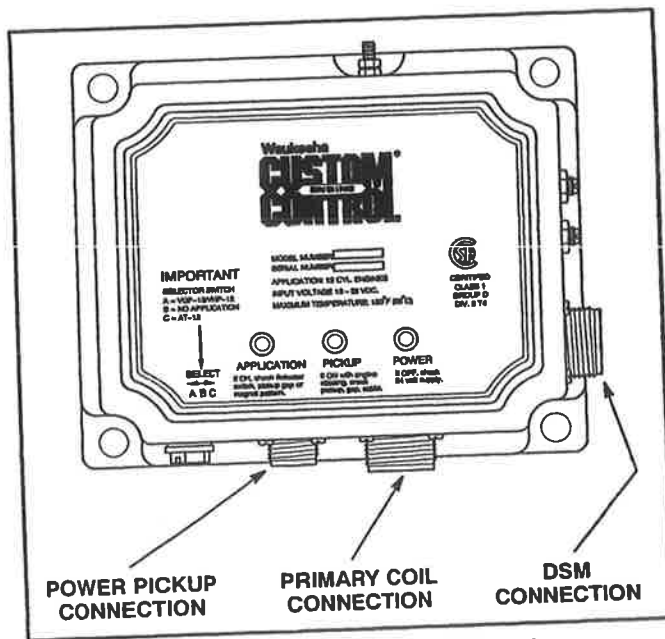


Figure 2.05-2. Ignition Module Wiring Harness Connections

# VHP IGNITION MODULE ELECTRICAL CONNECTIONS

Table 2.05-1. Power Requirements For The Ignition Module

CEC PRODUCT	NOMINAL VOLTAGE (volts DC)	TOLERANCE	OPERATING RANGE (volts DC)	PEAK-TO-PEAK RIPPLE (volts AC)	OPERATING CURRENT (amps)
Ignition Module	24	+33%, -58%	10.0 - 32.0*	less than 2*	2 (typical)

NOTE: \*For compatibility with other CEC products, a nominal supply of 24 VDC with less than a 2 volt peak-to-peak ripple is recommended to power the IM.

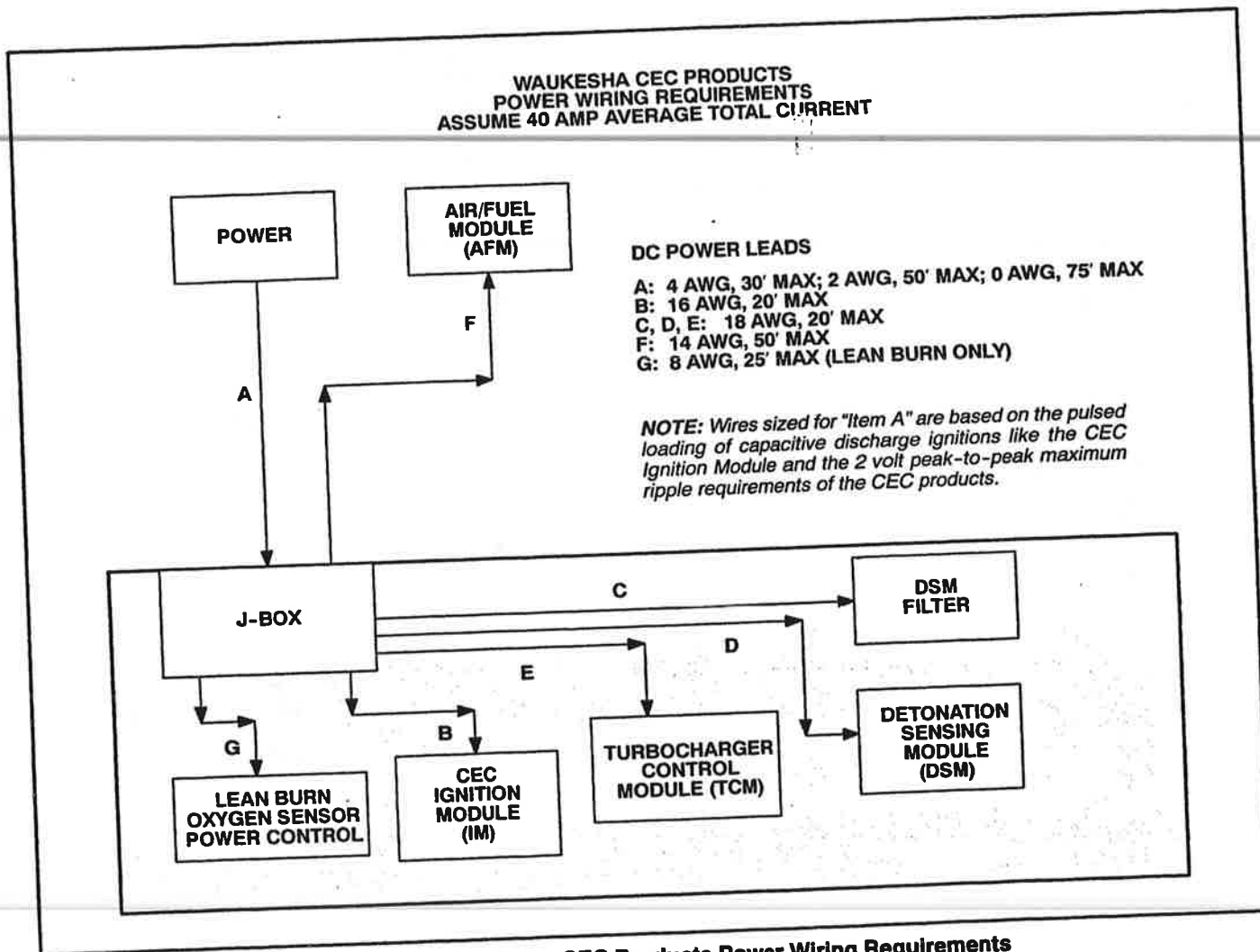


Figure 2.05-3. Waukesha CEC Products Power Wiring Requirements

# VHP IGNITION MODULE ELECTRICAL CONNECTIONS

## COMPLETING IGNITION MODULE WIRING

Complete IM electrical connections by following the steps below. Refer to Figure 2.05-5 through Figure 2.05-11 for IM wiring diagrams. Table 2.05-2 lists the page numbers of the wiring diagrams for each VHP wiring diagram.

**NOTE:** The wiring diagrams included in this manual are to be used as a reference only. Refer to the wiring diagrams received with the IM when making electrical connections.

**Table 2.05-2. Page Locations Of VHP Wiring Diagrams**

WIRING DIAGRAM	PAGE NUMBER
Figure 2.05-5. VHP 6 Cylinder (With Murphy Gas Valves) IM Wiring Diagram	2.05-6
Figure 2.05-6. VHP 6 Cylinder (Without Murphy Gas Valves) IM Wiring Diagram	2.05-7
Figure 2.05-7. VHP 12 Cylinder (With Murphy Gas Valves) IM Wiring Diagram	2.05-8
Figure 2.05-8. VHP 12 Cylinder (Without Murphy Gas Valves) IM Wiring Diagram	2.05-9
Figure 2.05-9. VHP 5115GL 12 Cylinder Engine IM Wiring Diagram	2.05-10
Figure 2.05-10. VHP 16 Cylinder (With Murphy Gas Valves) IM Wiring Diagram	2.05-11
Figure 2.05-11. VHP 16 Cylinder (Without Murphy Gas Valves) IM Wiring Diagram	2.05-12

### WARNING

Do not install, set up, maintain, or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

1. Connect a ground lead from the engine crankcase to the ground stud on the IM.
2. Connect the Primary Coil Harness to the IM connector.
3. Route the specified leads of the Primary Coil Harness to the ignition coils and cut to length (see applicable wiring diagram). Proper installation requires that the two end coils on 6 cylinder engines or the four corner coils on 12 and 16 cylinder engines are grounded to the engine. Install flashover protectors and new spark plugs to achieve optimum IM performance.

4. Connect the Power Pickup Harness to the Hall-effect pickup.

5. Connect the Power Pickup Harness from the Hall-effect pickup to the IM's 7 pin connector.

### WARNING

Disconnect all electrical power supplies before making any power connections to the Ignition Module. Electrical shock can cause severe personal injury or death.

### CAUTION

Engines that use TWO Murphy fuel shutoff valves for emergency fuel shutdowns must use an additional capacitor in parallel with the existing adapter. The additional capacitor is required to supply sufficient voltage to close both Murphy fuel shutdowns during emergency shutdowns.

### CAUTION

Do not bundle the Ignition Module wiring and Hall-effect pickup wiring together. Maintain a minimum separation of at least six inches.

**NOTE:** All wiring and IM setup must be completed BEFORE the power supply is turned on.

6. Connect the power lead from the Power Pickup Harness to the DC power supply (see applicable wiring diagram and Figure 2.05-4).

7. Continue with Section 2.10, *VHP Ignition Module Timing Adjustments*, to adjust engine timing.

Before applying power to the IM and starting the engine, complete the "Prestart Checklist" in Section 2.10, *VHP Ignition Module Timing Adjustments*.

**NOTE:** Refer to Custom Engine Control® Detonation Sensing Module (DSM) Installation, Operation, And Maintenance Manual (Form 6268) for information on completing wiring connections between the DSM system and the IM.

# VHP IGNITION MODULE ELECTRICAL CONNECTIONS

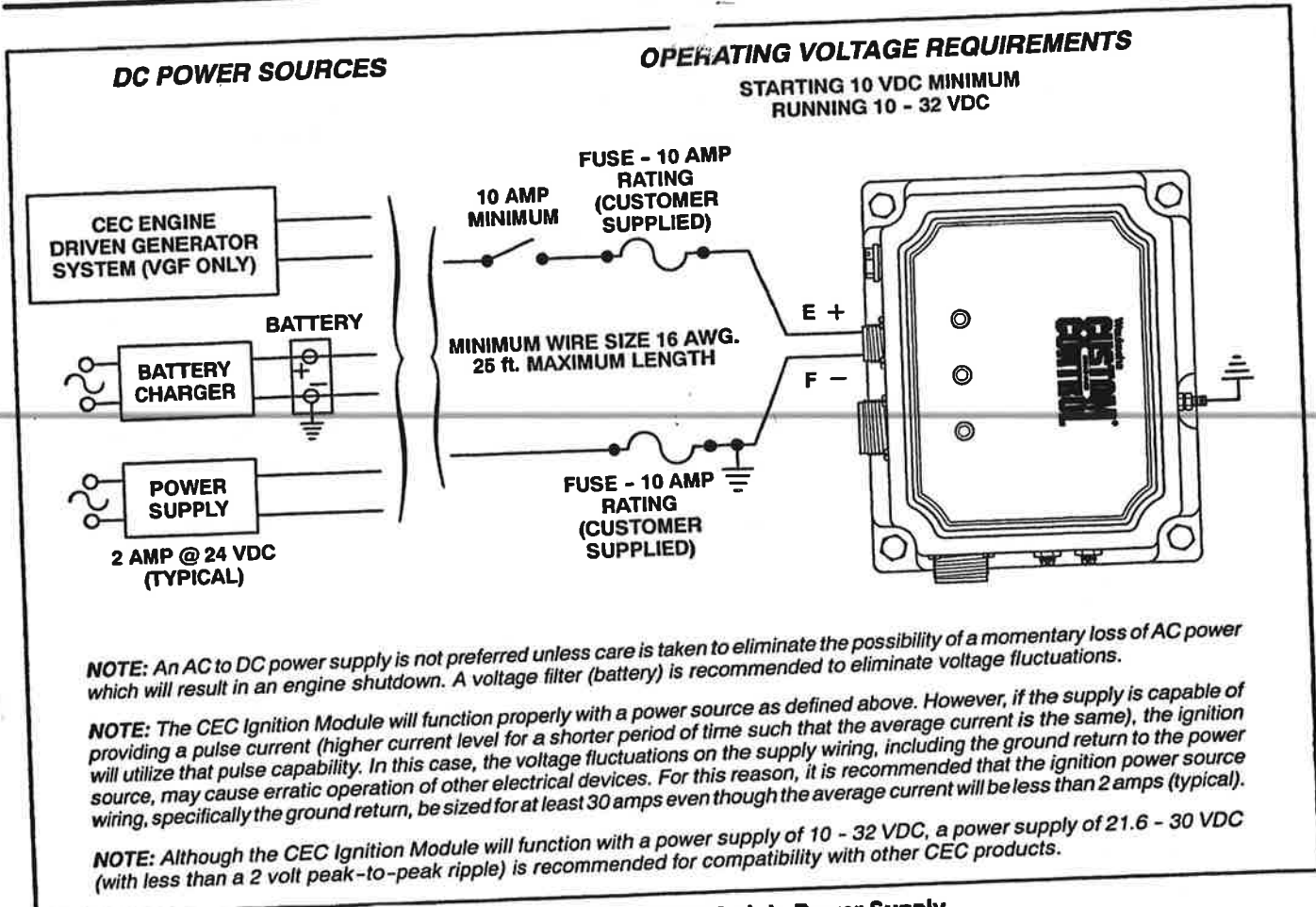


Figure 2.05-4. CEC Ignition Module Power Supply

# VHP IGNITION MODULE ELECTRICAL CONNECTIONS

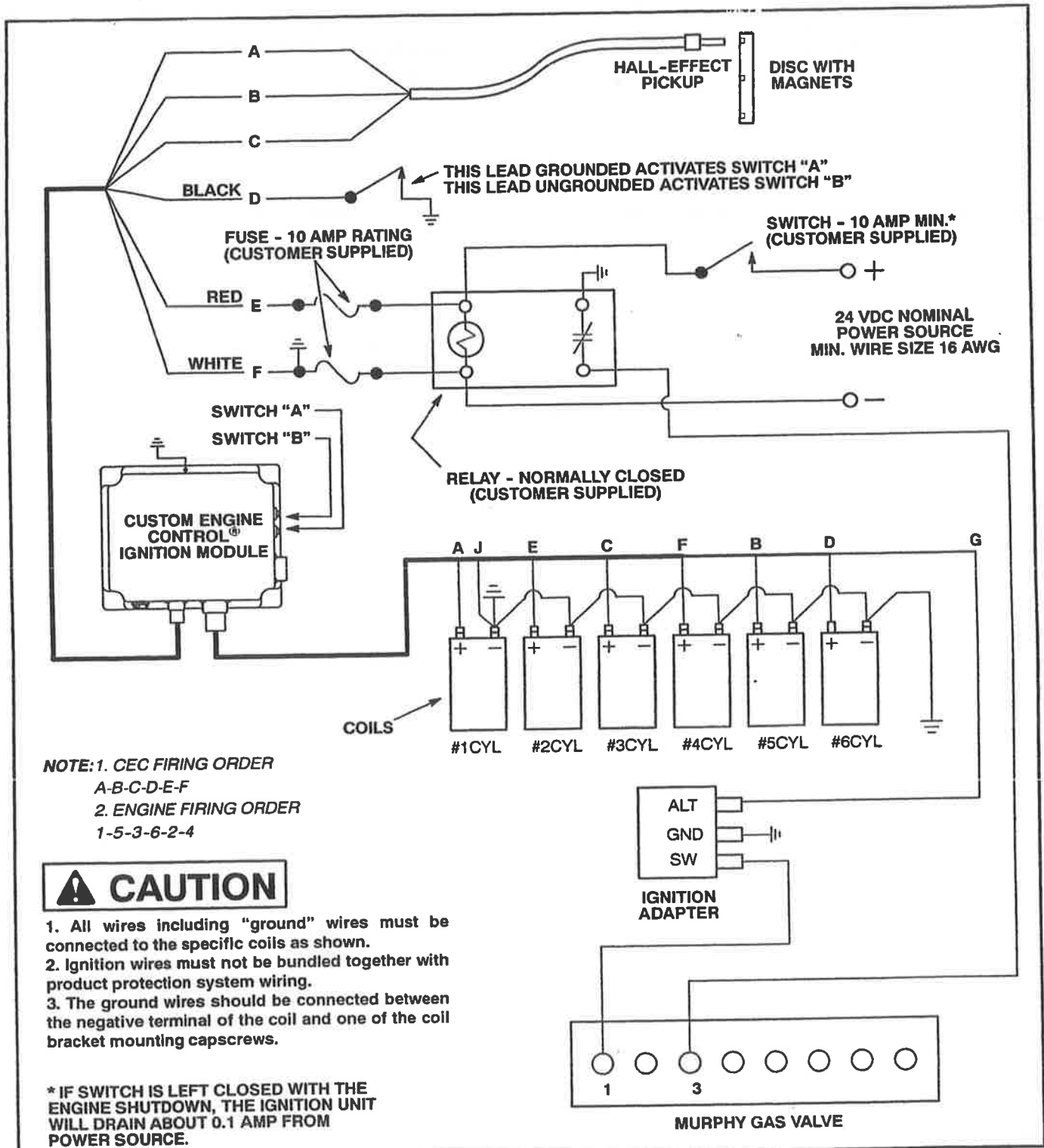


Figure 2.05-5. VHP 6 Cylinder (With Murphy Gas Valves) Ignition Module Wiring Diagram

# VHP IGNITION MODULE ELECTRICAL CONNECTIONS

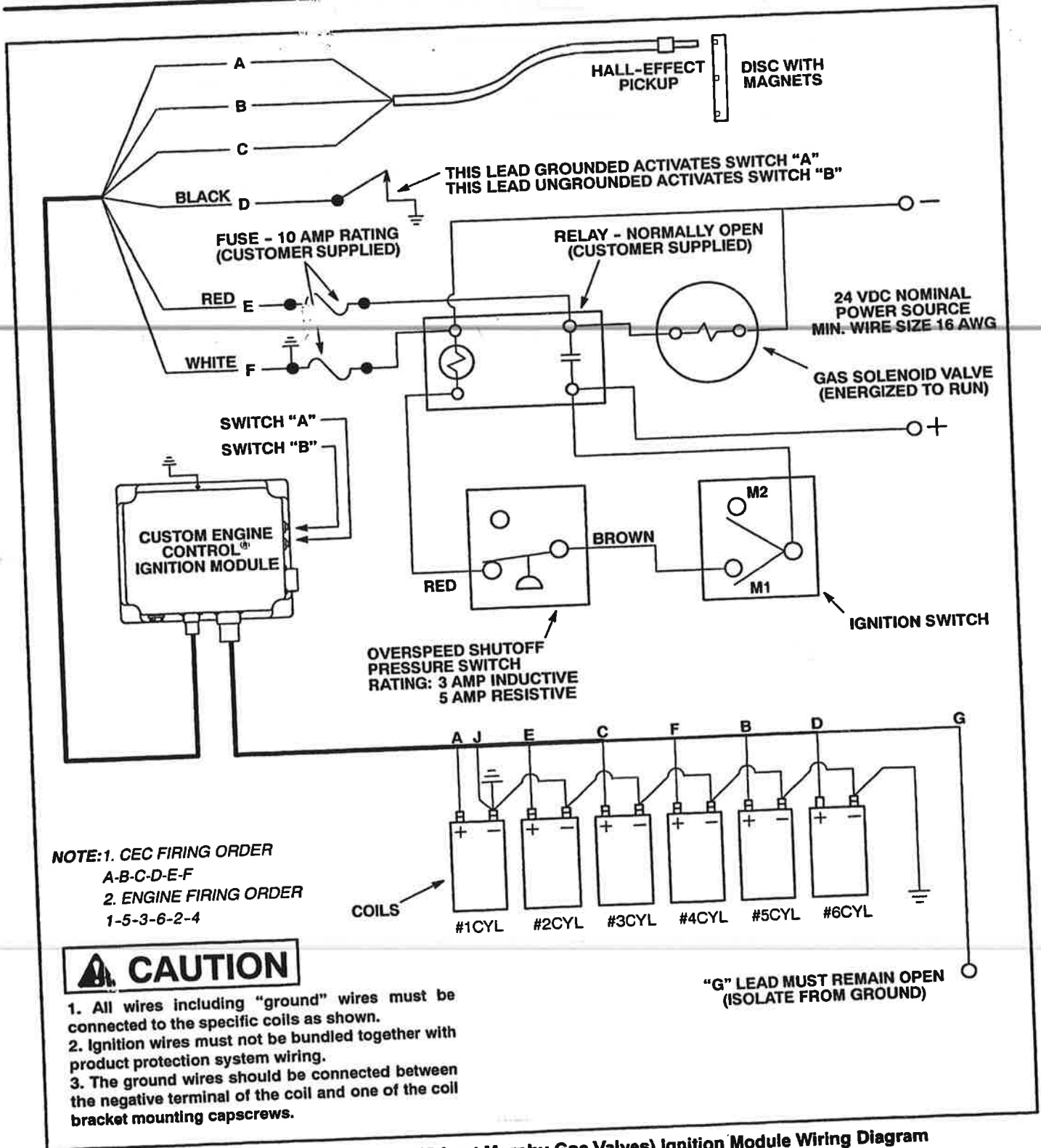


Figure 2.05-6. VHP 6 Cylinder (Without Murphy Gas Valves) Ignition Module Wiring Diagram



# VHP IGNITION MODULE ELECTRICAL CONNECTIONS

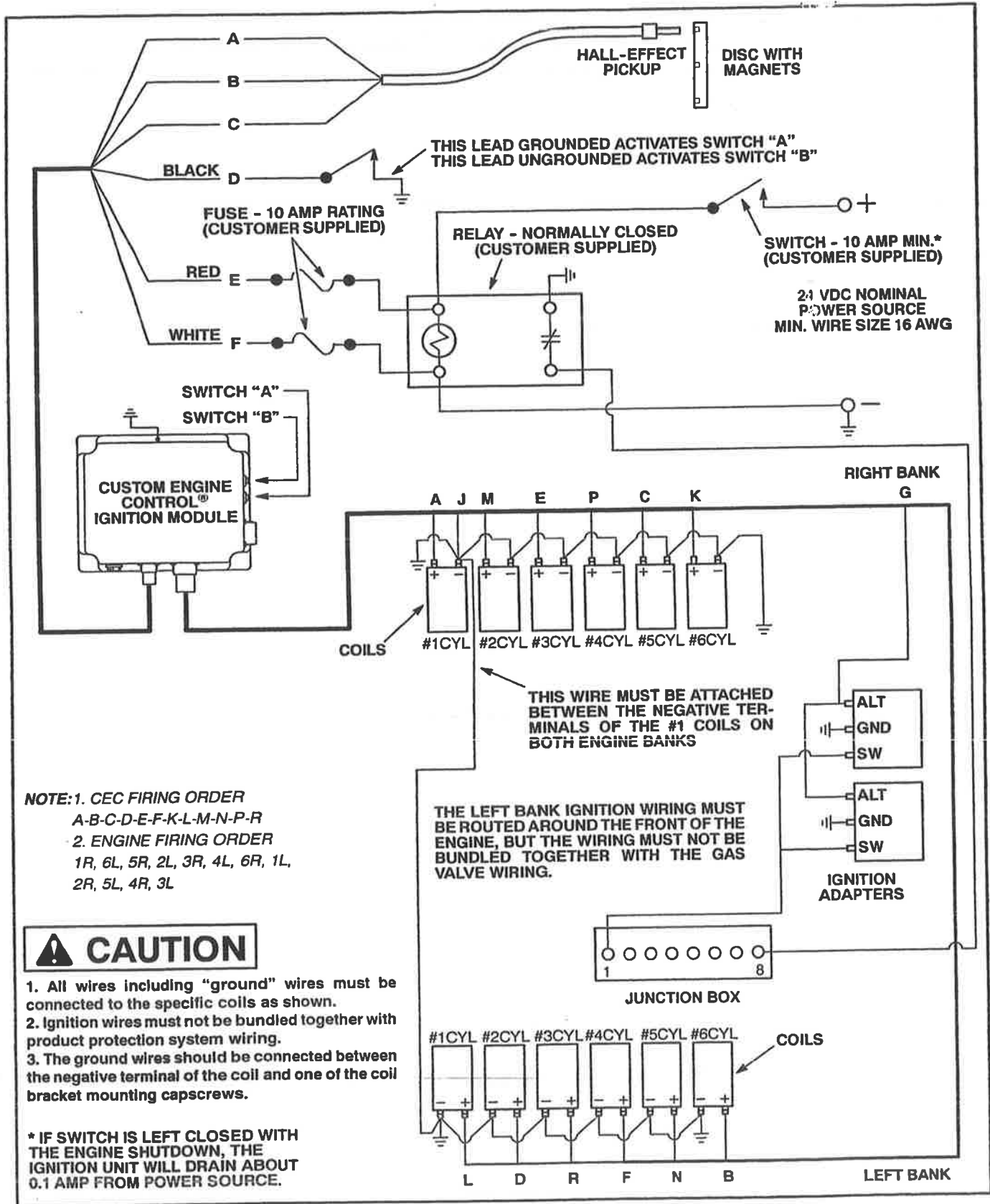


Figure 2.05-7. VHP 12 Cylinder (With Murphy Gas Valves) Ignition Module Wiring Diagram



# VHP IGNITION MODULE ELECTRICAL CONNECTIONS

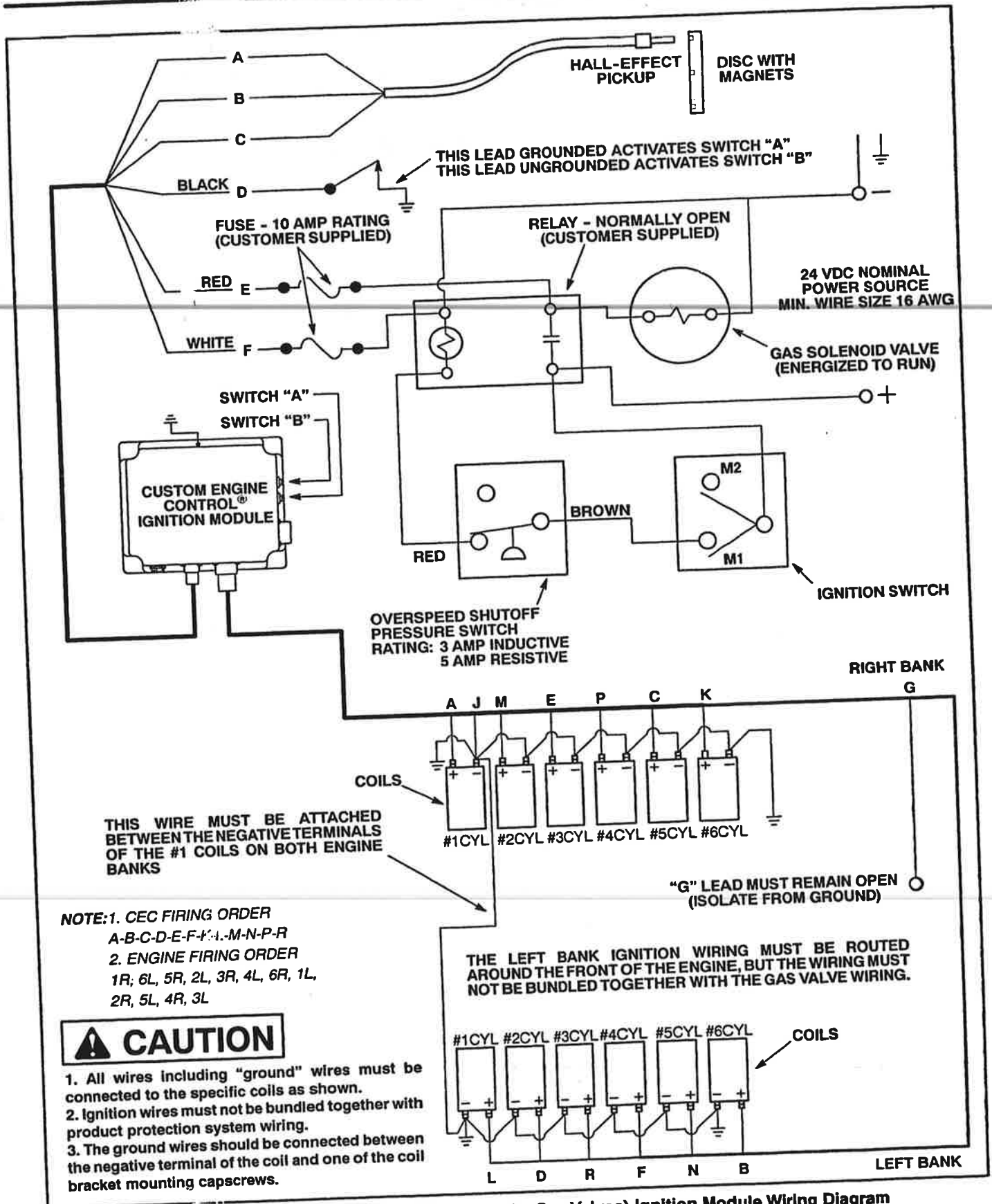


Figure 2.05-8. VHP 12 Cylinder (Without Murphy Gas Valves) Ignition Module Wiring Diagram

# VHP IGNITION MODULE ELECTRICAL CONNECTIONS

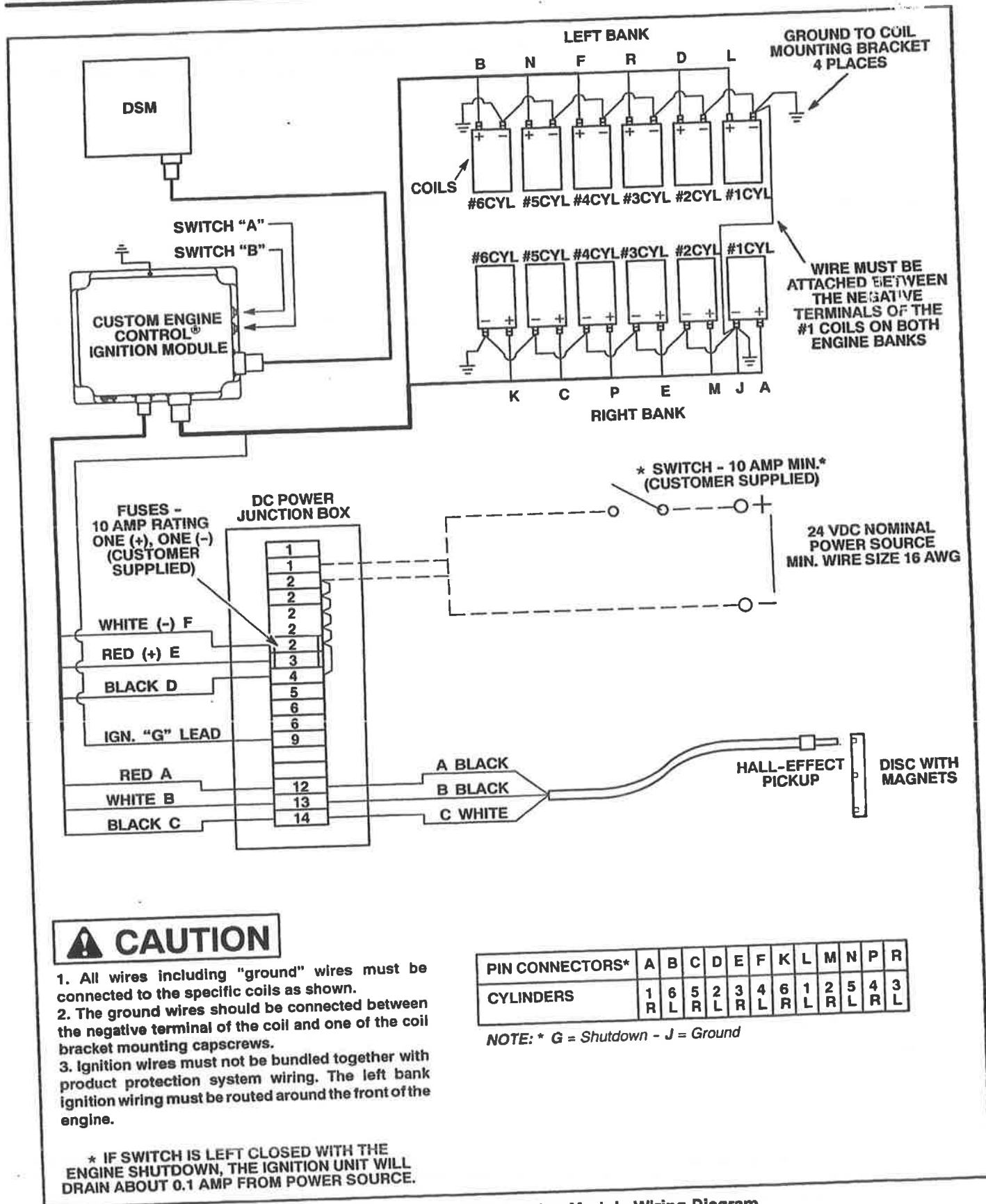


Figure 2.05-9. VHP 5115GL Ignition Module Wiring Diagram

# VHP IGNITION MODULE ELECTRICAL CONNECTIONS

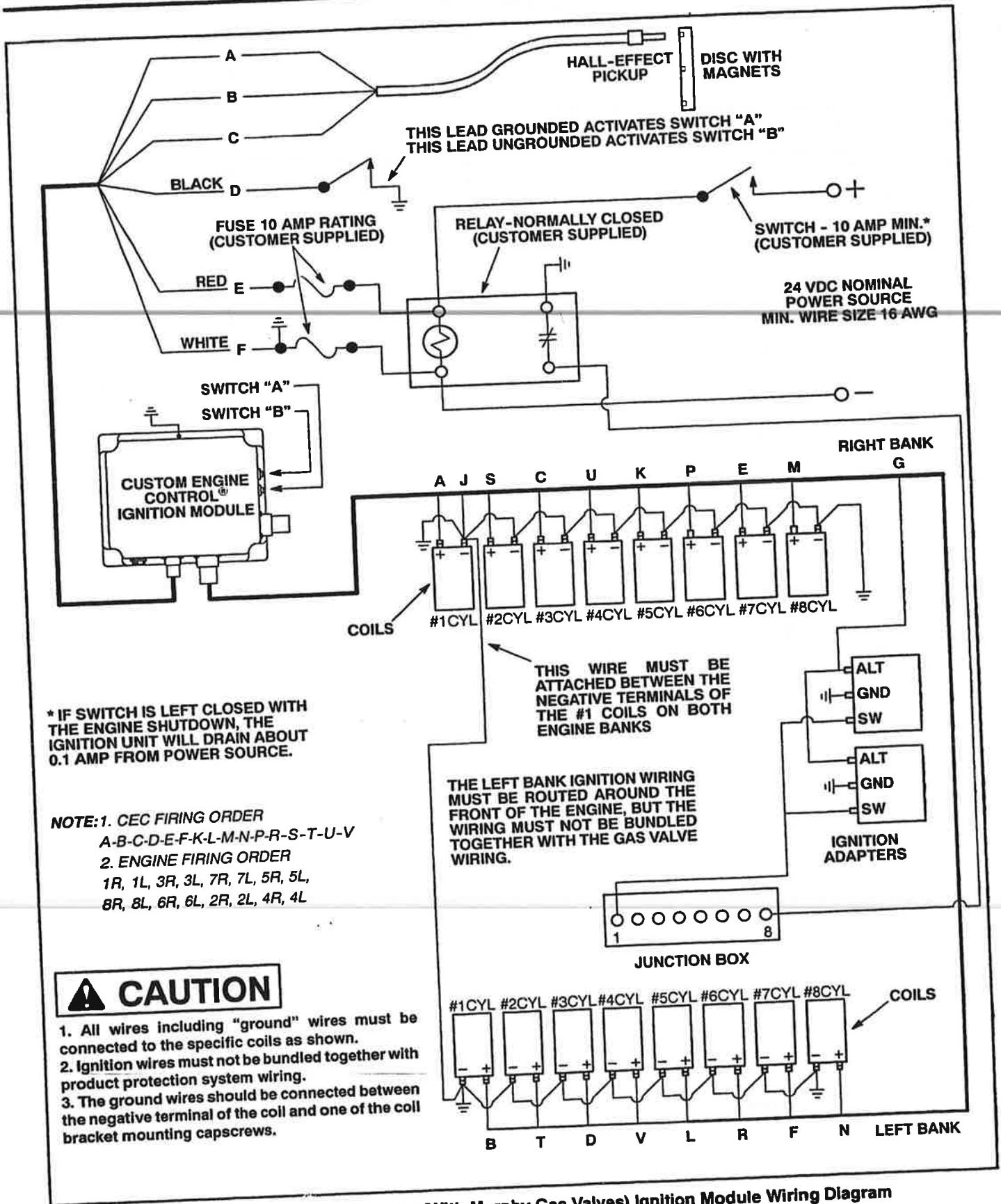
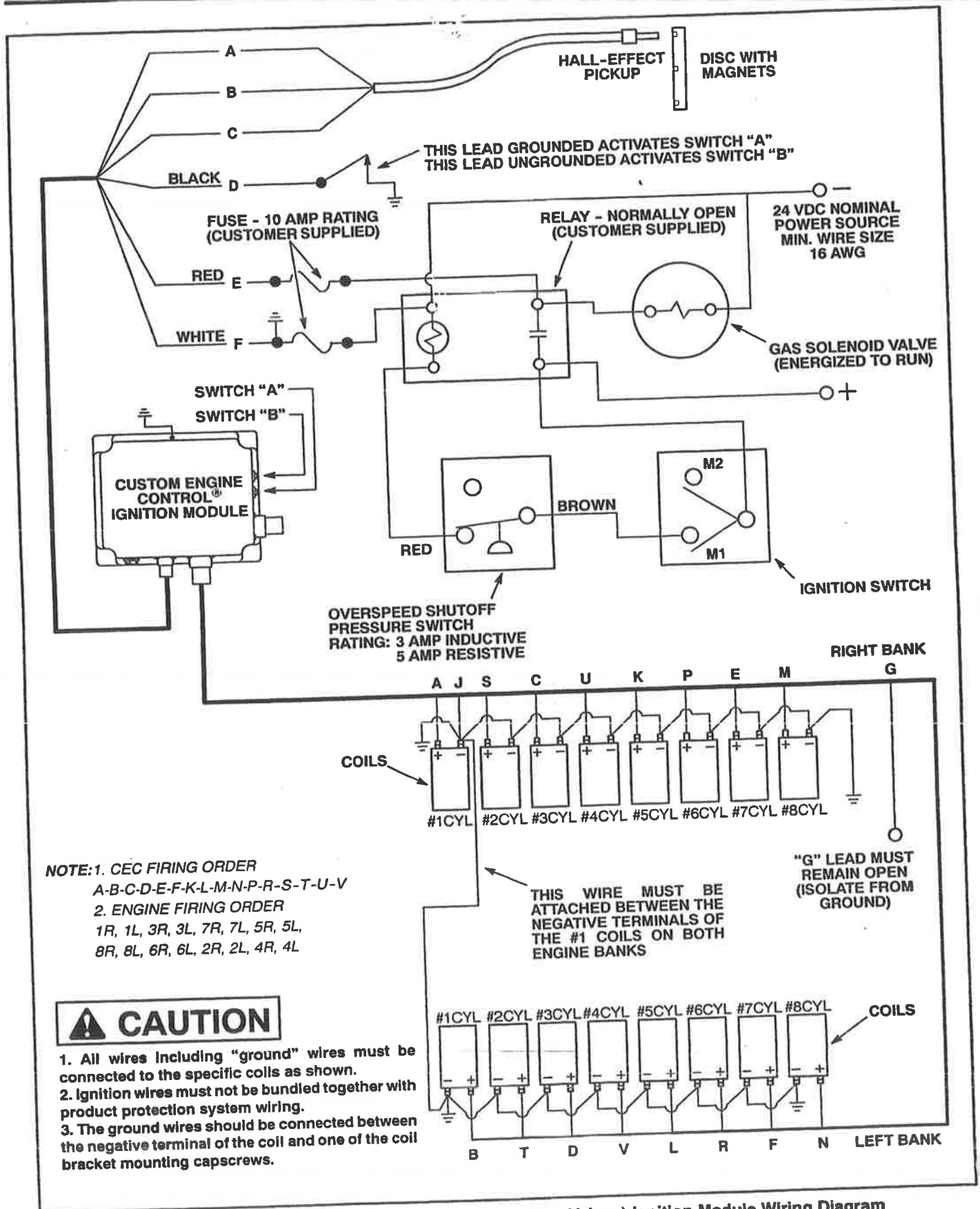


Figure 2.05-10. VHP 6 Cylinder (With Murphy Gas Valves) Ignition Module Wiring Diagram

# VHP IGNITION MODULE ELECTRICAL CONNECTIONS



**NOTE: 1. CEC FIRING ORDER**  
A-B-C-D-E-F-K-L-M-N-P-R-S-T-U-V  
**2. ENGINE FIRING ORDER**  
1R, 1L, 3R, 3L, 7R, 7L, 5R, 5L,  
8R, 8L, 6R, 6L, 2R, 2L, 4R, 4L

## CAUTION

- All wires including "ground" wires must be connected to the specific coils as shown.
- Ignition wires must not be bundled together with product protection system wiring.
- The ground wires should be connected between the negative terminal of the coil and one of the coil bracket mounting capscrews.

Figure 2.05-11. VHP 16 Cylinder (Without Murphy Gas Valves) Ignition Module Wiring Diagram

## SECTION 2.10

# VHP IGNITION MODULE TIMING ADJUSTMENTS

### PRESTART CHECKLIST

Before applying power to the IM (engine not running):

- Visually inspect the installation to be sure that all wiring conforms to the requirements of this manual, local codes, and regulatory bodies.
- Verify all grounding requirements. Refer to Section 2.00, *VHP Ignition Module Electrical Connections*, "Electrical Connections," for wiring diagrams.
- Leave the IM unpowered. Verify that the power supply is within specification. Refer to Section 2.00, *VHP Ignition Module Electrical Connections*, "Electrical Connections," for power specifications.

### VHP IGNITION TIMING SET

Timing is changed with two 16 position (0 - 15) timing switches located on the IM (see Figure 2.10-1). Each switch can be set to separate ignition timing settings for different applications. Timing switch position 15 gives the most advanced timing on the active timing switch, either switch "A" or "B." Switch "A" has a more advanced timing range than switch "B." Switch position 0 (zero) is full retard. The timing advances/retards 1.0 degree between each switch position. Grounding lead "D" in the Power Pickup Harness (7 pin connector) activates the timing selected by switch "A." Ungrounded lead "D" will activate the timing selected by switch "B."

For 6 and 12 cylinder engines, a 6 degree overlap between timing switch "A" and timing switch "B" gives the IM a combined timing range of 25 degrees.

For 16 cylinder engines, a 7 degree overlap between timing switch "A" and timing switch "B" gives the IM a combined timing range of 24 degrees.

Table 2.10-1 lists the IM firing order for 6 cylinder VHP engines. Table 2.10-2 lists the IM firing order for 12 cylinder VHP engines. Table 2.10-3 lists the IM firing order for 16 cylinder VHP engines.

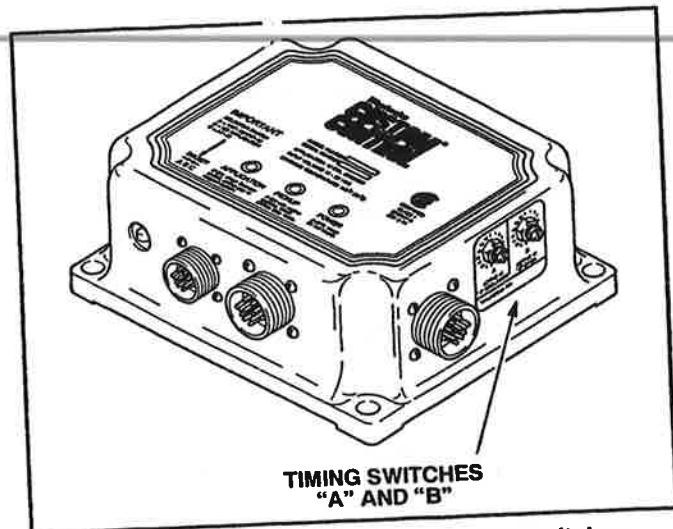


Figure 2.10-1. Ignition Module Timing Switches

Table 2.10-1. Firing Order For VHP 6 Cylinder Engines

PIN CONNECTORS*	A	B	C	D	E	F
CYLINDERS	1	5	3	6	2	4

Table 2.10-2. Firing Order For VHP 12 Cylinder Engines

PIN CONNECTORS*	A	B	C	D	E	F	K	L	M	N	P	R
CYLINDERS	1 R	6 L	5 R	2 L	3 R	4 L	6 R	1 L	2 R	5 L	4 R	3 L

NOTE: \* G=Shutdown - J=Ground

Table 2.10-3. Firing Order For VHP 16 Cylinder Engines

PIN CONNECTORS*	A	B	C	D	E	F	K	L
CYLINDERS	1R	1L	3R	3L	7R	7L	5R	5L
PIN CONNECTORS*	M	N	P	R	S	T	U	V
CYLINDERS	8R	8L	6R	6L	2R	2L	4R	4L

NOTE: \* G=Shutdown - J=Ground

# VHP IGNITION MODULE TIMING ADJUSTMENTS

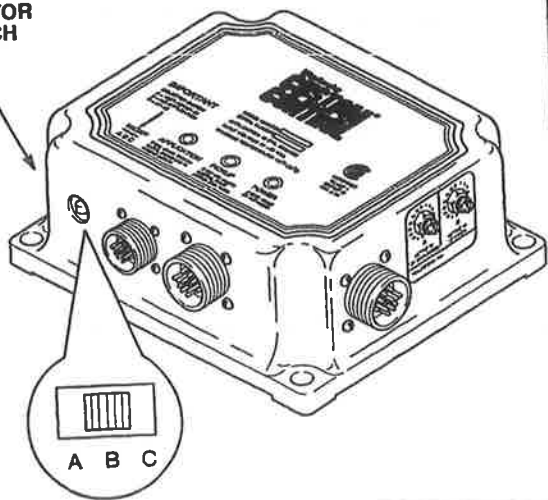
## STEPS REQUIRED TO ADJUST IGNITION MODULE TIMING

1. Complete the Prestart Checklist before running engine and adjusting timing.
2. Remove the cap from the Selector Switch access hole.
3. Set the appropriate timing application by adjusting the Selector Switch (see Table 2.10-4). The Selector Switch is a three position switch (A, B, and C). Use your finger or a screwdriver to switch to the proper application.
4. Replace the cover on the Selector Switch access hole.

Table 2.10-4. Ignition Module Selector Switch Settings

SELECTOR SWITCH SETTING	IGNITION MODULE MODELS		
	Model 811 for 6 & 8 Cylinder Engines	Model 1211 for All 12 Cylinder Engines	Model 1611 for All 16 Cylinder Engines
A	VHP/VGF 6 Cylinder Engines	VHP/VGF 12 Cylinder Engines	VHP/VGF 16 Cylinder Engines
B	No Application	No Application	No Application
C	ATGL/VGF 8 Cylinder Engines	ATGL 12 Cylinder Engines	ATGL 16 Cylinder Engines

SELECTOR SWITCH



5. Remove the white caps from the timing switches "A" and "B" on the side of the IM (see Figure 2.10-2).

6. Using a screwdriver, set both timing switches on the side of the IM to 10. Timing selection is made by the dot on the switch, not the screwdriver slot.

**NOTE:** If the IM being adjusted is replacing another IM, set the timing switches to the same positions as the IM being replaced.

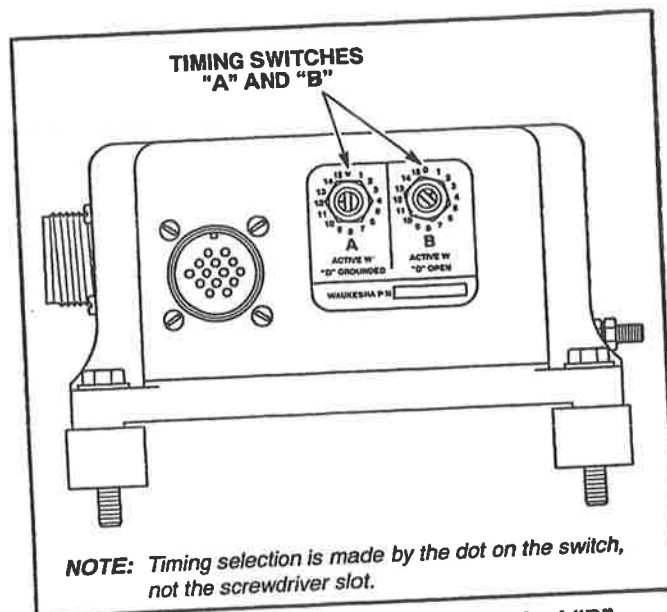


Figure 2.10-2. Timing Switches "A" And "B"

7. Check the engine's nameplate to determine the exact timing (or most advanced) of the primary and secondary (if equipped) fuels.

8. Apply power to IM. Refer to Section 2.05, VHP Ignition Module Electrical Connections, "Electrical Connections," for power specifications.

## WARNING

If a gas engine has been cranked excessively without starting, shut off the gas fuel supply and ignition, and then crank the engine to purge the cylinders and exhaust system of accumulated unburned gas. If this is not done a spark could ignite the gas and cause an exhaust explosion. Failure to comply could cause severe personal injury or death.

9. Start engine. Run engine at idle speed and with NO load.



## VHP IGNITION MODULE TIMING ADJUSTMENTS

10. Run the engine on primary fuel with the "D" lead (found in the 7 pin connector from the IM) grounded to the engine block and the CEC Detonation Sensing Module (DSM) deactivated (14 pin DSM harness disconnected from IM).

11. Check engine timing at the flywheel using a timing light (see Figure 2.10-3).

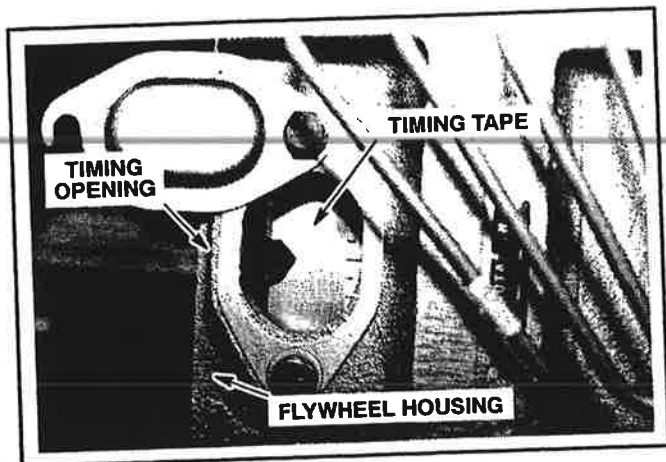


Figure 2.10-3. Flywheel Timing Opening

**CAUTION** Do not switch from position 15 to 0, 0 to 15 or make other large timing changes quickly while the engine is running. The large timing change may cause engine damage or shutdown.

**NOTE:** Increasing the timing switch position by one will advance the timing one degree. Decreasing the timing switch position by one will retard the timing one degree.

12. Adjust the "A" timing switch as required to achieve correct timing (see Figure 2.10-2). Single fuel ignition adjustments are now complete. If you have a single fuel application, continue with Step 16. If you have a dual fuel application, continue with Step 13.

13. Run the engine on secondary fuel with the "D" lead (found in the 7 pin connector from IM) open and the CEC Detonation Sensing Module (DSM) deactivated (14 pin DSM harness disconnected from IM).

14. Check engine timing at the flywheel using a timing light (see Figure 2.10-3).

**NOTE:** Increasing the timing switch position by one will advance the timing one degree. Decreasing the timing switch position by one will retard the timing one degree.

15. Adjust the "B" timing switch as required to achieve correct timing (see Figure 2.10-2). Dual fuel ignition adjustments are now complete.

**CAUTION** To prevent the timing from being altered, always replace the white caps over the timing switches once the desired setting has been selected. Disregarding this information could result in product damage and/or personal injury.

16. When timing adjustments are complete, replace the white caps on the timing switches "A" and "B."

17. If applicable, reconnect the DSM harness to the 14 pin connector on the IM. Activate the DSM. Refer to *Custom Engine Control® Detonation Sensing Module (DSM) Installation, Operation, And Maintenance Manual* (Form 6268) for programming information.

**CAUTION** It is the sole responsibility of the customer to ensure that all product protection devices effectively shut off both the ignition and gas simultaneously in the event of any malfunctions. Disregarding this information could result in product damage and/or personal injury.

18. Verify shutdown switches and load carrying ability.

### DISCHARGING THE STORAGE CAPACITOR

#### **WARNING**

If the Ignition switch is left in the ON position when a Ignition Module is disconnected, then the spark plugs may fire when the Ignition system harness is reconnected, and could cause severe personal injury or death.

Before connecting the ignition harness (to the coils) to the IM, discharge the storage capacitors to ground. Attach one end of a wire lead to the crankcase and then touch the other end to the harness connector pins on the IM, one at a time. A snap may be heard when a capacitor discharges.

#### **WARNING**

As a safety measure, ground all the pins. Some breakerless ignition systems have more than one storage capacitor. Severe personal injury or death could result.

# VHP IGNITION MODULE TIMING ADJUSTMENTS

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# **CHAPTER 3 - ATGL IGNITION MODULE INSTALLATION AND OPERATION**

## **CONTENTS**

**SECTION 3.00 - IGNITION MODULE OPERATION ON  
ATGL ENGINES**

**SECTION 3.05 - ATGL IGNITION MODULE  
ELECTRICAL CONNECTIONS**

**SECTION 3.10 - ATGL IGNITION MODULE TIMING ADJUSTMENTS**



## SECTION 3.00

# IGNITION MODULE OPERATION ON ATGL ENGINES

### IGNITION MODULE OPERATION ON ATGL ENGINES

The purpose of this section is to describe IM operation on ATGL engines and to describe the location of Hall-effect pickup(s).

#### 8L-AT27GL ENGINES

##### Location Of Hall-effect Pickups

The IM system consists of the following components: module, timing disc, two Hall-effect pickups, pickup cable assembly, and a magnet-embedded flywheel.

The 8L-AT27GL has a two pickup, crankshaft-fired ignition system. The 8L-AT27GL has an index disc mounted on the rear end of the camshaft and a camshaft Hall-effect pickup mounted on the rear plate of the engine (see Figure 3.00-1). The index disc has one magnet—the index magnet.

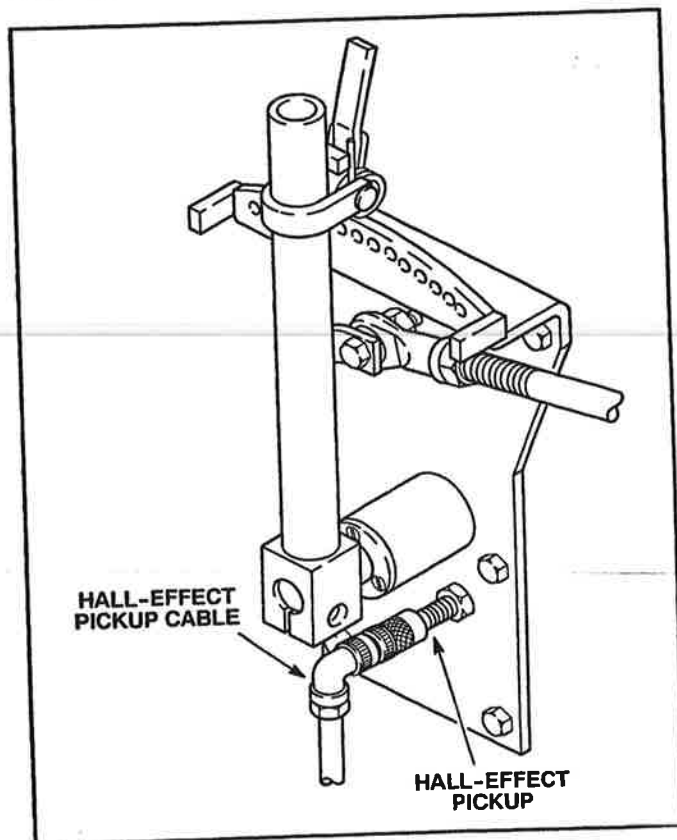


Figure 3.00-1. AT27GL Hall-effect Pickup

The 8L-AT27GL has a second Hall-effect pickup mounted at the flywheel (see Figure 3.00-2). The flywheel Hall-effect pickup senses the passing of four magnets on the rear of the flywheel and sends a signal to the IM which fires the appropriate cylinders. (Since there is one camshaft revolution for every two flywheel revolutions, the four flywheel magnets are sensed *twice* for every one revolution of the camshaft.) The center of the Hall-effect pickup face lines up with the center of each magnet embedded in the face of the timing disc as it rotates on the camshaft. The camshaft Hall-effect pickup, in conjunction with the index magnet, signals the IM that another camshaft revolution is about to begin.

The advantage of the two pickup system on the 8L-AT27GL is that it allows for increased accuracy in timing by eliminating the effects of camshaft gear lash from information relayed to the IM.

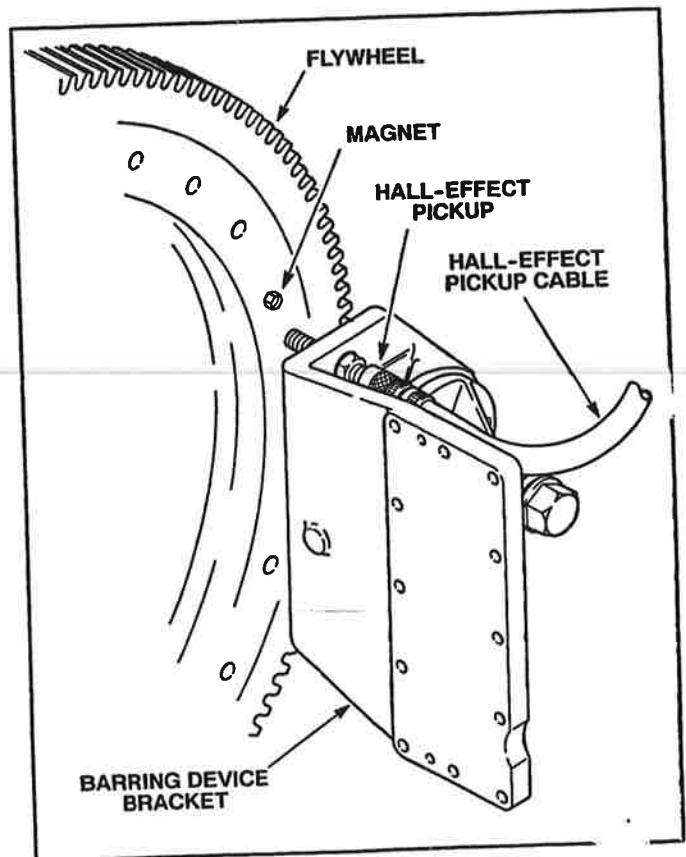


Figure 3.00-2. AT27GL Hall-effect Pickup

# IGNITION MODULE OPERATION ON ATGL ENGINES

## Setting The Air Gap

To set the air gap specification, complete the following steps.

1. Thread the Hall-effect pickup into the engine rear plate until the pickup comes in contact with the timing disc.
2. Scribe a reference mark on the Hall-effect pickup and at the same point mark the mounting bracket.
3. Using the reference mark on the pickup as the starting point, rotate the Hall-effect pickup **one (1)** full turn (+0, -1/16 of a turn) counterclockwise to set the pickup to timing disc clearance.
4. After the clearance is set, snug the locking nut.

## 12V-AT27GL ENGINES

### Location Of Hall-effect Pickups

The 12V-AT27GL IM system consists of the following components: module, aluminum disc mounted on the camshaft gear, two Hall-effect pickups, pickup cable assembly, magnet imbedded flywheel, and flywheel Hall-effect pickup.

The 12V-AT27GL has a two pickup, crankshaft-fired ignition system with an index disc mounted on the rear end of the right bank camshaft and a camshaft Hall-effect pickup mounted on the right bank side of the rear plate (see Figure 3.00-3 and Figure 3.00-4). The index disc has one magnet—the index magnet.

The 12V-AT27GL engine also has a second Hall-effect pickup mounted at the flywheel (see Figure 3.00-5). This flywheel Hall-effect pickup senses the passing of six magnets on the rear of the flywheel and sends a signal to the IM which fires the appropriate cylinders. (Since there is one camshaft revolution for every two flywheel revolutions, the six flywheel magnets are sensed *twice* for every one revolution of the camshaft.) The camshaft Hall-effect pickup, in conjunction with the index magnet, signals the IM that another camshaft revolution is about to begin.

The advantage of the two pickup system on the 12V-AT27GL is that it allows for increased accuracy in timing by eliminating the effects of camshaft gear lash from information relayed to the IM.

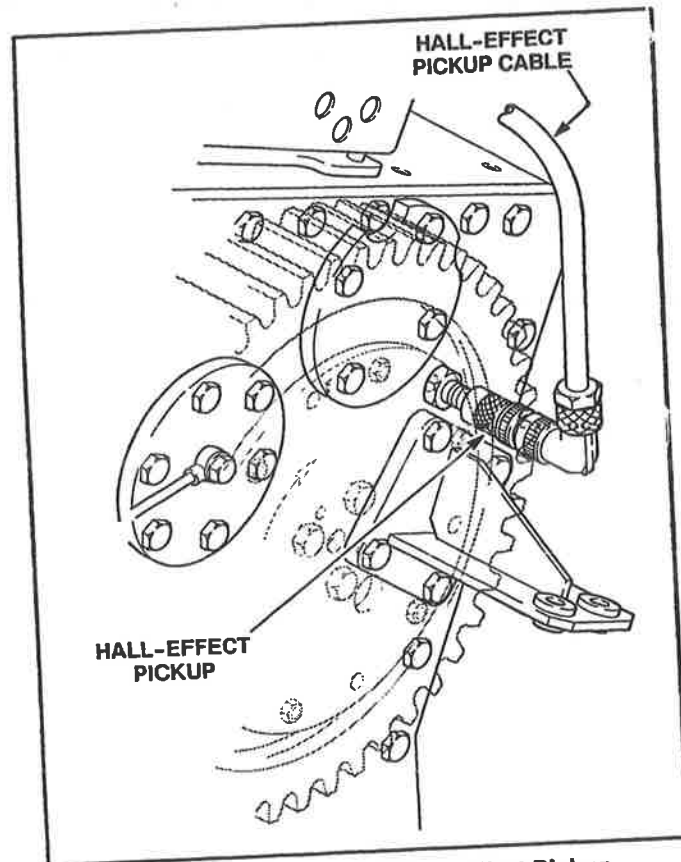


Figure 3.00-3. Camshaft Hall-effect Pickup

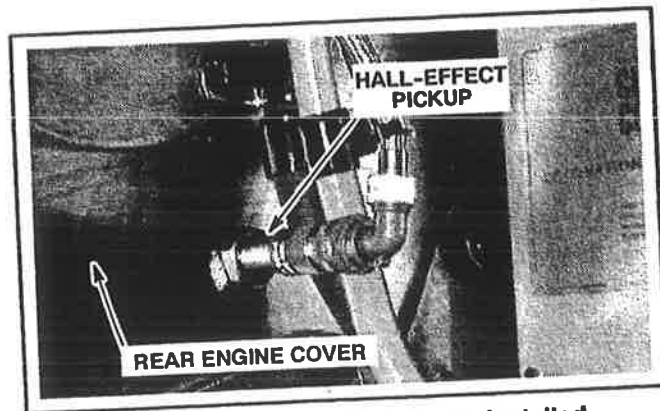


Figure 3.00-4. Hall-effect Pickup Installed

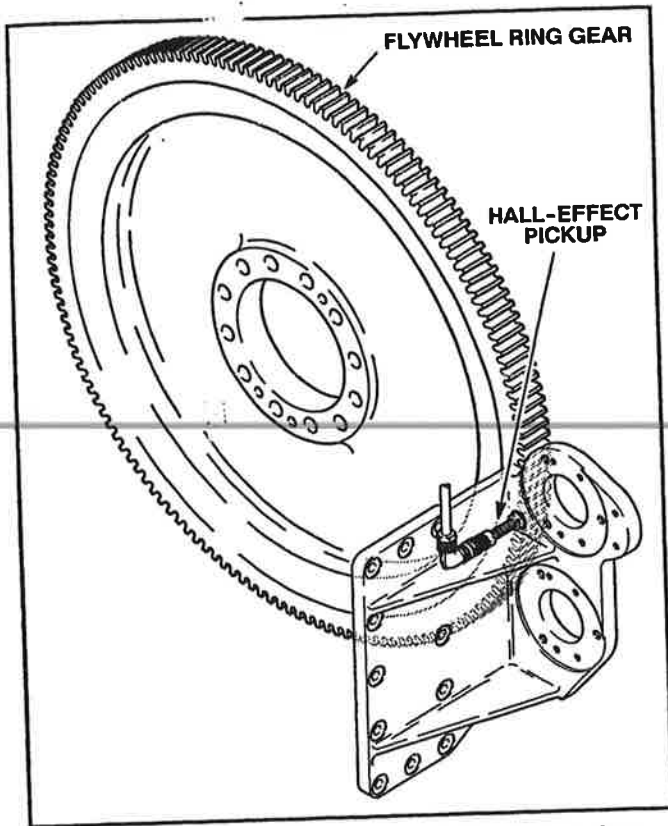


Figure 3.00-5. AT27GL Flywheel Hall-effect Pickup

### Setting The Air Gap

To set the air gap specification, complete the following steps.

1. Thread the Hall-effect pickup into the engine rear plate until the pickup comes in contact with the timing disc.
2. Scribe a reference mark on the Hall-effect pickup and at the same point mark the mounting bracket.
3. Using the reference mark on the pickup as the starting point, rotate the Hall-effect pickup **one (1)** full turn (+0, -1/16 of a turn) counterclockwise to set the pickup to timing disc clearance.
4. After the clearance is set, snug the locking nut.

## 12V-AT25GL ENGINES

### Location Of Hall-effect Pickup

The 12V-AT25GL IM system consists of the following components: module, aluminum disc mounted on the camshaft gear, one Hall-effect pickup, and pickup cable assembly.

The 12V-AT25GL has a one pickup, camshaft-fired ignition system. A timing disc is mounted on the rear end of the right bank camshaft (see Figure 3.00-6). The timing disc has thirteen magnets. Twelve of the magnets are for firing the appropriate cylinder. Trailing 15 degrees after the last magnet is an index magnet that signals the IM that another camshaft revolution is about to begin. The camshaft Hall-effect pickup, mounted on the right bank side of the rear plate, senses the passing of these magnets and sends a signal to the IM which fires the appropriate cylinders (see Figure 3.00-3).

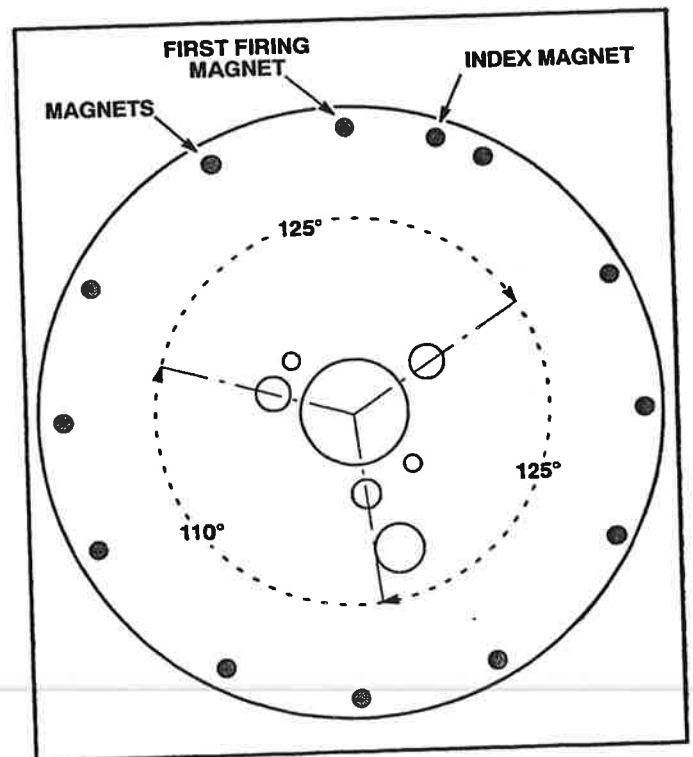


Figure 3.00-6. 12V-AT25GL Timing Disc

## **IGNITION MODULE OPERATION ON ATGL ENGINES**

---

### **Setting The Air Gap**

To set the air gap specification, complete the following steps.

1. Thread the Hall-effect pickup into the engine rear plate until the pickup comes in contact with the timing disc.
2. Scribe a reference mark on the Hall-effect pickup and at the same point mark the mounting bracket.
3. Using the reference mark on the pickup as the starting point, rotate the Hall-effect pickup  $\frac{3}{4}$  of a turn ( $\pm 1/16$  of a turn) counterclockwise to set the pickup to timing disc clearance.
4. After the clearance is set, snug the locking nut.

## SECTION 3.05

# ATGL IGNITION MODULE ELECTRICAL CONNECTIONS

### MOUNTING THE IGNITION MODULE

Mount the IM using the vibration isolators supplied with the IM (see Figure 3.05-1). Note the following:

- When the IM is being mounted on an earlier rear plate in a retrofit situation, the IM is mounted in the manner shown in Figure 3.05-1 (see asterisked components).

- The outside temperature of IM casing should not exceed 150° F (65° C) in operation.

**CAUTION** Do not weld on or around engine unless the Ignition Module has been unplugged. Failure to do so may damage the Ignition Module.

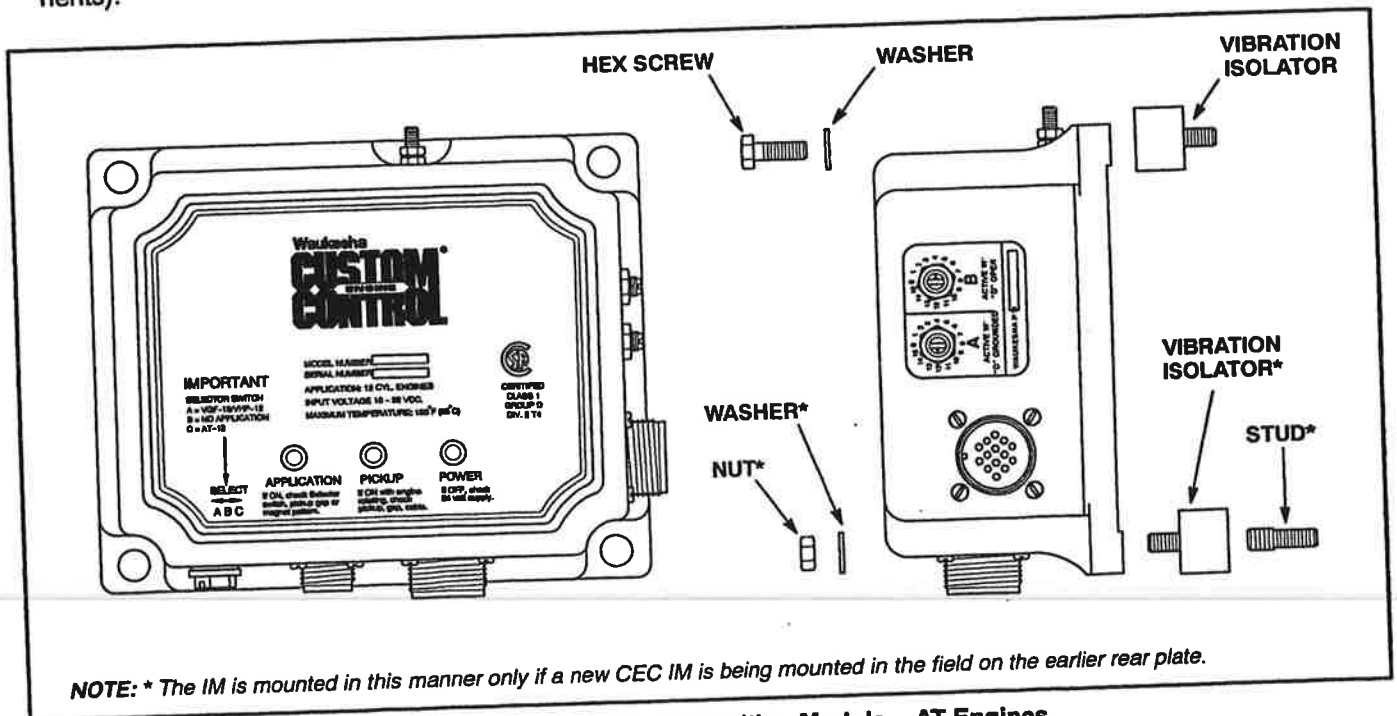


Figure 3.05-1. Mounting The Ignition Module - AT Engines

# ATGL IGNITION MODULE ELECTRICAL CONNECTIONS

## ELECTRICAL CONNECTIONS

### IGNITION MODULE POWER REQUIREMENTS

The power connections made for the IM must be in accordance with the applicable local electrical codes. The IM is suitable for installation in Canadian Standards Association (CSA) Class I, Group D, Division 2 locations. All power sizing must be in accordance with Figure 3.05-3, "Waukesha CEC Products Power Wiring Requirements."

See Table 3.05-1 for IM power requirements.

**NOTE:** An AC to DC power supply is not preferred unless care is taken to eliminate the possibility of a momentary loss of AC power which will result in an engine shutdown. A DC voltage filter (battery) is recommended to eliminate voltage fluctuations.

**NOTE:** For compatibility with other CEC products, a nominal supply of 24 VDC with less than a 2 volt peak-to-peak ripple is recommended to power the IM.

**NOTE:** Refer to Section 1.05, General Information, "Power Requirements for Custom Engine Control® Products," for the power requirements of all Waukesha Engine CEC products.

### POWER SOURCE WIRING SIZING AND GROUNDING

The IM, a capacitive discharge (CD) ignition system, requires an external power source which presents special wiring requirements. The IM will function properly with a power source as defined in Table 3.05-1. However, if the supply is capable of providing a pulse current (higher current level for a shorter period of time such that the average current is the same), the IM will utilize that pulse capability. In this case, the voltage fluctuations on the supply wiring, including the ground return to the power source, may interfere with the operation of other electrical devices. For this reason, it is recommended that the IM power source wiring, specifically the ground return, be sized for at least 30 amps even though the average current will be less than 2 amps (typical).

In addition, the grounding, particularly where the ground is "referenced," is critical. It is necessary to reference all of the grounds to the same point. The engine crankcase has been chosen as THE GROUND reference to minimize interference with sensor signals. By following the recommended wiring and grounding procedures, the concerns associated with the ignition power supply wiring voltage drops can be greatly reduced or eliminated.

**NOTE:** For additional information on capacitive discharge and grounding, see Section 1.05, General Information, "Capacitive Discharge And Grounding."

### AT ENGINE WIRING HARNESS CONNECTIONS

The IM has three external wiring harness connectors (see Figure 3.05-2). The Power Pickup Harness which includes leads for DC power, the Hall-effect pickup, and the "D" lead connects to the Main J-box and the 7 pin connector on the IM. The Primary Coil Harness which includes leads to the ignition coils connects to the Ignition J-Box and the IM. The 14 pin connector is used to interface with the CEC Detonation Sensing Module (DSM). The 14 pin connector is only used when the DSM is installed on the engine.

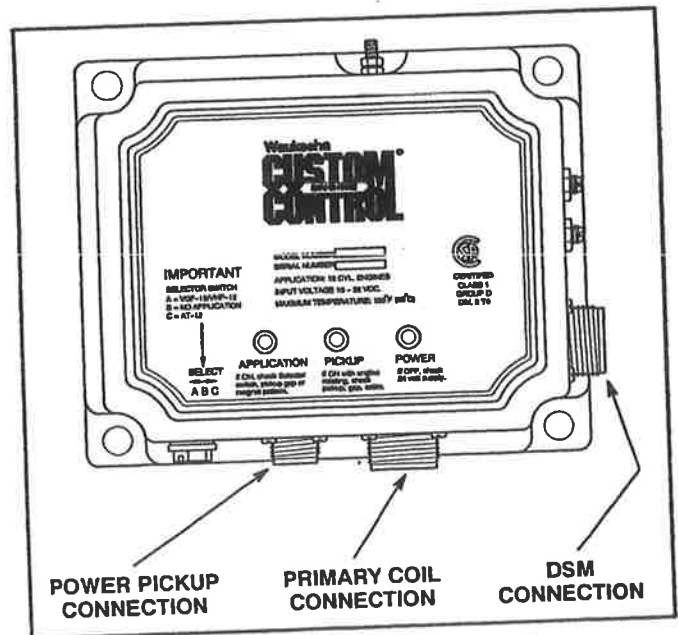


Figure 3.05-2. Ignition Module Wiring Harness Connections

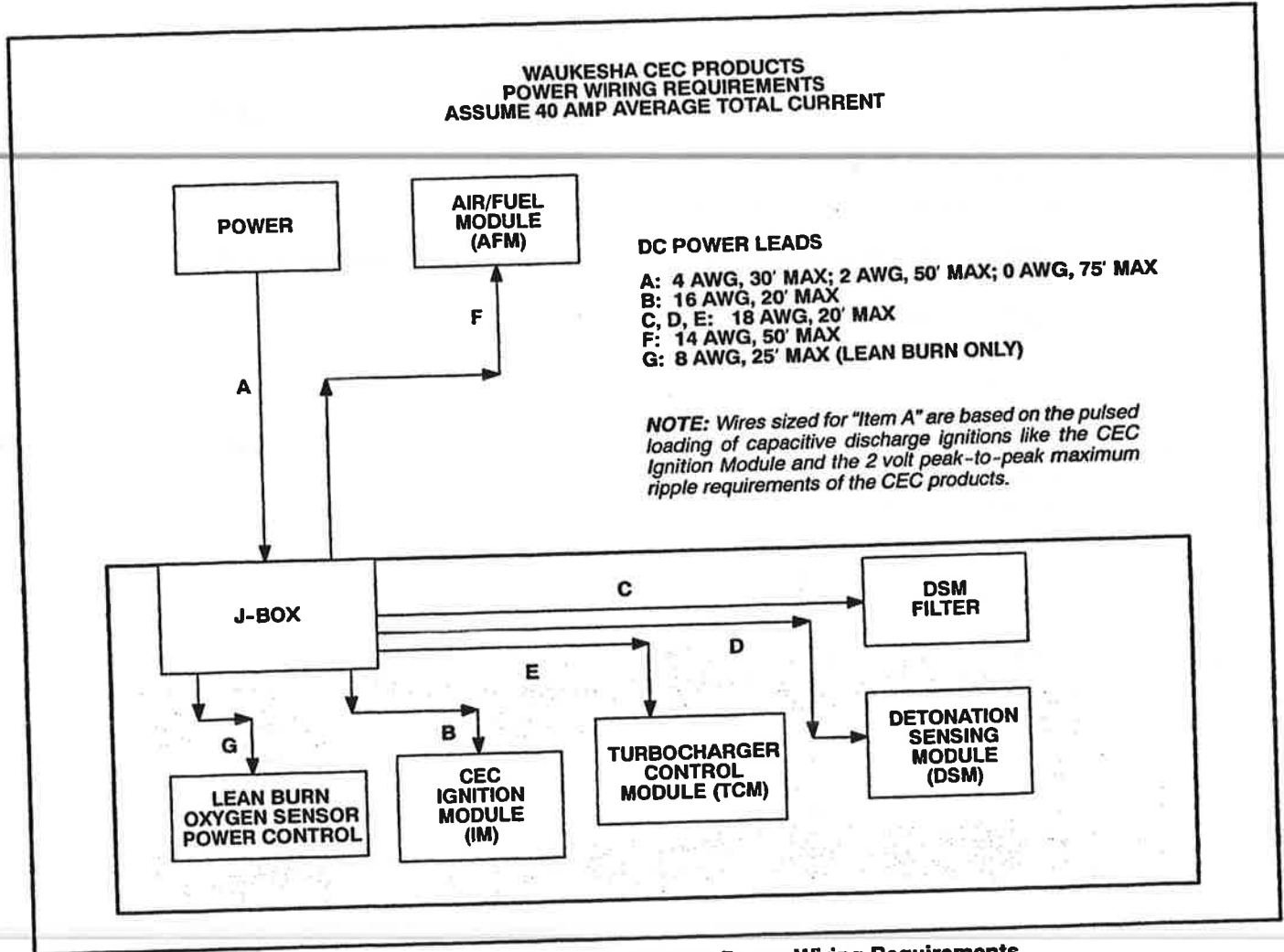


# ATGL IGNITION MODULE ELECTRICAL CONNECTIONS

**Table 3.05-1. Power Requirements For The Ignition Module**

CEC PRODUCT	NOMINAL VOLTAGE (volts DC)	TOLERANCE	OPERATING RANGE (volts DC)	PEAK-TO-PEAK RIPPLE (volts AC)	OPERATING CURRENT (amps)
Ignition Module	24	+33%, -58%	10.0 - 32.0*	less than 2*	2 (typical)

**NOTE:** \*For compatibility with other CEC products, a nominal supply of 24 VDC with less than a 2 volt peak-to-peak ripple is recommended to power the IM.



**Figure 3.05-3. Waukesha CEC Products Power Wiring Requirements**

# ATGL IGNITION MODULE ELECTRICAL CONNECTIONS

## COMPLETING IGNITION MODULE WIRING

Complete IM electrical connections by following the steps below. Refer to Figure 3.05-8 through Figure 3.05-10 for IM wiring diagrams. Table 3.05-2 lists the page numbers of the wiring diagrams for each AT wiring diagram.

**NOTE:** The wiring diagrams included in this manual are to be used as a reference only. Refer to the wiring diagrams received with the IM when making electrical connections.

Table 3.05-2. Page Locations Of AT Wiring Diagrams

WIRING DIAGRAM	PAGE NUMBER
Figure 3.05-8. 8L-AT27GL IM Wiring Diagram	3.05-9
Figure 3.05-9. 12V-AT27GL IM Wiring Diagram	3.05-10
Figure 3.05-10. 12V-AT25GL IM Wiring Diagram	3.05-11

## WARNING

Do not install, set up, maintain or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

1. Connect a ground lead from the engine crankcase to the ground stud on the IM.
2. Connect the Primary Coil Harness to the IM connector.
3. Route the specified leads of the Primary Coil Harness into the Ignition J-box.
4. Attach the leads of the Primary Coil Harness to the proper terminals inside the Ignition J-box. Install new spark plugs to achieve optimum ignition system performance.
5. Complete wiring connections to ignition coils from the Ignition J-box.
6. Route the harness(es) from the Hall-effect pickup(s) to the Main J-box (see Figure 3.05-5, Figure 3.05-6, and Figure 3.05-7). AT27GL engines have two Hall-effect pickups and harnesses.

## WARNING

Disconnect all electrical power supplies before making any power connections to the Ignition Module. Electrical shock can cause severe personal injury or death.

## CAUTION

Engines that use TWO Murphy fuel shutoff valves for emergency fuel shutdowns must use an additional capacitor in parallel with the existing adapter. The additional capacitor is required to supply sufficient voltage to close both Murphy fuel shutdowns during emergency shutdowns. Disregarding this information could result in product damage and/or personal injury.

## CAUTION

Do not bundle the Ignition Module wiring and Hall-effect pickup wiring together. Maintain a minimum separation of at least six inches. Disregarding this information could result in product damage and/or personal injury.

**NOTE:** All wiring and IM setup must be completed BEFORE the power supply is turned on.

7. Wire the IM power supply to the Main J-box. All wiring must be completed BEFORE the power supply is turned on.
  8. Connect the Power Pickup Harness from the Main J-Box to the 7 pin connector on the IM.
  9. Continue with Section 3.10, *ATGL Ignition Module Timing Adjustments*, to adjust engine timing.
- Before applying power to the IM and starting the engine, complete the "Prestart Checklist" in Section 3.10, *ATGL Ignition Module Timing Adjustments*.
- NOTE:** Refer to Custom Engine Control® Detonation Sensing Module (DSM) Installation, Operation, And Maintenance Manual (Form 6268), for information on completing wiring connections between the DSM system and the IM.

# ATGL IGNITION MODULE ELECTRICAL CONNECTIONS

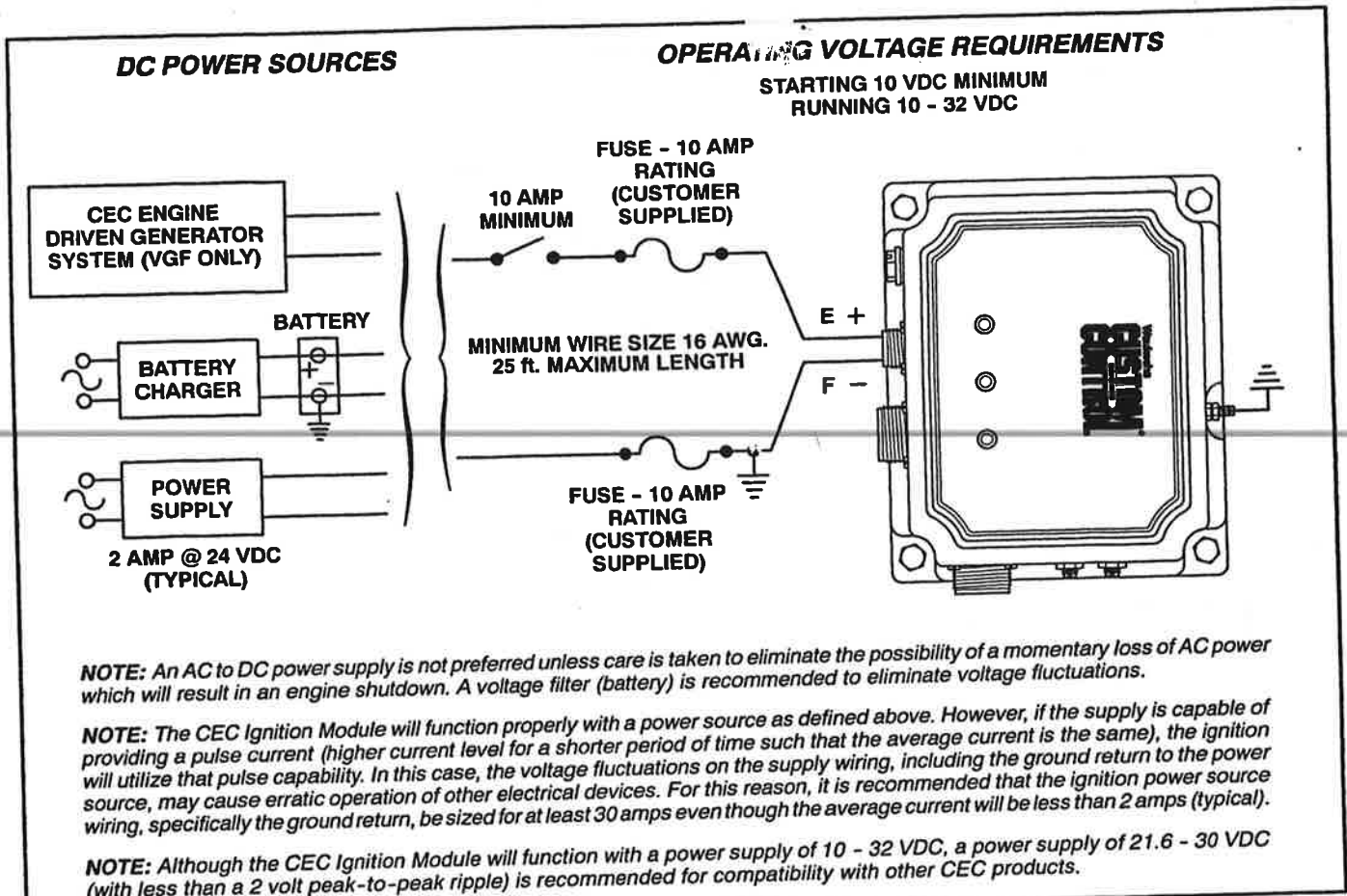


Figure 3.05-4. CEC Ignition Module Power Supply

# ATGL IGNITION MODULE ELECTRICAL CONNECTIONS

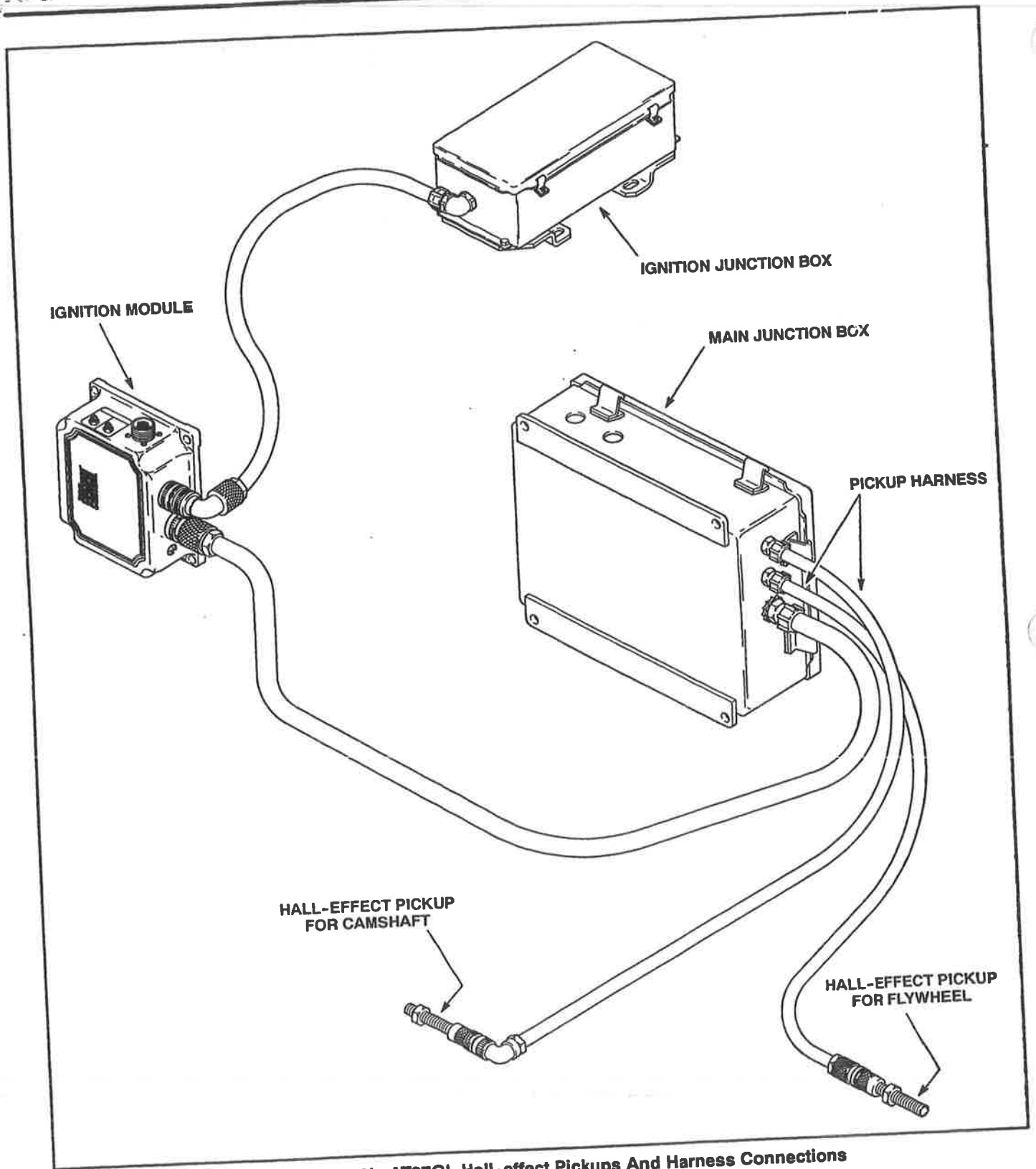


Figure 3.05-5. 8L-AT27GL Hall-effect Pickups And Harness Connections

# ATGL IGNITION MODULE ELECTRICAL CONNECTIONS

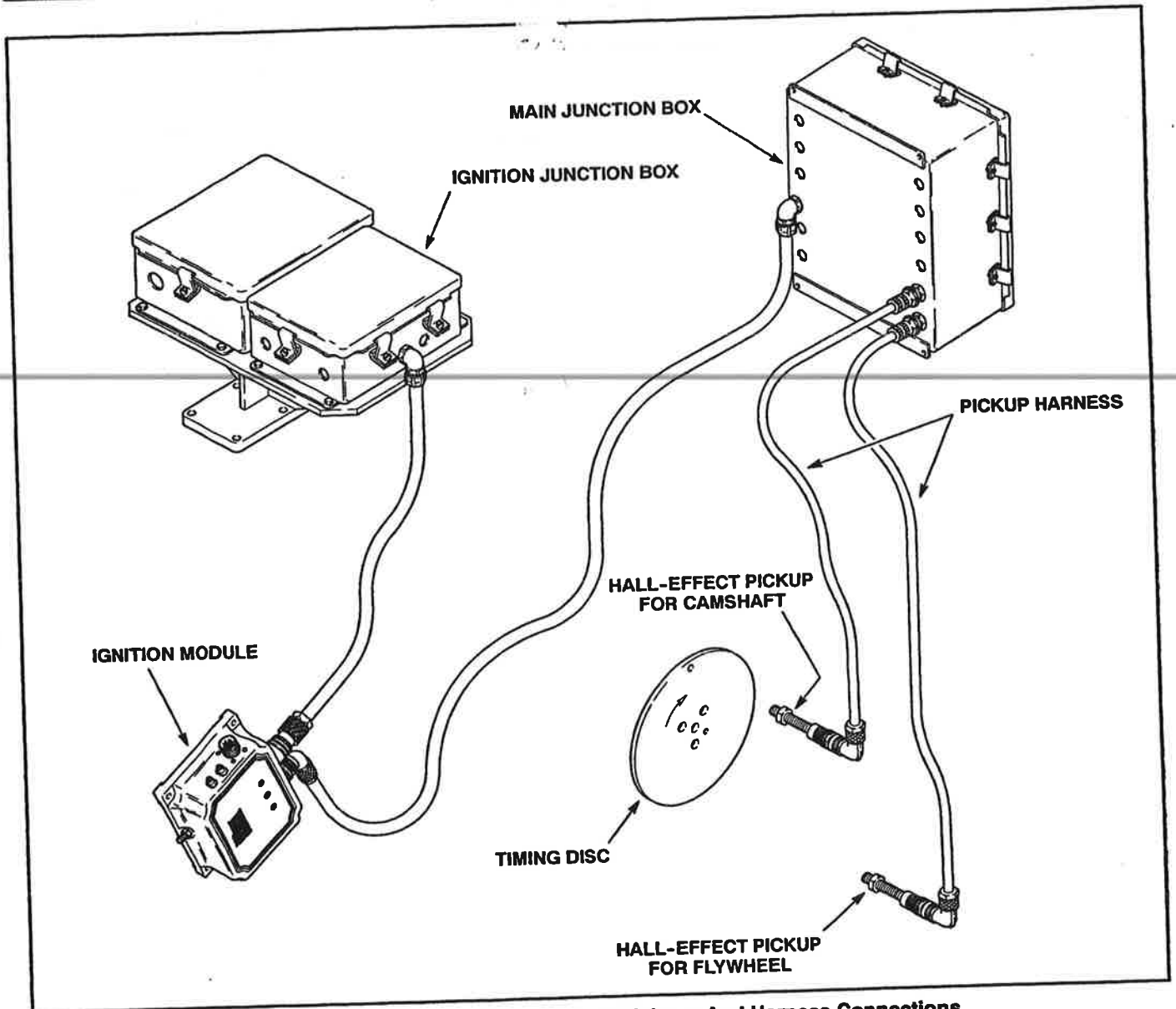


Figure 3.05-6. 12V-AT27GL Hall-effect Pickups And Harness Connections

# ATGL IGNITION MODULE ELECTRICAL CONNECTIONS

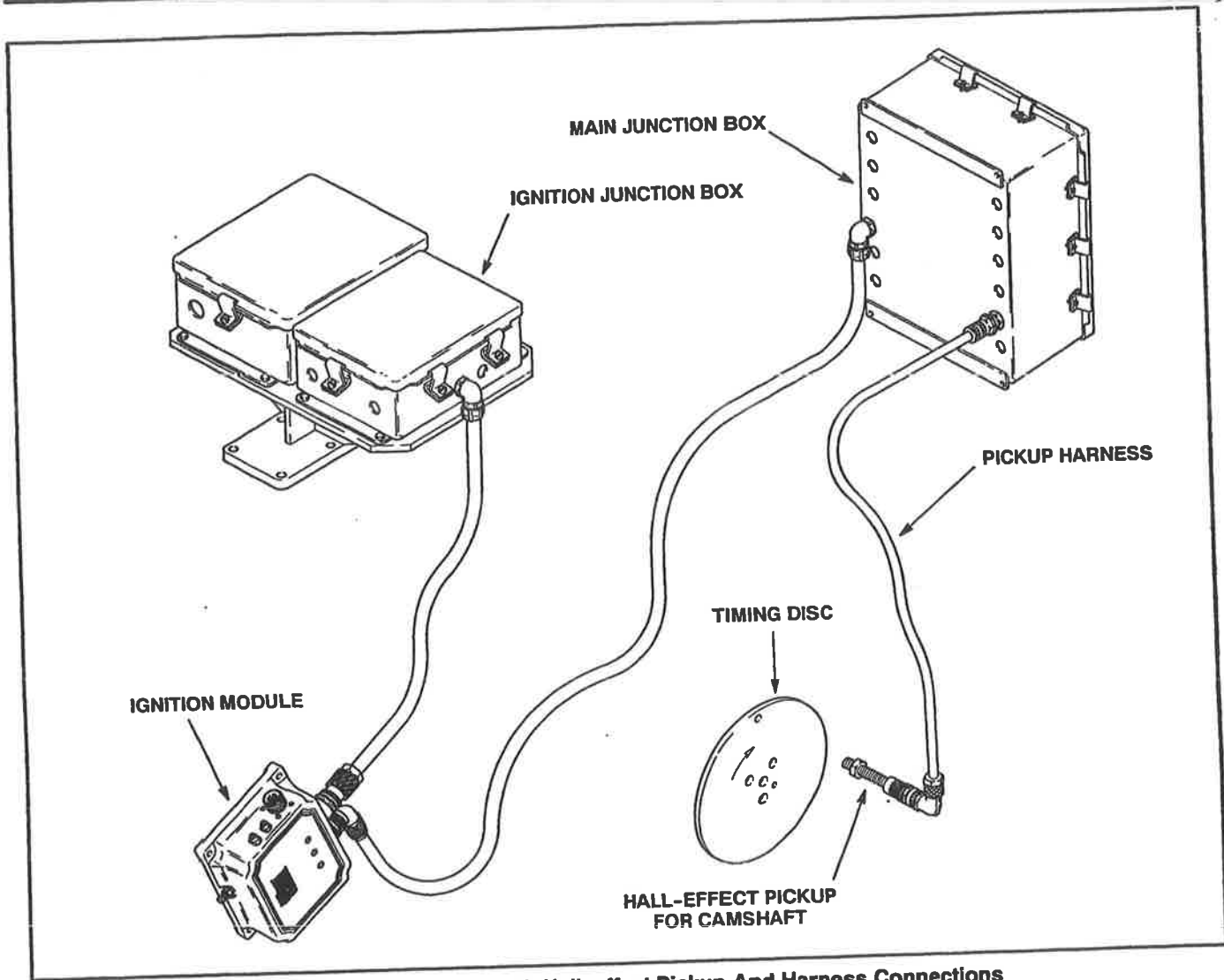
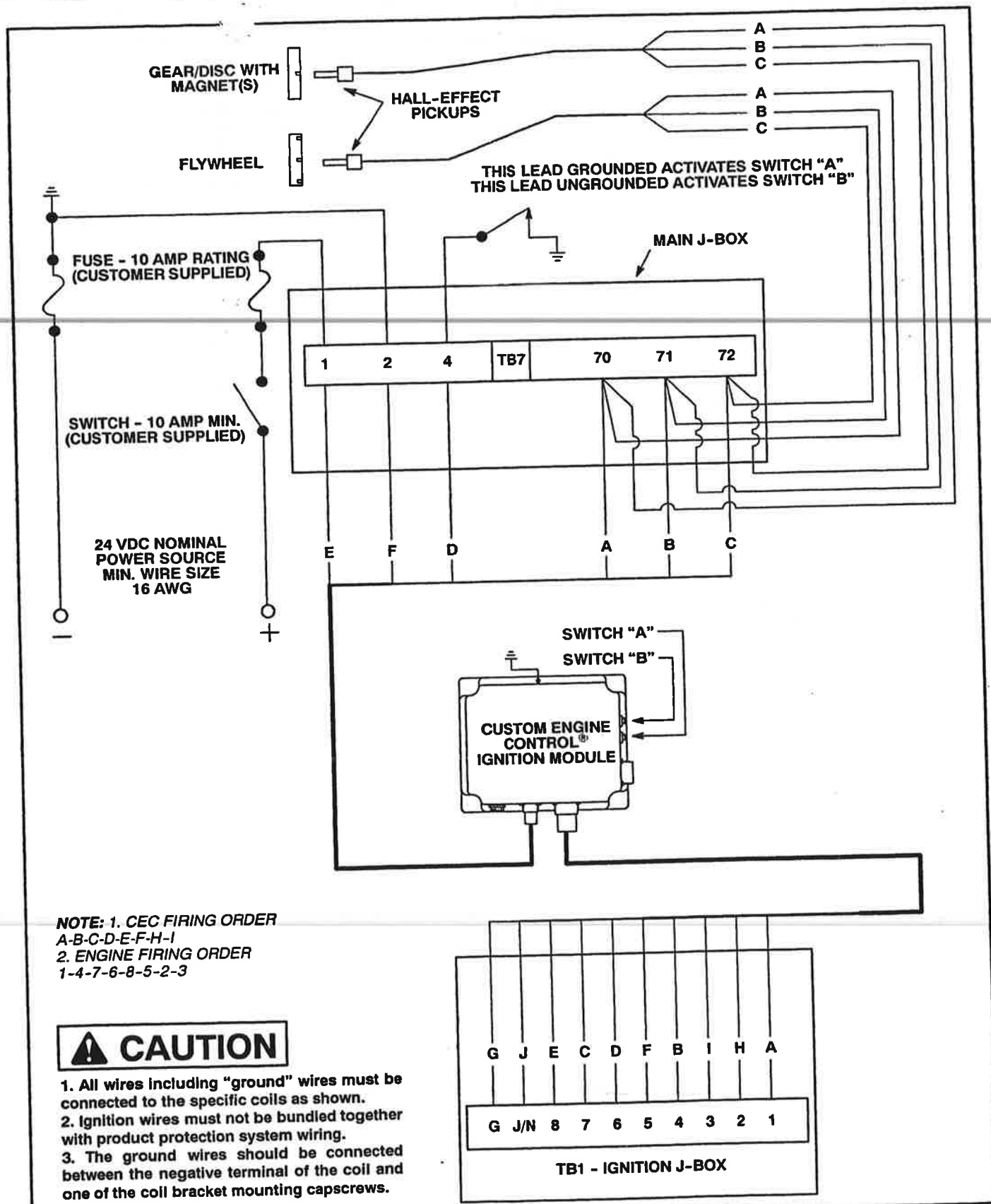


Figure 3.05-7. 12V-AT25GL Hall-effect Pickup And Harness Connections

# ATGL IGNITION MODULE ELECTRICAL CONNECTIONS



**NOTE:** 1. CEC FIRING ORDER  
A-B-C-D-E-F-H-I  
2. ENGINE FIRING ORDER  
1-4-7-6-8-5-2-3

## ⚠ CAUTION

1. All wires including "ground" wires must be connected to the specific coils as shown.
2. Ignition wires must not be bundled together with product protection system wiring.
3. The ground wires should be connected between the negative terminal of the coil and one of the coil bracket mounting capscrews.

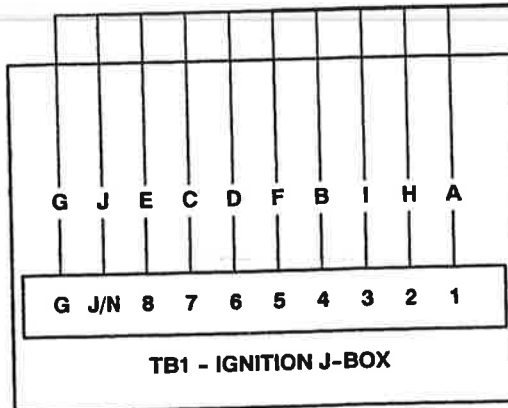
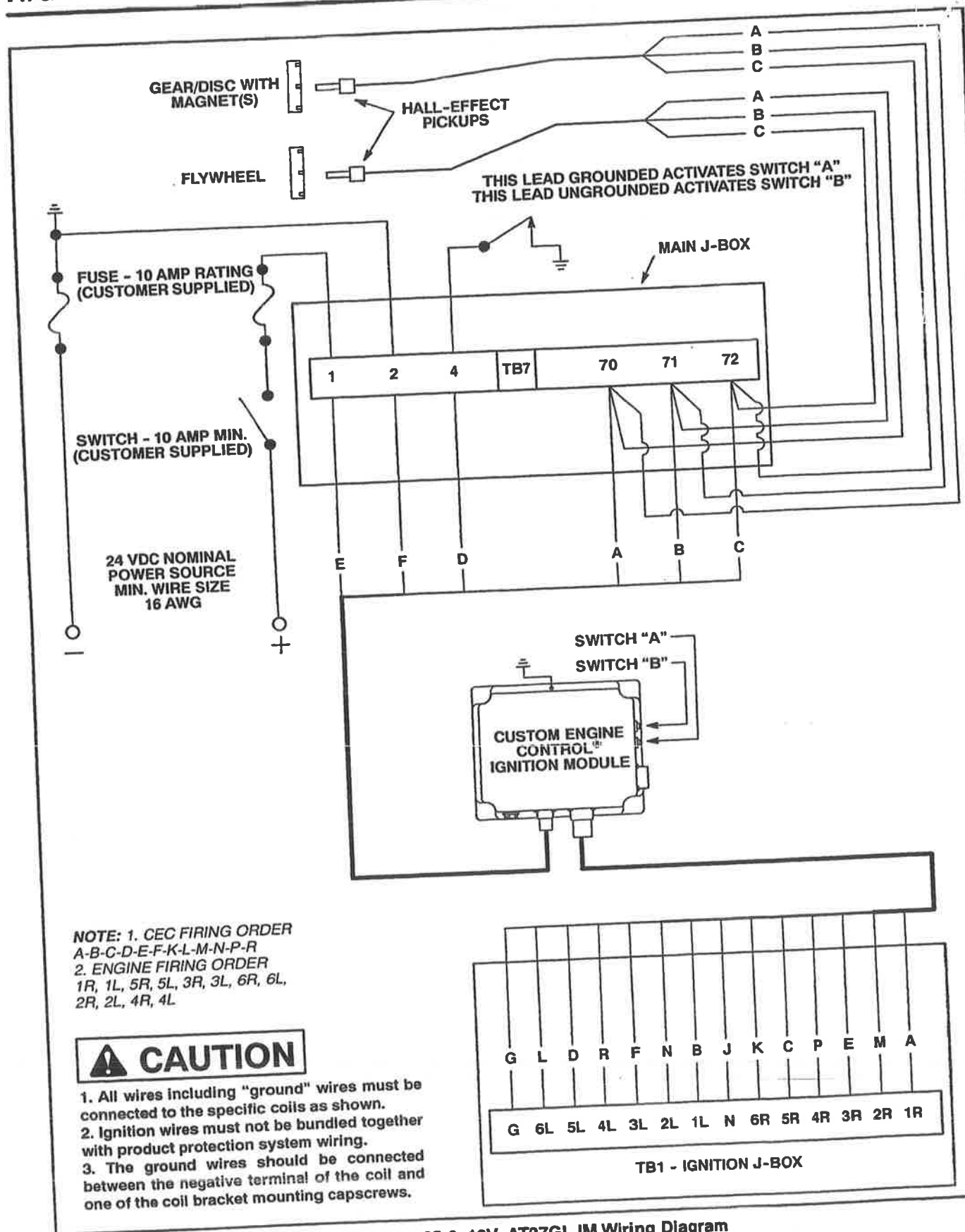


Figure 3.05-8. 8L-AT27GL IM Wiring Diagram

# ATGL IGNITION MODULE ELECTRICAL CONNECTIONS



**NOTE:** 1. CEC FIRING ORDER  
A-B-C-D-E-F-K-L-M-N-P-R  
2. ENGINE FIRING ORDER  
1R, 1L, 5R, 5L, 3R, 3L, 6R, 6L,  
2R, 2L, 4R, 4L

## CAUTION

1. All wires including "ground" wires must be connected to the specific coils as shown.
2. Ignition wires must not be bundled together with product protection system wiring.
3. The ground wires should be connected between the negative terminal of the coil and one of the coil bracket mounting capscrews.

Figure 3.05-9. 12V-AT27GL IM Wiring Diagram



# ATGL IGNITION MODULE ELECTRICAL CONNECTIONS

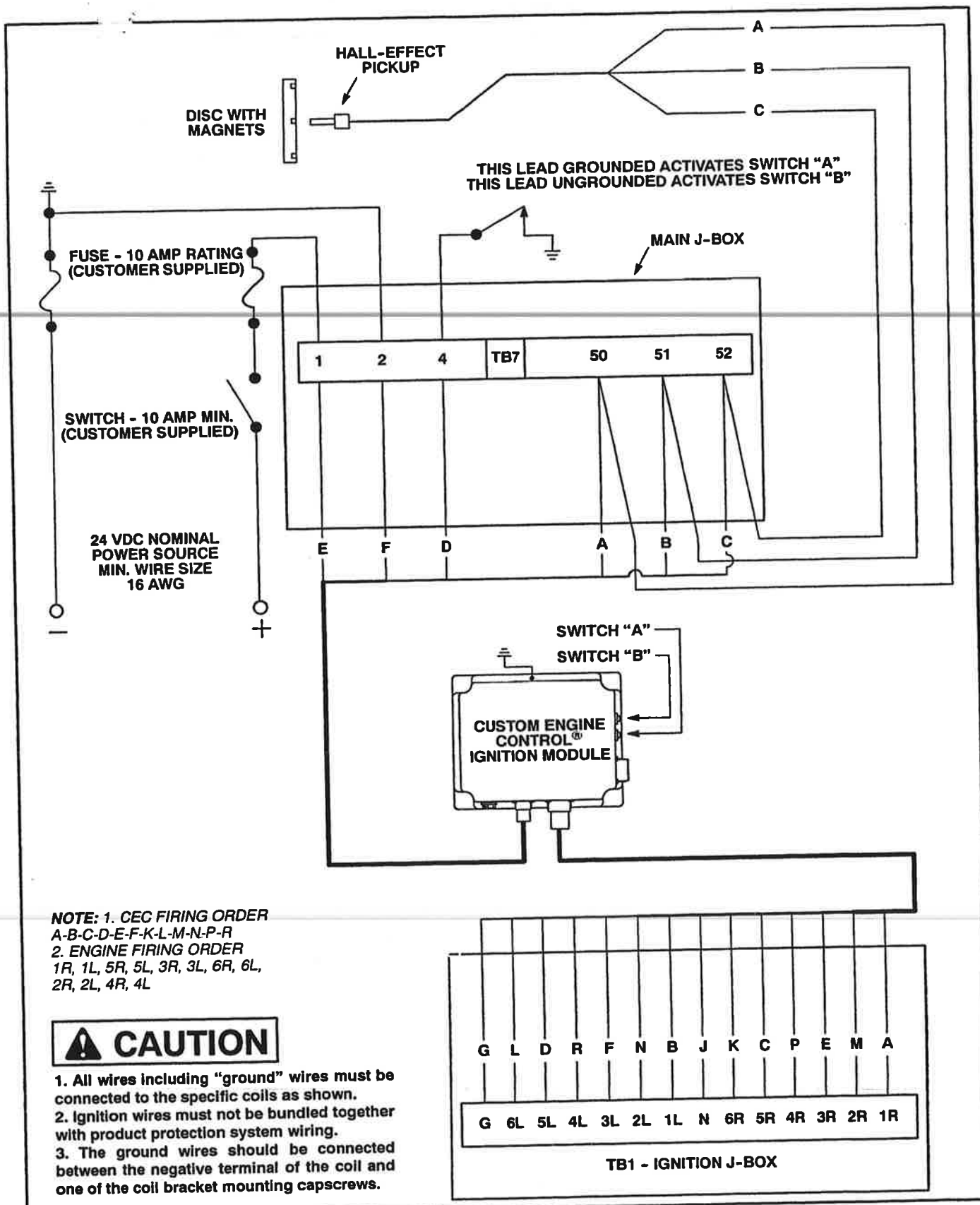


Figure 3.05-10. 12V-AT25GL IM Wiring Diagram

# ATGL IGNITION MODULE ELECTRICAL CONNECTIONS

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## SECTION 3.10

# ATGL IGNITION MODULE TIMING ADJUSTMENTS

### PRESTART CHECKLIST

Before applying power to the IM (engine not running):

- A. Visually inspect the installation to be sure that all wiring conforms to the requirements of this manual, local codes, and regulatory bodies.
- B. Verify all grounding requirements. Refer to Section 3.00, *ATGL Ignition Module Electrical Connections*, "Electrical Connections," for wiring diagrams.
- C. Leave the IM unpowered. Verify that the power supply is within specification. Refer to Section 3.00, *ATGL Ignition Module Electrical Connections*, "Electrical Connections," for power specifications.

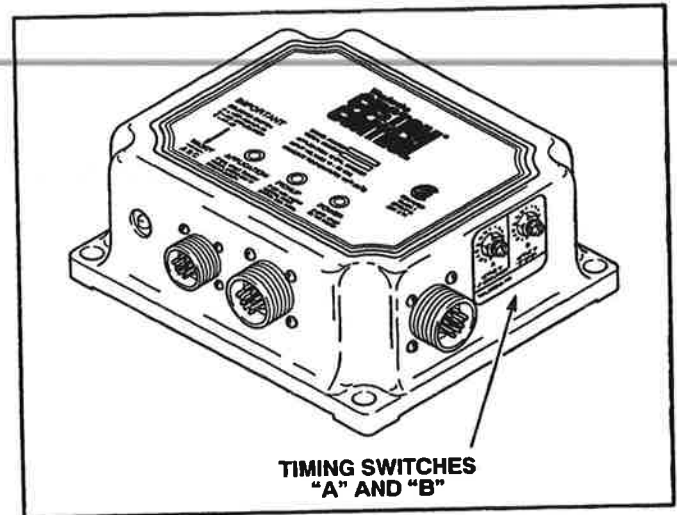


Figure 3.10-1. Ignition Module Timing Switches

### ATGL IGNITION TIMING SET

Timing is changed with two 16 position (0 - 15) timing switches located on the IM (see Figure 3.10-1). Each switch can be set to separate ignition timing settings for different applications. Timing switch position 15 gives the most advanced timing on the active timing switch, either switch "A" or "B." Switch "A" has a more advanced timing range than switch "B." Switch position 0 (zero) is full retard. The timing advances/retards 1.0 degree between each switch position. Grounding lead "D" in the Power Pickup Harness (7 pin connector) activates the timing selected by switch "A." Ungrounded lead "D" will activate the timing selected by switch "B."

For 8 and 12 cylinder ATGL engines, a 6 degree overlap between timing switch "A" and timing switch "B" gives the IM a combined timing range of 25 degrees.

For 16 cylinder ATGL engines, an 8 degree overlap between timing switch "A" and timing switch "B" gives the IM a combined timing range of 23 degrees.

Table 3.10-1 lists the IM firing order for 8L-ATGL engines. Table 3.10-2 lists the IM firing order for 12V-ATGL engines. Table 3.10-3 lists the IM firing order for 16V-ATGL engines.

Table 3.10-1. Firing Order For 8L-ATGL Cylinder Engines

PIN CONNECTORS*	A	B	C	D	E	F	H	I
CYLINDERS	1	4	7	6	8	5	2	3

Table 3.10-2. Firing Order For 12V-ATGL Cylinder Engines

PIN CONNECTORS*	A	B	C	D	E	F	K	L	M	N	P	R
CYLINDERS	1 R	1 L	5 R	5 L	3 R	3 L	6 R	6 L	2 R	2 L	4 R	4 L

NOTE: \* G=Shutdown - J=Ground

Table 3.10-3. Firing Order For VGF 16 Cylinder Engines

PIN CONNECTORS*	A	B	C	D	E	F	K	L
CYLINDERS	1R	1L	4R	4L	7R	7L	6R	6L
PIN CONNECTORS*	M	N	P	R	S	T	U	V
CYLINDERS	8R	8L	5R	5L	2R	2L	3R	3L

NOTE: \* G=Shutdown - J=Ground

# ATGL IGNITION MODULE TIMING ADJUSTMENTS

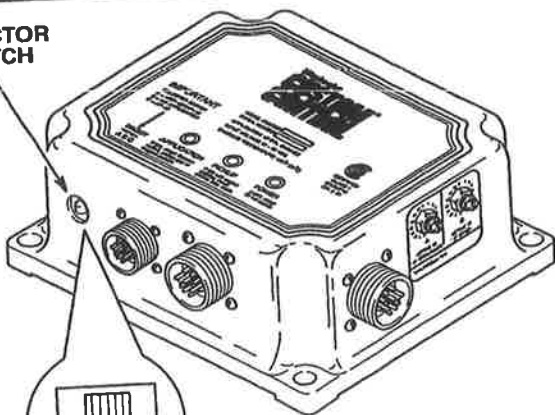
## STEPS REQUIRED TO ADJUST IGNITION MODULE TIMING

1. Complete the Prestart Checklist before running engine and adjusting timing.
2. Remove the cap from the Selector Switch access hole.
3. Set the appropriate timing application by adjusting the Selector Switch (see Table 3.10-4). The Selector Switch is a three position switch (A, B, and C). Use your finger or a screwdriver to switch to the proper application.
4. Replace the cover on the Selector Switch access hole.

Table 3.10-4. Ignition Module Selector Switch Settings

SELECTOR SWITCH SETTING	IGNITION MODULE MODELS		
	Model 811 for 6 & 8 Cylinder Engines	Model 1211 for All 12 Cylinder Engines	Model 1611 for All 16 Cylinder Engines
A	VHP/VGF 6 Cylinder Engines	VHP/VGF 12 Cylinder Engines	VHP/VGF 16 Cylinder Engines
B	No Application	No Application	No Application
C	ATGL/VGF 8 Cylinder Engines	ATGL 12 Cylinder Engines	ATGL 16 Cylinder Engines

SELECTOR SWITCH

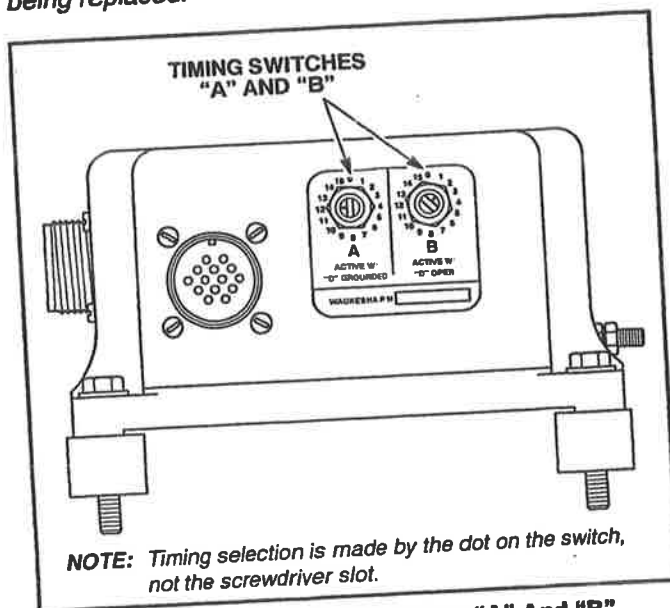


A B C

5. Remove the white caps from the timing switches "A" and "B" on the side of the IM (see Figure 3.10-2).

6. Using a screwdriver, set both timing switches on the side of the IM to 10. Timing selection is made by the dot on the switch, not the screwdriver slot.

**NOTE:** If the IM being adjusted is replacing another IM, set the timing switches to the same positions as the IM being replaced.



**NOTE:** Timing selection is made by the dot on the switch, not the screwdriver slot.

Figure 3.10-2. Timing Switches "A" And "B"

7. Check the engine's nameplate to determine the exact timing (or most advanced) of the primary and secondary (if equipped) fuels.

8. Apply power to IM. Refer to Section 3.05, ATGL Ignition Module Electrical Connections, "Electrical Connections," for power specifications.

## ⚠ WARNING

If a gas engine has been cranked excessively without starting, shut off the gas fuel supply and ignition, and then crank the engine to purge the cylinders and exhaust system of accumulated unburned gas. If this is not done a spark could ignite the gas and cause an exhaust explosion. Failure to comply could cause severe personal injury or death.

9. Start engine. Run engine at idle speed and with NO load.

10. Run the engine on primary fuel with the "D" lead (found in the 7 pin connector from the IM) **grounded** to the engine block and the CEC Detonation Sensing Module (DSM) deactivated (14 pin DSM harness disconnected from IM).

**NOTE:** The actual ignition timing will depend on the particular engine that the IM is installed. Actual timing may be off a few degrees; therefore, timing should be reset as required.

11. Check engine timing at the flywheel using a timing light.

**CAUTION** Do not switch from position 15 to 0, 0 to 15 or make other large timing changes quickly while the engine is running. The large timing change may cause engine damage or shutdown.

**NOTE:** Increasing the timing switch position by one will advance the timing one degree. Decreasing the timing switch position by one will retard the timing one degree.

12. Adjust the "A" timing switch as required to achieve correct timing (see Figure 3.10-2). Single fuel ignition adjustments are now complete. If you have a single fuel application, continue with Step 16. If you have a dual fuel application, continue with Step 13.

13. Run the engine on secondary fuel with the "D" lead (found in the 7 pin connector from IM) **open** and the CEC Detonation Sensing Module deactivated.

14. Check engine timing at the flywheel using a timing light.

**NOTE:** Increasing the timing switch position by one will advance the timing one degree. Decreasing the timing switch position by one will retard the timing one degree.

15. Adjust the "B" timing switch as required to achieve correct timing (see Figure 3.10-2). Dual fuel ignition adjustments are now complete.

**CAUTION** To prevent the timing from being altered, always replace the white caps over the timing switches once the desired setting has been selected. Disregarding this information could result in product damage and/or personal injury.

16. When timing adjustments are complete, replace the white caps on the timing switches "A" and "B."

17. If applicable, reconnect the DSM harness to the 14 pin connector on the IM. Activate the DSM. Refer to *Custom Engine Control® Detonation Sensing Module (DSM) Installation, Operation, And Maintenance Manual* (Form 6268) for programming information.

**CAUTION** It is the sole responsibility of the customer to ensure that all product protection devices effectively shut off both the ignition and gas simultaneously in the event of any malfunctions. Disregarding this information could result in product damage and/or personal injury.

18. Verify shutdown switches and load carrying ability.  
**DISCHARGING THE STORAGE CAPACITOR**

**WARNING**

If the ignition switch is left in the ON position when a Ignition Module is disconnected, then the spark plugs may fire when the ignition system harness is reconnected, and could cause severe personal injury or death.

Before connecting the ignition harness (to the coils) to the IM, discharge the storage capacitors to ground. Attach one end of a wire lead to the crankcase and then touch the other end to the harness connector pins on the IM, one at a time. A snap may be heard when a capacitor discharges.

**WARNING**

As a safety measure, ground all the pins. Some breakerless ignition systems have more than one storage capacitor. Severe personal injury or death could result.

# ATGI. IGNITION MODULE TIMING ADJUSTMENTS

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# **CHAPTER 4 - VGF IGNITION MODULE INSTALLATION AND OPERATION**

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## **CONTENTS**

**SECTION 4.00 - IGNITION MODULE OPERATION ON  
VGF ENGINES**

**SECTION 4.05 - VGF IGNITION MODULE  
ELECTRICAL CONNECTIONS**

**SECTION 4.10 - VGF IGNITION MODULE TIMING ADJUSTMENTS**

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## SECTION 4.00

# IGNITION MODULE OPERATION ON VGF ENGINES

### IGNITION MODULE OPERATION ON VGF ENGINES

The purpose of this section is to describe IM operation on VGF engines and describe the location of the Hall-effect pickup.

#### VGF 6 AND 8 CYLINDER ENGINES

The IM uses a Hall-effect pickup, a magnetic switching device, to read magnetic reference marks on a disc attached to the front of the cam gear. This method of timing determines the exact position of the crankshaft. The microcircuit-based, digital IM interprets the pickup's impulses to set the optimum ignition timing. The IM then directs a precisely timed voltage to the appropriate coil.

#### Location Of Hall-effect Pickup

The Hall-effect pickup is located on the front gear cover. The pickup senses each magnet as it passes and trips the logic circuit of the IM to fire (see Figure 4.00-1).

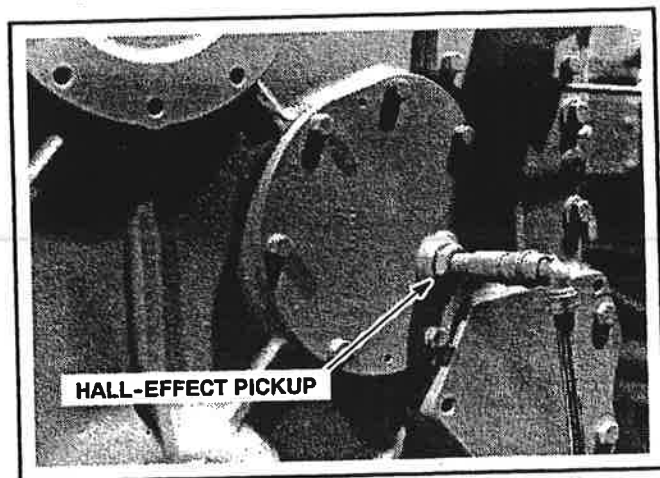


Figure 4.00-1. Hall-effect Pickup Location

#### Setting The Air Gap

To set the air gap specification, complete the following steps.

1. Install the Hall-effect pickup into the front gear cover.
2. Thread the Hall-effect pickup clockwise until the pickup touches the timing disc.
3. Scribe a reference mark on the Hall-effect pickup and at the same point mark the front gear cover.
4. Using the reference mark on the pickup as the starting point, rotate the Hall-effect pickup  $\frac{3}{4}$  of a turn ( $\pm \frac{1}{16}$  of a turn) counterclockwise to set the pickup to timing disc clearance.
5. After the clearance is set, snug the locking nut.

#### VGF 12 AND 16 CYLINDER ENGINES

The IM uses a Hall-effect pickup, a magnetic switching device, to read reference magnets installed in the left bank cam gear. This method of timing determines the exact position of the crankshaft. The microcircuit-based, digital IM interprets the pickup's impulses to set the optimum ignition timing. The IM then directs a precisely timed voltage to the appropriate coil.

## IGNITION MODULE OPERATION ON VGF ENGINES

### Location Of Hall-effect Pickup

The Hall-effect pickup is located on the front surface of the rear gear housing, above the barring device (see Figure 4.00-2). The pickup senses each magnet as it passes and trips the logic circuit of the IM to fire (see Figure 4.00-3).



Figure 4.00-2. Hall-effect Pickup

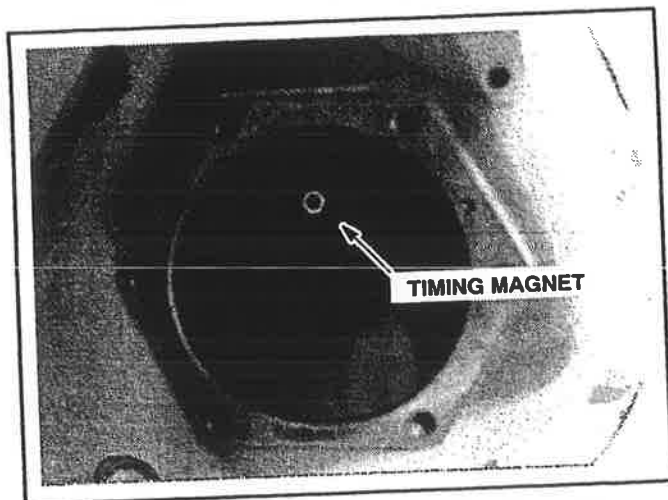


Figure 4.00-3. CEC Ignition Timing Magnets

### Setting The Air Gap

To set the air gap specification, complete the following steps.

1. Install the Hall-effect pickup into the rear gear housing.
2. Thread the Hall-effect pickup clockwise until the pickup touches the timing disc.
3. Scribe a reference mark on the Hall-effect pickup and at the same point mark the rear gear housing.
4. Using the reference mark on the pickup as the starting point, rotate the Hall-effect pickup  $3/4$  of a turn ( $\pm 1/16$  of a turn) counterclockwise to set the pickup to timing disc clearance.
5. After the clearance is set, snug the locking nut.

## SECTION 4.05

# VGF IGNITION MODULE ELECTRICAL CONNECTIONS

### MOUNTING THE IGNITION MODULE

Mount the IM using the vibration isolators supplied with the IM (see Figure 4.05-1). Note the following:

- The outside temperature of IM casing should not exceed 150° F (65° C) in operation.

**CAUTION** Do not weld on or around engine unless the Ignition Module has been unplugged. Failure to do so may damage the Ignition Module.

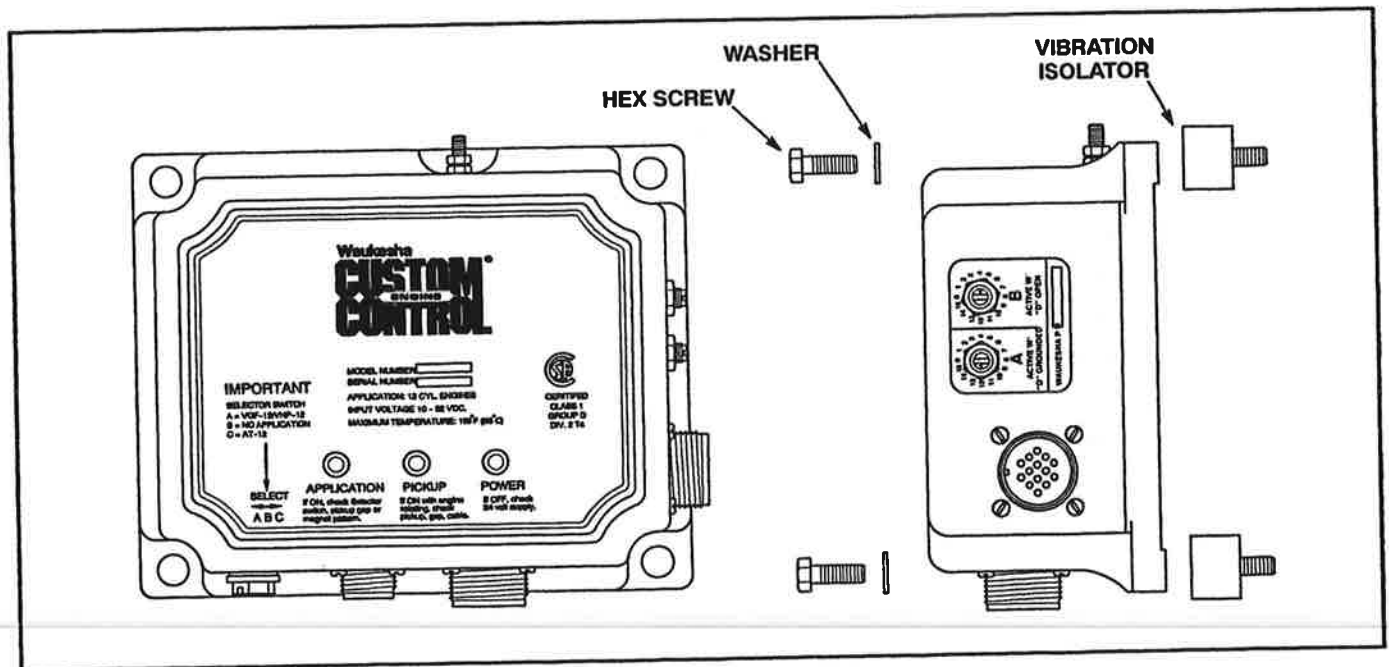


Figure 4.05-1. Mounting The Ignition Module - VGF Engines

# VGF IGNITION MODULE ELECTRICAL CONNECTIONS

## ELECTRICAL CONNECTIONS

### IGNITION MODULE POWER REQUIREMENTS

The power connections made for the IM must be in accordance with the applicable local electrical codes. The IM is suitable for installation in Canadian Standards Association (CSA) Class I, Group D, Division 2 locations. All power sizing must be in accordance with Figure 4.05-3, "Waukesha CEC Products Power Wiring Requirements."

See Table 4.05-1 for IM power requirements.

**NOTE:** An AC to DC power supply is not preferred unless care is taken to eliminate the possibility of a momentary loss of AC power which will result in an engine shutdown. A DC voltage filter (battery) is recommended to eliminate voltage fluctuations.

**NOTE:** For compatibility with other CEC products, a nominal supply of 24 VDC with less than a 2 volt peak-to-peak ripple is recommended to power the IM.

**NOTE:** Refer to Section 1.05, General Information, "Power Requirements for Custom Engine Control® Products," for the power requirements of all Waukesha Engine CEC products.

### POWER SOURCE WIRING SIZING AND GROUNDING

The IM, a capacitive discharge (CD) ignition system, requires an external power source which presents special wiring requirements. The IM will function properly with a power source as defined in Table 4.05-1. However, if the supply is capable of providing a pulse current (higher current level for a shorter period of time such that the average current is the same), the IM will utilize that pulse capability. In this case, the voltage fluctuations on the supply wiring, including the ground return to the power source, may interfere with the operation of other electrical devices. For this reason, it is recommended that the IM power source wiring, specifically the ground return, be sized for at least 30 amps even though the average current will be less than 2 amps (typical).

In addition, the grounding, particularly where the ground is "referenced," is critical. It is necessary to reference all of the grounds to the same point. The engine crankcase has been chosen as THE GROUND reference to minimize interference with sensor signals. By following the recommended wiring and grounding procedures, the concerns associated with the ignition power supply wiring voltage drops can be greatly reduced or eliminated.

**NOTE:** For additional information on capacitive discharge and grounding, see Section 1.05, General Information, "Capacitive Discharge And Grounding."

### WIRING HARNESS CONNECTIONS

The IM has three external wiring harness connectors (see Figure 4.05-2). The Power Pickup Harness connects to the 7 pin connector on the IM and includes leads for DC power, the Hall-effect pickup, and the "D" lead which determines which timing switch is used. The Primary Coil Harness connects to the IM and includes leads to the ignition coils. The 14 pin connector is used to interface with the CEC Detonation Sensing Module (DSM). The 14 pin connector is only used when the DSM is installed on the engine.

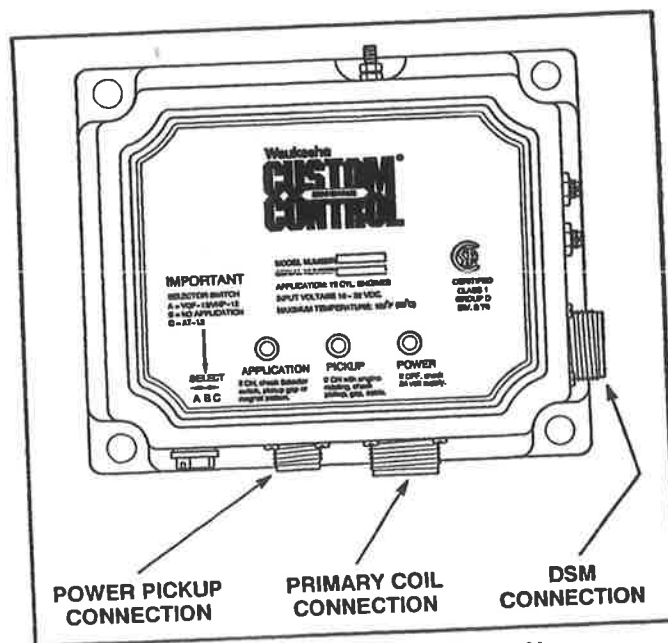


Figure 4.05-2. Ignition Module Wiring Harness Connections

# VGF IGNITION MODULE ELECTRICAL CONNECTIONS

Table 4.05-1. Power Requirements For The Ignition Module

CEC PRODUCT	NOMINAL VOLTAGE (volts DC)	TOLERANCE	OPERATING RANGE (volts DC)	PEAK-TO-PEAK RIPPLE (volts AC)	OPERATING CURRENT (amps)
Ignition Module	24	+33%, -58%	10.0 - 32.0*	less than 2*	2 (typical)

**NOTE:** \*For compatibility with other CEC products, a nominal supply of 24 VDC with less than a 2 volt peak-to-peak ripple is recommended to power the IM.

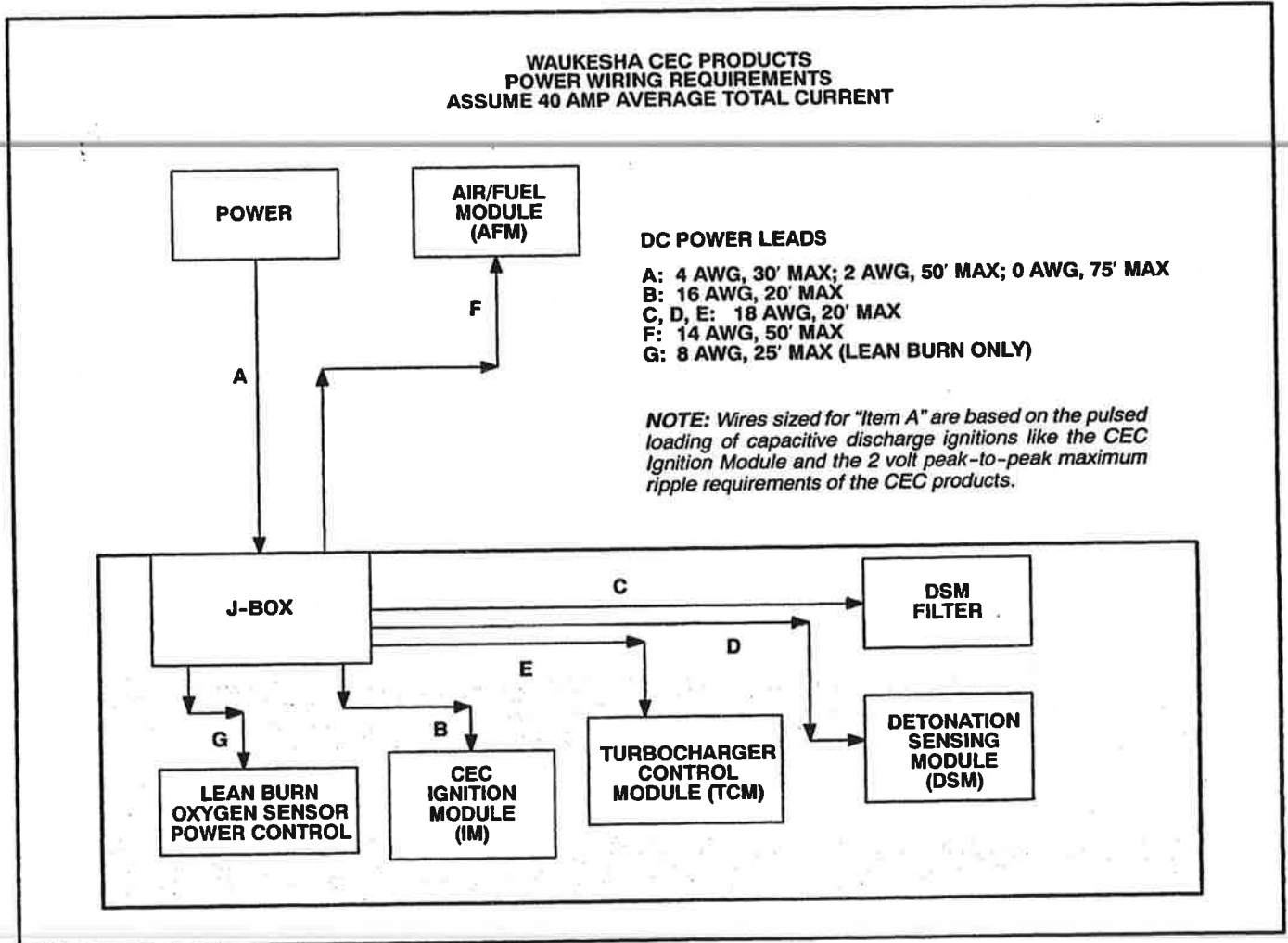


Figure 4.05-3. Waukesha CEC Products Power Wiring Requirements

# VGF IGNITION MODULE ELECTRICAL CONNECTIONS

## COMPLETING IGNITION MODULE WIRING

Complete IM electrical connections by following the steps below. Refer to Figure 4.05-5 through Figure 4.05-11 for IM wiring diagrams. Table 4.05-2 lists the page numbers of the wiring diagrams for each VGF wiring diagram.

**NOTE:** The wiring diagrams included in this manual are to be used as a reference only. Refer to the wiring diagrams received with the IM when making electrical connections.

Table 4.05-2. Page Locations Of VGF Wiring Diagrams

WIRING DIAGRAM	PAGE NUMBER
Figure 4.05-5. VGF 6 Cylinder (With Murphy Gas Valves - Retrofit Only) IM Wiring Diagram	4.05-6
Figure 4.05-6. VGF 6 Cylinder (Without Murphy Gas Valves - Retrofit Or Production) IM Wiring Diagram	4.05-7
Figure 4.05-7. VGF 8 Cylinder (With Murphy Gas Valves - Retrofit Only) IM Wiring Diagram	4.05-8
Figure 4.05-8. VGF 8 Cylinder (Without Murphy Gas Valves - Retrofit Or Production) IM Wiring Diagram	4.05-9
Figure 4.05-9. VGF 12 Cylinder (Without Murphy Gas Valves) IM Wiring Diagram	4.05-10
Figure 4.05-10. VGF 12 Cylinder IM Wiring Diagram	4.05-11
Figure 4.05-11. VGF 16 Cylinder IM Wiring Diagram	4.05-12

### WARNING

Do not install, set up, maintain or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

1. Connect a ground lead from the engine crankcase to the ground stud on the IM.
2. Connect the Primary Coil Harness to the IM connector.
3. Route the specified leads of the Primary Coil Harness to the ignition coils and cut to length (see applicable wiring diagram). Proper installation requires that the two end coils on 6 and 8 cylinder engines or the four corner coils on 12 and 16 cylinder engines are grounded to the engine. Install flashover protectors and new spark plugs to achieve optimum IM performance.

4. Connect the Power Pickup Harness to the Hall-effect pickup.

5. Connect the Power Pickup Harness from the Hall-effect pickup to the IM's 7 pin connector.

### WARNING

Disconnect all electrical power supplies before making any power connections to the Ignition Module. Electrical shock can cause severe personal injury or death.

### CAUTION

Engines that use TWO Murphy fuel shutoff valves for emergency fuel shutdowns must use an additional capacitor in parallel with the existing adapter. The additional capacitor is required to supply sufficient voltage to close both Murphy fuel shutdowns during emergency shutdowns. Disregarding this information could result in product damage and/or personal injury.

### CAUTION

Do not bundle the Ignition Module wiring and Hall-effect pickup wiring together. Maintain a minimum separation of at least six inches. Disregarding this information could result in product damage and/or personal injury.

**NOTE:** All wiring and IM setup must be completed BEFORE the power supply is turned on.

6. Connect the power lead from the Power Pickup Harness to the DC power supply (see applicable wiring diagram and Figure 4.05-4).

Before applying power to the IM and starting the engine, complete the "Prestart Checklist" in Section 4.10, VGF Ignition Module Timing Adjustments.

**NOTE:** Refer to Custom Engine Control® Detonation Sensing Module (DSM) Installation, Operation, And Maintenance Manual (Form 6268) for information on completing wiring connections between the DSM system and the IM.



# VGF IGNITION MODULE ELECTRICAL CONNECTIONS

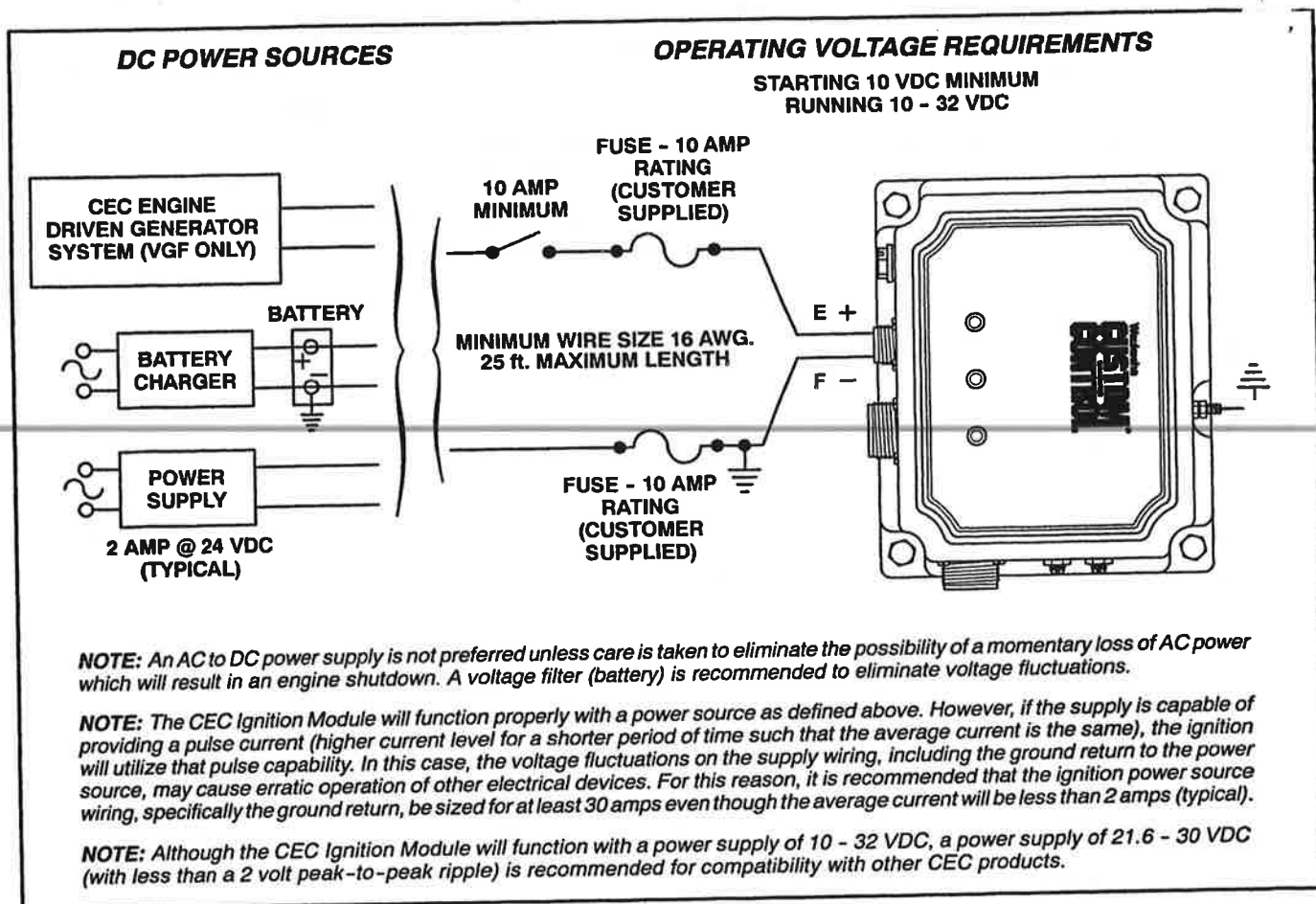


Figure 4.05-4. CEC Ignition Module Power Supply

# VGF IGNITION MODULE ELECTRICAL CONNECTIONS

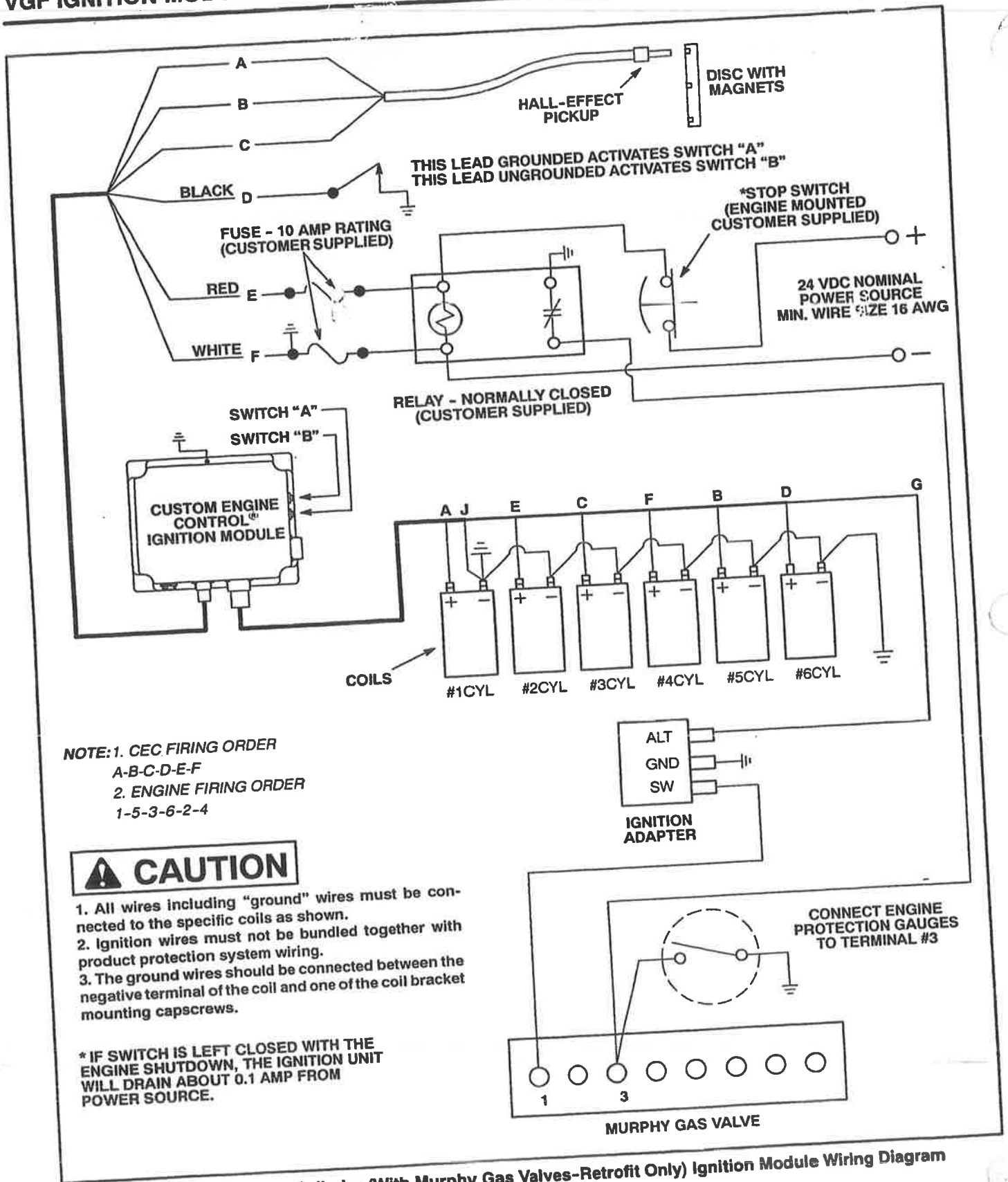


Figure 4.05-5. VGF 6 Cylinder (With Murphy Gas Valves-Retrofit Only) Ignition Module Wiring Diagram



# VGF IGNITION MODULE ELECTRICAL CONNECTIONS

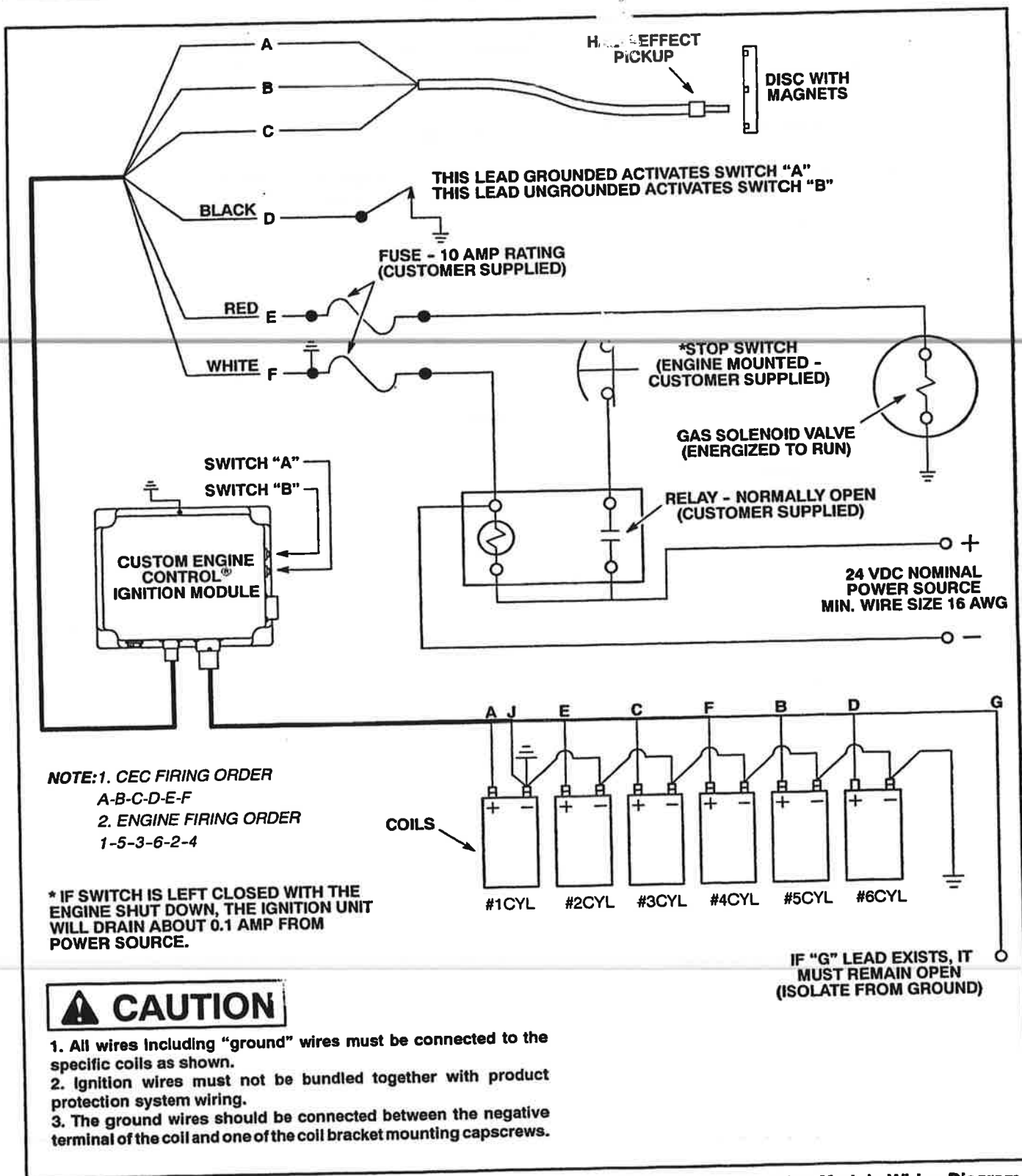


Figure 4.05-6. VGF 6 Cylinder (Without Murphy Gas Valves-Retrofit Or Production) Ignition Module Wiring Diagram

# VGF IGNITION MODULE ELECTRICAL CONNECTIONS

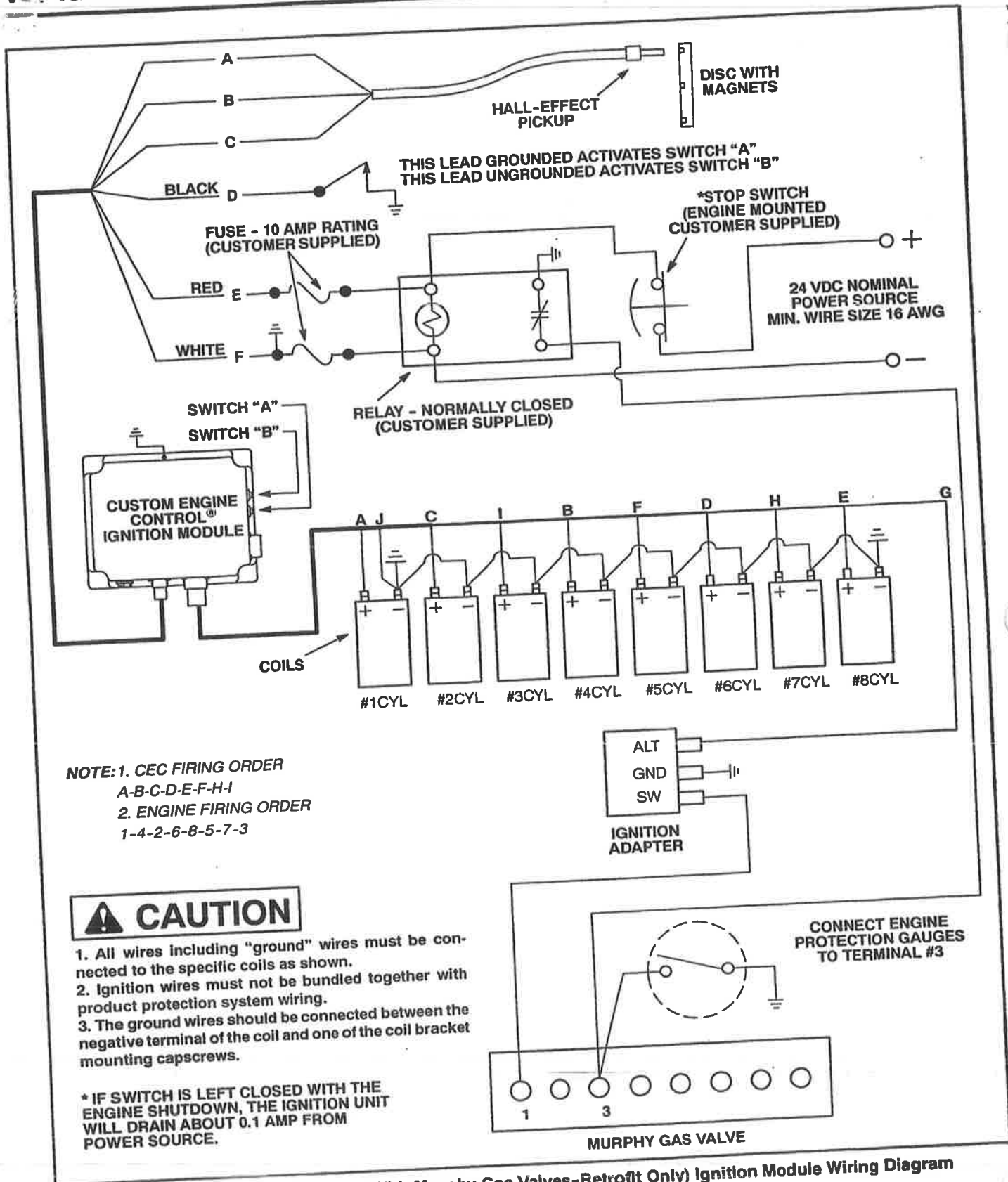


Figure 4.05-7. VGF 8 Cylinder (With Murphy Gas Valves-Retrofit Only) Ignition Module Wiring Diagram

# VGF IGNITION MODULE ELECTRICAL CONNECTIONS

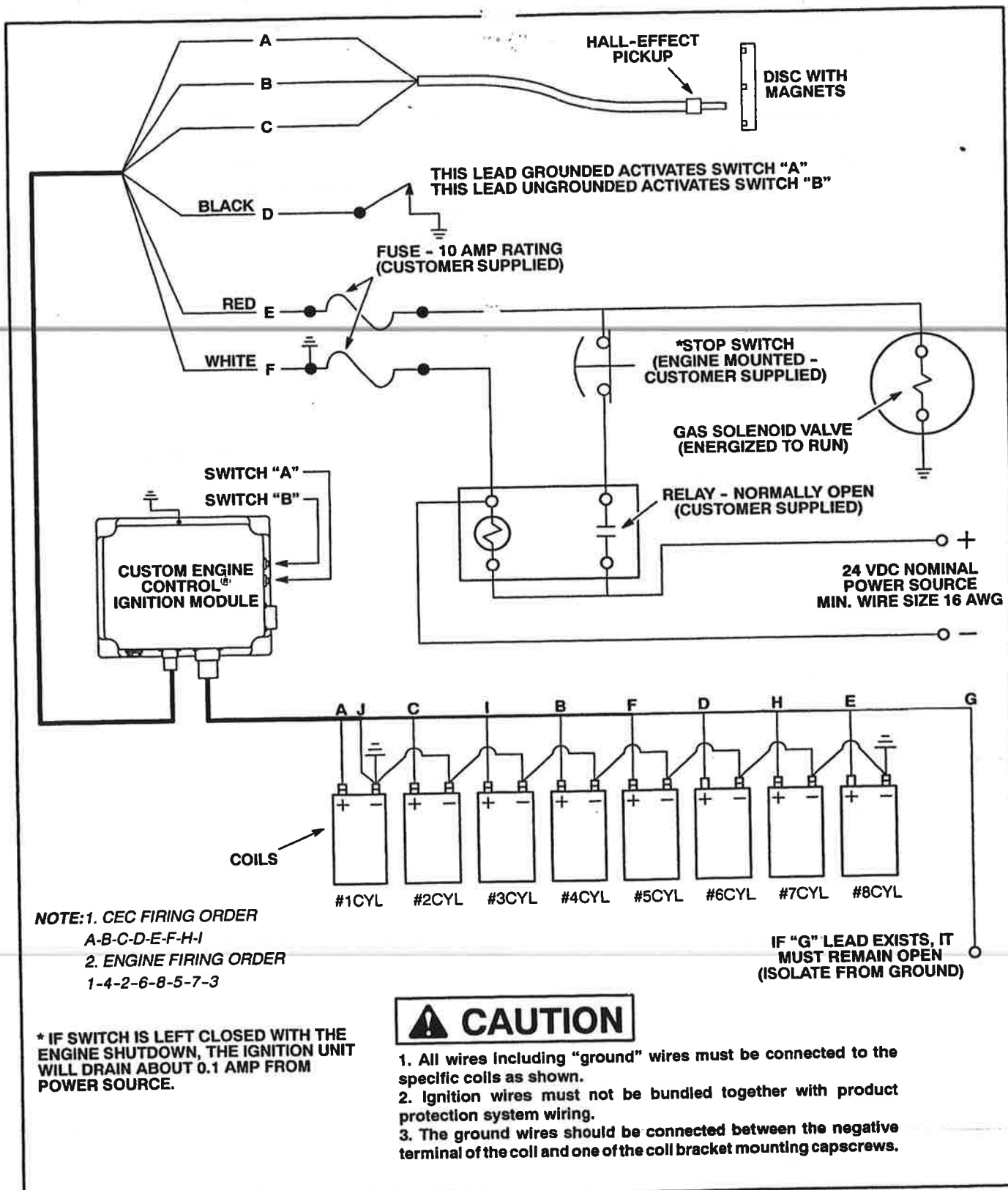


Figure 4.05-8. VGF 8 Cylinder (Without Murphy Gas Valves-Retrofit or Production) Ignition Module Wiring Diagram

# VGF IGNITION MODULE ELECTRICAL CONNECTIONS

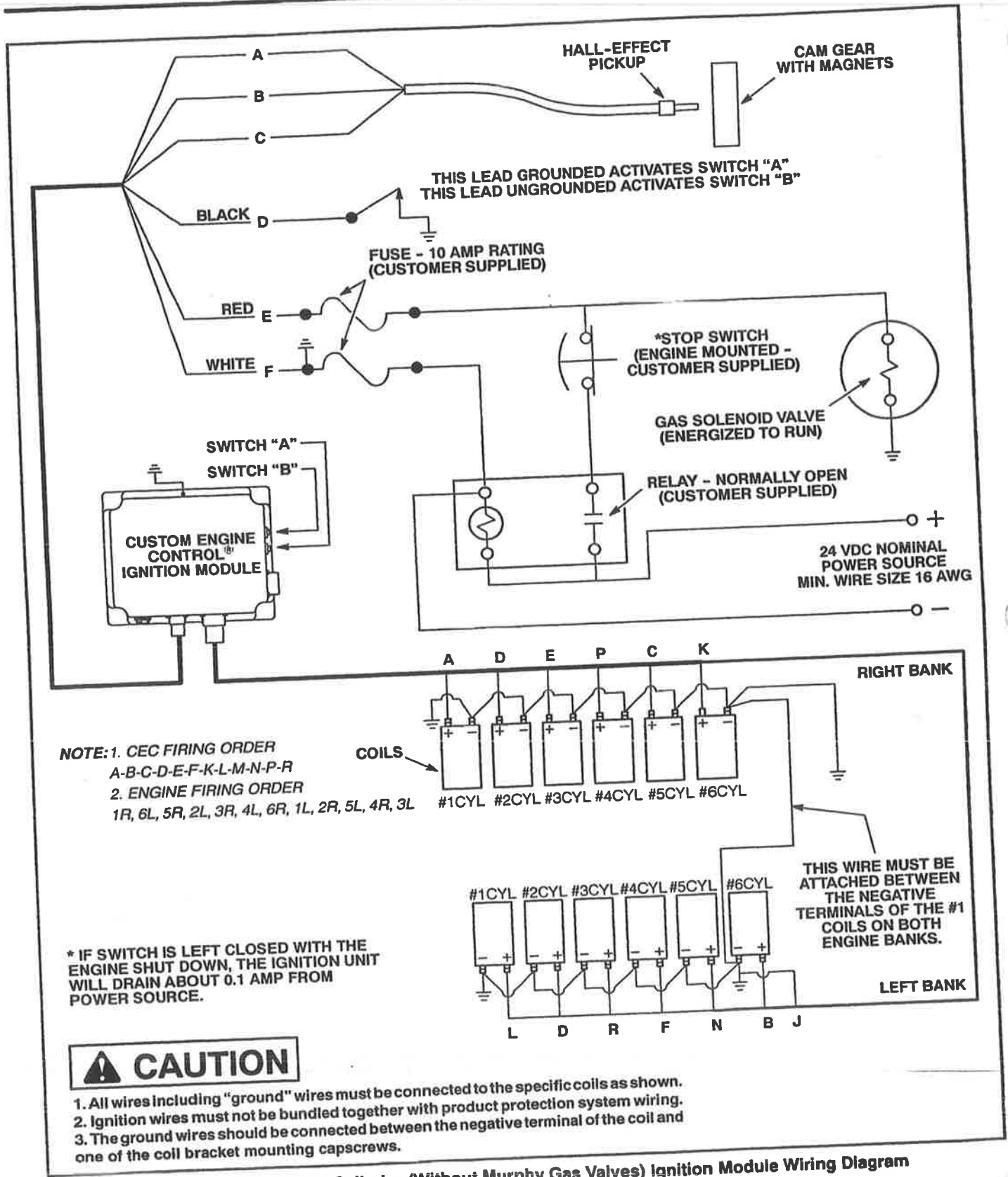


Figure 4.05-9. VGF 12 Cylinder (Without Murphy Gas Valves) Ignition Module Wiring Diagram

# VGF IGNITION MODULE ELECTRICAL CONNECTIONS

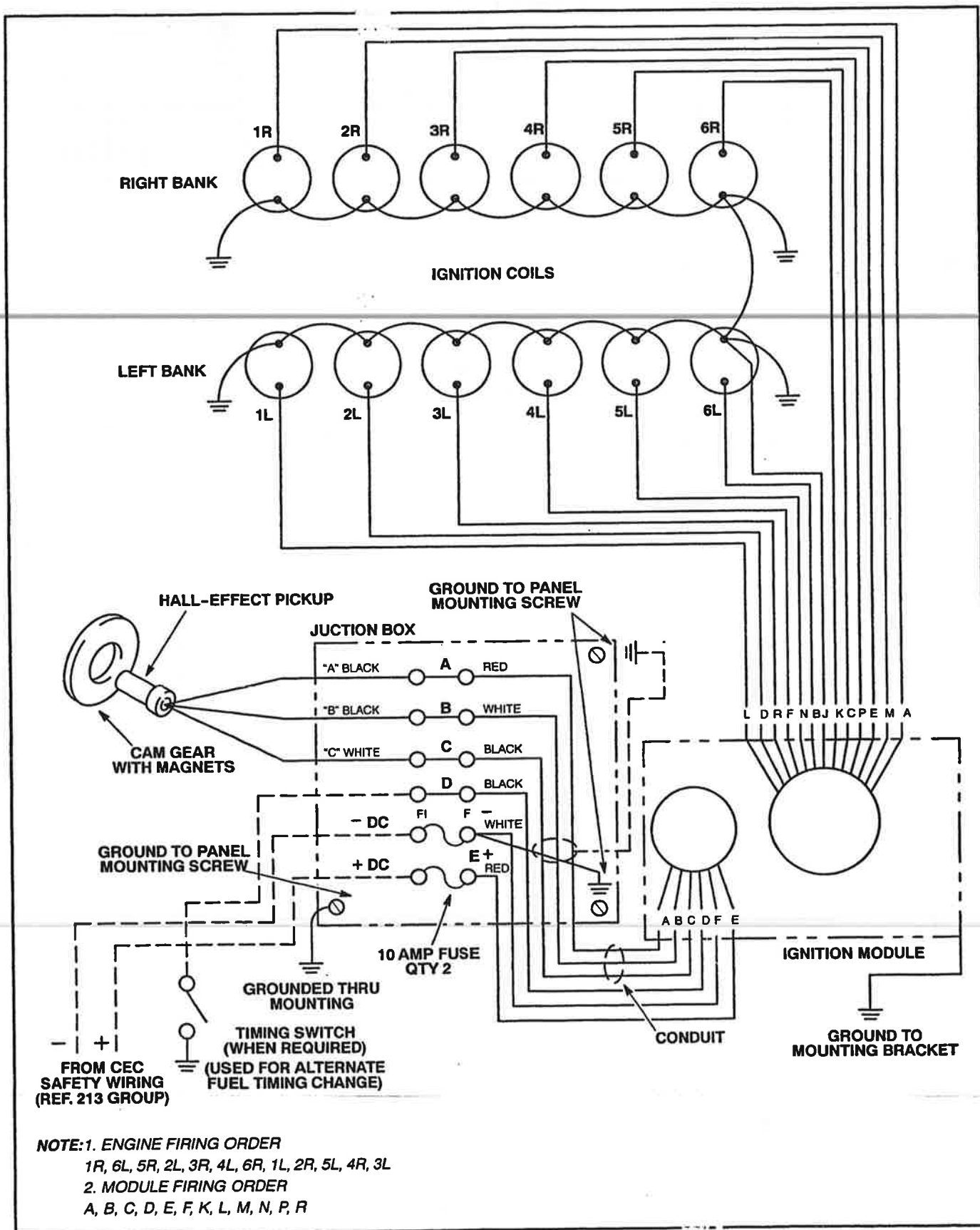


Figure 4.05-10. VGF 12 Cylinder Ignition Module Wiring Diagram



## SECTION 4.10

### VGF IGNITION MODULE TIMING ADJUSTMENTS

#### PRESTART CHECKLIST

Before applying power to the IM (engine not running):

- A. Visually inspect the installation to be sure that all wiring conforms to the requirements of this manual, local codes, and regulatory bodies.
- B. Verify all grounding requirements. Refer to Section 4.00, *VGF Ignition Module Electrical Connections*, "Electrical Connections," for wiring diagrams.
- C. Leave the IM unpowered. Verify that the power supply is within specification. Refer to Section 4.00, *VGF Ignition Module Electrical Connections*, "Electrical Connections," for power specifications.

#### VGF IGNITION TIMING SET

Timing is changed with two 16 position (0 - 15) timing switches located on the IM (see Figure 4.10-1). Each switch can be set to separate ignition timing settings for different applications. Timing switch position 15 gives the most advanced timing on the active timing switch, either switch "A" or "B." Switch "A" has a more advanced timing range than switch "B." Switch position 0 (zero) is full retard. The timing advances/retards 1.0 degree between each switch position. Grounding lead "D" in the Power Pickup Harness (7 pin connector) activates the timing selected by switch "A." Ungrounded lead "D" will activate the timing selected by switch "B."

For 6, 8, and 12 cylinder engines, a 6 degree overlap between timing switch "A" and timing switch "B" gives the IM a combined timing range of 25 degrees.

For 16 cylinder engines, a 7 degree overlap between timing switch "A" and timing switch "B" gives the IM a combined timing range of 24 degrees.

Table 4.10-1 lists the IM firing order for 6 cylinder VGF engines. Table 4.10-2 lists the IM firing order for 8 cylinder VGF engines. Table 4.10-3 lists the IM firing order for 12 cylinder VGF engines. Table 4.10-4 lists the IM firing for 16 cylinder VGF engines.

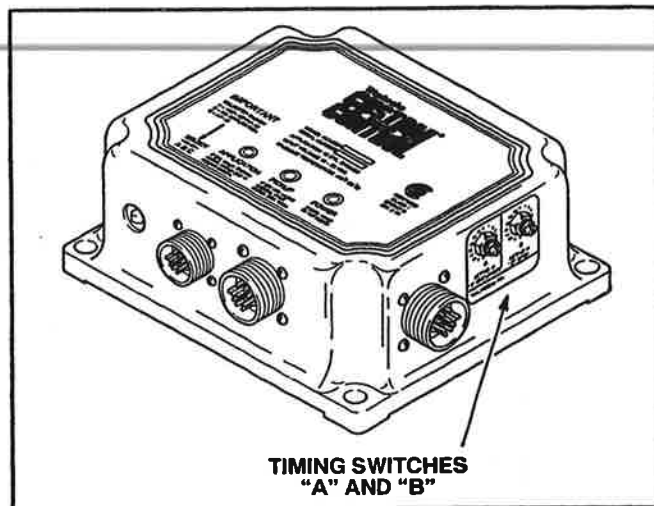


Figure 4.10-1. Ignition Module Timing Switches

Table 4.10-1. Firing Order For VGF 6 Cylinder Engines

PIN CONNECTORS*	A	B	C	D	E	F
CYLINDERS	1	5	3	6	2	4

Table 4.10-2. Firing Order For VGF 8 Cylinder Engines

PIN CONNECTORS*	A	B	C	D	E	F	H	I
CYLINDERS	1	4	2	6	8	5	7	3

NOTE: \* G=Shutdown

Table 4.10-3. Firing Order For VGF 12 Cylinder Engines

PIN CONNECTORS*	A	B	C	D	E	F	K	L	M	N	P	R
CYLINDERS	1 R	6 L	5 R	2 L	3 R	4 L	6 R	1 L	2 R	5 L	4 R	3 L

NOTE: \* G=Shutdown - J=Ground

Table 4.10-4. Firing Order For VGF 16 Cylinder Engines

PIN CONNECTORS*	A	B	C	D	E	F	K	L
CYLINDERS	1R	1L	4R	4L	2R	2L	6R	6L
PIN CONNECTORS*	M	N	P	R	S	T	U	V
CYLINDERS	8R	8L	5R	5L	7R	7L	3R	3L

NOTE: \* G=Shutdown - J=Ground



# VGF IGNITION MODULE TIMING ADJUSTMENTS

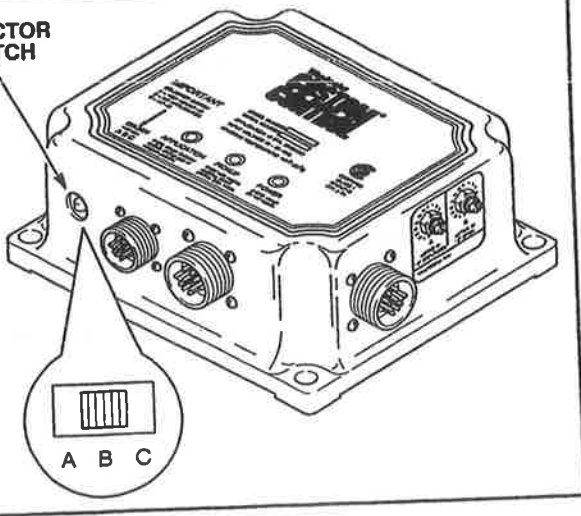
## STEPS REQUIRED TO ADJUST IGNITION MODULE TIMING

1. Complete the Prestart Checklist before running engine and adjusting timing.
2. Remove the cap from the Selector Switch access hole.
3. Set the appropriate timing application by adjusting the Selector Switch (see Table 4.10-5). The Selector Switch is a three position switch (A, B, and C). Use your finger or a screwdriver to switch to the proper application.
4. Replace the cover on the Selector Switch access hole.

Table 4.10-5. Ignition Module Selector Switch Settings

SELECTOR SWITCH SETTING	IGNITION MODULE MODELS		
	Model 811 for 6 & 8 Cylinder Engines	Model 1211 for All 12 Cylinder Engines	Model 1611 for All 16 Cylinder Engines
A	VHP/VGF 6 Cylinder Engines	VHP/VGF 12 Cylinder Engines	VHP/VGF 16 Cylinder Engines
B	No Application	No Application	No Application
C	ATGL/VGF 8 Cylinder Engines	AT 12 Cylinder Engines	AT 16 Cylinder Engines

SELECTOR SWITCH



5. Remove the white caps from the timing switches "A" and "B" on the side of the IM (see Figure 4.10-2).
6. Using a screwdriver, set both timing switches on the side of the IM to 10. Timing selection is made by the dot on the switch, not the screwdriver slot.

**NOTE:** If the IM being adjusted is replacing another IM, set the timing switches to the same positions as the IM being replaced.

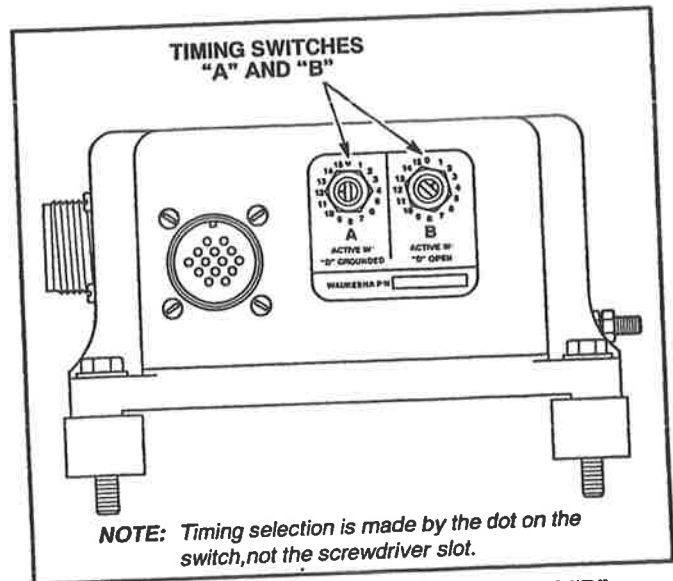


Figure 4.10-2. Timing Switches "A" And "B"

7. Check the engine's nameplate to determine the exact timing (or most advanced) of the primary and secondary (if equipped) fuels.
8. Apply power to IM. Refer to Section 2.05, VGF Ignition Module Electrical Connections, "Electrical Connections," for power specifications.

### ⚠ WARNING

If a gas engine has been cranked excessively without starting, shut off the gas fuel supply and ignition, and then crank the engine to purge the cylinders and exhaust system of accumulated unburned gas. If this is not done a spark could ignite the gas and cause an exhaust explosion. Failure to comply could cause severe personal injury or death.

9. Start engine. Run engine at idle speed and with NO load.



1. Run the engine on primary fuel with the "D" lead (found in the 7 pin connector from the IM) **grounded** to the engine block and the CEC Detonation Sensing Module (DSM) deactivated (14 pin DSM harness disconnected from IM).

11. Check engine timing at the flywheel using a timing light.

**CAUTION** Do not switch from position 15 to 0, 0 to 15 or make other large timing changes quickly while the engine is running. The large timing change may cause engine damage or shutdown.

*NOTE: Increasing the timing switch position by one will advance the timing one degree. Decreasing the timing switch position by one will retard the timing one degree.*

12. Adjust the "A" timing switch as required to achieve correct timing (see Figure 4.10-2). Single fuel ignition adjustments are now complete. If you have a single fuel application, continue with Step 16. If you have a dual fuel application, continue with Step 13.

13. Run the engine on secondary fuel with the "D" lead (found in the 7 pin connector from IM) **open** and the CEC Detonation Sensing Module deactivated (14 pin DSM harness disconnected from IM).

14. Check engine timing at the flywheel using a timing light.

*NOTE: Increasing the timing switch position by one will advance the timing one degree. Decreasing the timing switch position by one will retard the timing one degree.*

15. Adjust the "B" timing switch as required to achieve correct timing (see Figure 4.10-2). Dual fuel ignition adjustments are now complete.

**CAUTION** To prevent the timing from being altered, always replace the white caps over the timing switches once the desired setting has been selected. Disregarding this information could result in product damage and/or personal injury.

16. When timing adjustments are complete, replace the white caps on the timing switches "A" and "B."

17. If applicable, reconnect the DSM harness to the 14 pin connector on the IM. Activate the DSM. Refer to *Custom Engine Control® Detonation Sensing Module (DSM) Installation, Operation, And Maintenance Manual* (Form 6268) for programming information.

**CAUTION** It is the sole responsibility of the customer to ensure that all product protection devices effectively shut off both the Ignition and gas simultaneously in the event of any malfunctions. Disregarding this information could result in product damage and/or personal injury.

18. Verify shutdown switches and load carrying ability.

### DISCHARGING THE STORAGE CAPACITOR

**WARNING**

If the Ignition switch is left in the ON position when a CEC Ignition Module is disconnected, then the spark plugs may fire when the Ignition system harness is reconnected, and could cause severe personal injury or death.

Before connecting the ignition harness (to the coils) to the IM, discharge the storage capacitors to ground. Attach one end of a wire lead to the crankcase and then touch the other end to the harness connector pins on the IM, one at a time. A snap may be heard when a capacitor discharges.

**WARNING**

As a safety measure, ground all the pins. Some breakerless ignition systems have more than one storage capacitor. Severe personal injury or death could result.

# VGF IGNITION MODULE TIMING ADJUSTMENTS

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**CONTENTS**

**SECTION 5.00 - IGNITION MODULE DIAGNOSTICS  
AND TROUBLESHOOTING**

FORM 6272 (Rev. 12-13-61)

## SECTION 5.00

# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

## IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

### DIAGNOSTICS CHART

The IM is equipped with three diagnostic LEDs on front of the IM housing: "Power," "Pickup," and "Application" (see Figure 5.00-1). These LEDs give operators visual confirmation on (1) incoming power, (2) Hall-effect pickup signal, and (3) proper application settings.

During normal operation with the engine running the "Power" LED is on, the "Pickup" LED is off, and the "Application" LED is off. When the engine is not running and power is applied to IM the "Power" LED is on, the "Pickup" LED is on, and the "Application" LED is off. If a different condition exists, refer to Table 5.00-1.

Table 5.00-1 describes what an inerrant LED indicates and provides troubleshooting suggestions to remedy the situation if required.

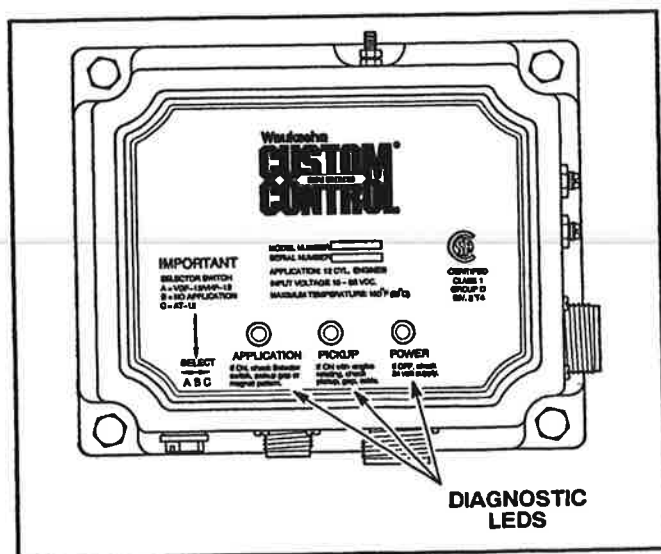


Figure 5.00-1. Ignition Module Diagnostic LEDs

### TROUBLESHOOTING CHART

Table 5.00-2 is provided to assist the user in determining the possible causes of unsatisfactory IM operation, as well as point out the corrective action that may be taken to remedy the problem.

If problems persist, contact your local Waukesha Engine Distributor or Waukesha Engine Product Support for assistance.

Troubleshooting the IM can involve some disassembly of circuit board assemblies and other work of similar nature. Only "qualified technicians" should undertake these activities. Improper handling of circuit boards and electronic components can cause damage that may render them unusable.

**NOTE:** Table 5.00-2 is only provided as a service to our customers. The table should not be viewed as a reflection of Waukesha Engine's actual experience with this product.

### WARNING

Allow the engine to cool to room temperature before cleaning, servicing, or repairing the unit. Hot components or fluids can cause severe personal injury or death.

### WARNING

Always wear OSHA approved body, sight, hearing, and respiratory system protection. Never wear loose clothing, jewelry, or long hair around an engine. The use of improper attire may result in severe personal injury or death.

### WARNING

Do not install, set up, maintain, or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

Table 5.00-1. Ignition Module Diagnostics Chart

LED	IF LED IS ...	THEN
"Power" LED (Green)	OFF*	<ul style="list-style-type: none"> <li>• IM does not have power (10 – 32 VDC).</li> <li>a. Check to see if power source is within specification. Refer to "IM Power Requirements" in Section 2.05 (VHP), Section 3.05 (AT), or Section 4.05 (VGF) for power supply requirements.</li> <li>b. Check wiring for proper connections. Refer to "IM Power Requirements" in Section 2.05 (VHP), Section 3.05 (AT), or Section 4.05 (VGF).</li> <li>c. Perform diagnostic test on IM circuit board assemblies by completing the steps in "Ignition Module Testing" in this section. Replace power board assembly if required and retest IM.</li> </ul>
	ON* (ENGINE NOT RUNNING)	<ul style="list-style-type: none"> <li>• Normal operation.</li> </ul>
"Pickup" LED (Red)	ON* (ENGINE RUNNING)	<ul style="list-style-type: none"> <li>• Engine is at rest.</li> <li>• No Hall-effect pickup signal is being sensed by the IM.</li> <li>a. Reset air gap between timing disc/gear and Hall-effect pickup. Refer to "Hall-effect Pickup Testing On Engine With Ohmmeter" and Table 5.00-14 for instructions on resetting the air gap.</li> <li>b. Check wiring for proper connections. Refer to "IM Power Requirements" in Section 2.05 (VHP), Section 3.05 (AT), or Section 4.05 (VGF).</li> <li>c. Check the Hall-effect pickup for proper operation. Refer to "Hall-effect Pickup Testing" in this section. Replace Hall-effect pickup if necessary.</li> <li>d. Check the magnetism of the magnets in the timing disc/gear. To check magnetism, take a small steel object like a stiff feeler gauge approximately 0.040 (1.0 mm) thick, and pass the gauge over the top of one of the magnets. The relative pull on the gauge should then be compared with the pull of the other magnets. The pull on the feeler gauge should be about the same for all the magnets. Replace magnet(s) or timing disc if necessary.</li> </ul>
	ON*	<ul style="list-style-type: none"> <li>• Magnet pattern does not match the application for which the IM Selector Switch is set ( for example: 6 versus 8 cylinder) OR the Selector Switch is in the B position (No Application).</li> <li>a. Check the Selector Switch setting on IM. Refer to Table 5.00-7 for Selector Switch settings.</li> <li>b. Check IM part number. If part number of IM is not correct for the application, replace IM. Refer to Table 5.00-3 for IM part numbers.</li> <li>c. Check P/N of timing disc installed versus engine application. If part number of timing disc is not correct for the application, replace timing disc. Refer to Table 5.00-3 for timing disc part numbers.</li> <li>• Timing disc magnet is lost or is very weak.</li> <li>a. Reset air gap between timing disc/gear and Hall-effect pickup. Refer to "Hall-effect Pickup Testing On Engine With Ohmmeter" and Table 5.00-14 for instructions on resetting the air gap.</li> <li>b. Check the magnetism of the magnets in the timing disc/gear. To check magnetism, take a small steel object like a stiff feeler gauge approximately 0.040 (1.0 mm) thick, and pass the gauge over the top of one of the magnets. The relative pull on the gauge should then be compared with the pull of the other magnets. The pull on the feeler gauge should be about the same for all the magnets. Replace magnet(s) or timing disc if necessary.</li> <li>• Hall-effect pickup is lost (disconnected or failed) on a two pickup system (AT engines).</li> <li>a. Determine which timing disc is not being sensed.</li> <li>b. Reset air gap between timing disc/gear and Hall-effect pickup. Refer to "Hall-effect Pickup Testing On Engine With Ohmmeter" and Table 5.00-14 for instructions on resetting the air gap.</li> <li>c. Check wiring for proper connections. Refer to "IM Power Requirements" in Section 2.05 (VHP), Section 3.05 (AT), or Section 4.05 (VGF).</li> </ul>
"Application" LED (Red)	ON*	<ul style="list-style-type: none"> <li>• Magnet pattern does not match the application for which the IM Selector Switch is set ( for example: 6 versus 8 cylinder) OR the Selector Switch is in the B position (No Application).</li> <li>a. Check the Selector Switch setting on IM. Refer to Table 5.00-7 for Selector Switch settings.</li> <li>b. Check IM part number. If part number of IM is not correct for the application, replace IM. Refer to Table 5.00-3 for IM part numbers.</li> <li>c. Check P/N of timing disc installed versus engine application. If part number of timing disc is not correct for the application, replace timing disc. Refer to Table 5.00-3 for timing disc part numbers.</li> <li>• Timing disc magnet is lost or is very weak.</li> <li>a. Reset air gap between timing disc/gear and Hall-effect pickup. Refer to "Hall-effect Pickup Testing On Engine With Ohmmeter" and Table 5.00-14 for instructions on resetting the air gap.</li> <li>b. Check the magnetism of the magnets in the timing disc/gear. To check magnetism, take a small steel object like a stiff feeler gauge approximately 0.040 (1.0 mm) thick, and pass the gauge over the top of one of the magnets. The relative pull on the gauge should then be compared with the pull of the other magnets. The pull on the feeler gauge should be about the same for all the magnets. Replace magnet(s) or timing disc if necessary.</li> <li>• Hall-effect pickup is lost (disconnected or failed) on a two pickup system (AT engines).</li> <li>a. Determine which timing disc is not being sensed.</li> <li>b. Reset air gap between timing disc/gear and Hall-effect pickup. Refer to "Hall-effect Pickup Testing On Engine With Ohmmeter" and Table 5.00-14 for instructions on resetting the air gap.</li> <li>c. Check wiring for proper connections. Refer to "IM Power Requirements" in Section 2.05 (VHP), Section 3.05 (AT), or Section 4.05 (VGF).</li> </ul>

**NOTE:** \* During normal operation with the engine running the "Power" LED is on, the "Pickup" LED is off, and the "Application" LED is off. When the engine is not running and power is applied to IM the "Power" LED is on, the "Pickup" LED is on, and the "Application" LED is off. If a different condition exists, refer to the diagnostics provided in the table.

## IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

Before referring to the troubleshooting procedures in Table 5.00-2, check IM LEDs. During normal operation with the engine running the "Power" LED is on, the "Pickup" LED is off, and the "Application" LED is off. When the engine is not running and power is applied to IM the "Power" LED is on, the "Pickup" LED is on, and the "Application" LED is off.

- If the LEDs are displaying normal LED operation and IM operation is unsatisfactory, use Table 5.00-2 to troubleshoot the IM system.

**NOTE:** If you completed the diagnostics in Table 5.00-1, some of the troubleshooting checks listed in Table 5.00-2 have already been completed.

- If a different condition exists, refer to the IM diagnostics in Table 5.00-1.

**Table 5.00-2. Ignition Module Troubleshooting Chart**

SYMPTOM	TEST OR CHECK DESCRIPTION	IF CHECK IS OK	IF CHECK IS NOT OK
No Spark	1A. Verify 10 - 32 VDC is available to IM.	Go to 1B	Supply 10 - 32 VDC to IM.
	1B. Verify Hall-effect pickup gap is within specification (see section "Hall-effect Pickup Testing" and Table 5.00-14).	Go to 1C	Reset air gap.
	1C. Verify that IM installed on engine is correct model for engine application (see Table 5.00-3).	Go to 1D	Install correct IM for application.
	1D. Verify no short exists in wiring connected to "G" lead. Disconnect "G" lead from on/off switch, safety switches, etc.	Go to 1E	Find and correct short in wiring connected to "G" lead.
	1E. Visually check Power Pickup Harness for damage and check harness with ohmmeter for continuity.	Go to 1F	Replace Power Pickup Harness.
	1F. Verify proper operation of Hall-effect pickup using CEC Ignition Tester (see "Hall-effect Pickup Testing").	Go to 1G	Replace Hall-effect pickup.
	1G. Verify ground wire is securely attached to ground stud on IM and engine crankcase.	Go to 1H	Secure ground wire.
	1H. Test IM to determine problem circuit board following testing procedures in "Ignition Module Testing."	---	Replace problem circuit board assembly.
One Output Does not Fire	2A. Check spark plug and spark plug lead.	Go to 2B	Replace faulty part.
	2B. Check Primary Coil Harness from IM to ignition coils.	Go to 2C	Repair connection or replace harness.
	2C. Check ignition coils.	Go to 2D	Replace faulty ignition coil(s).
	2D. Replace IM's power board assembly following the procedure in "Ignition Module Repair."	---	If problems persist, contact your local Waukesha Engine Distributor or Waukesha Engine Product Support.
One Output Fires Continuously	3A. Replace IM's power board assembly.	---	If problems persist, contact your local Waukesha Engine Distributor or Waukesha Engine Product Support.
Timing is Not Correct	4A. Verify Selector Switch setting is correct for application (see Table 5.00-7).	Go to 4B	Select correct application setting on Selector Switch.
	4B. Adjust engine timing with timing switch "A" or "B" on IM.	Go to 4C	Adjust timing switch to desired timing.
	4C. Check if "D" lead of 7 pin harness is grounded ("A" switch active) or open ("B" switch active).	Go to 4D	Adjust corresponding timing switch according to connection of "D" lead.
	4D. Check timing disc reference position to #1 cylinder position.	Go to 4E	Correct timing disc mount to #1 cylinder position.
	4E. Replace IM's logic board assembly.	---	If problems persist, contact your local Waukesha Engine Distributor or Waukesha Engine Product Support.

# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

## TESTING IGNITION MODULE COMPONENTS

This section includes troubleshooting information for IM components. Testing of the components may be performed on the engine or using a test bench. Both of these testing methods are included in this section. The purpose of these tests is to determine the condition of the IM and which circuit boards inside the IM need to be replaced.

**NOTE:** The test bench required will be very similar to ones used for testing magnetos. These bench tests should only be performed by those individuals who have the appropriate equipment (test bench) and prior knowledge required to test magnetos.

The IM is an electronic, digital-circuit ignition system for Waukesha spark-ignited engines (see Figure 5.00-2 and Figure 5.00-3). The system has no wearing parts and uses the capacitor discharge principle providing high energy, precision timed sparks for maximum engine performance.

- Table 5.00-3 lists the Waukesha Engine part numbers for the various IM components.
- Table 5.00-4 lists the Waukesha Engine part numbers for the wiring harnesses used in the IM system.
- Table 5.00-5 lists the internal parts of the IM.
- Table 5.00-6 lists IM specifications.
- Table 5.00-7 lists the Selector Switch settings used to set the IM for the engine application.
- Table 5.00-8 and Table 5.00-9 lists the part numbers of the triggering magnets and Hall-effect pickup(s).

In operation, the IM steps up the DC supply voltage to charge an energy storage capacitor. SCR (silicon controlled rectifiers) switching devices release this stored energy in response to signals from the IM's logic circuitry which processes signals from the rotating trigger magnets. Six, eight, and twelve cylinder engines employ one magnet for every firing cylinder of the engine. Each firing occurs at a programmed number of degrees after the magnet signal is received (see Table 5.00-6). Units for the 16 cylinder engines use one magnet for every two firing cylinders with the odd firing angle electronically synthesized by the IM circuitry. All IMs use one additional index magnet that trails the last firing magnet by 9 degrees or 15 degrees (depending on application). This indicates that another firing cycle is beginning.

The 8L-AT27GL, 12V-AT27GL, and 16V-AT27GL use a slightly different system of components than the standard IM found on all other Waukesha Engine products. These engines use two Hall-effect pickups, a timing disc, and a flywheel with magnets. The timing disc, containing one magnet, is mounted on the cam gear and signals the IM that another firing cycle is beginning. The flywheel contains four (on 8L-AT27GL and 16V-AT27GL) or six (on 12V-AT27GL) trigger magnets which accurately signal the engine's crankshaft timing to the IM.

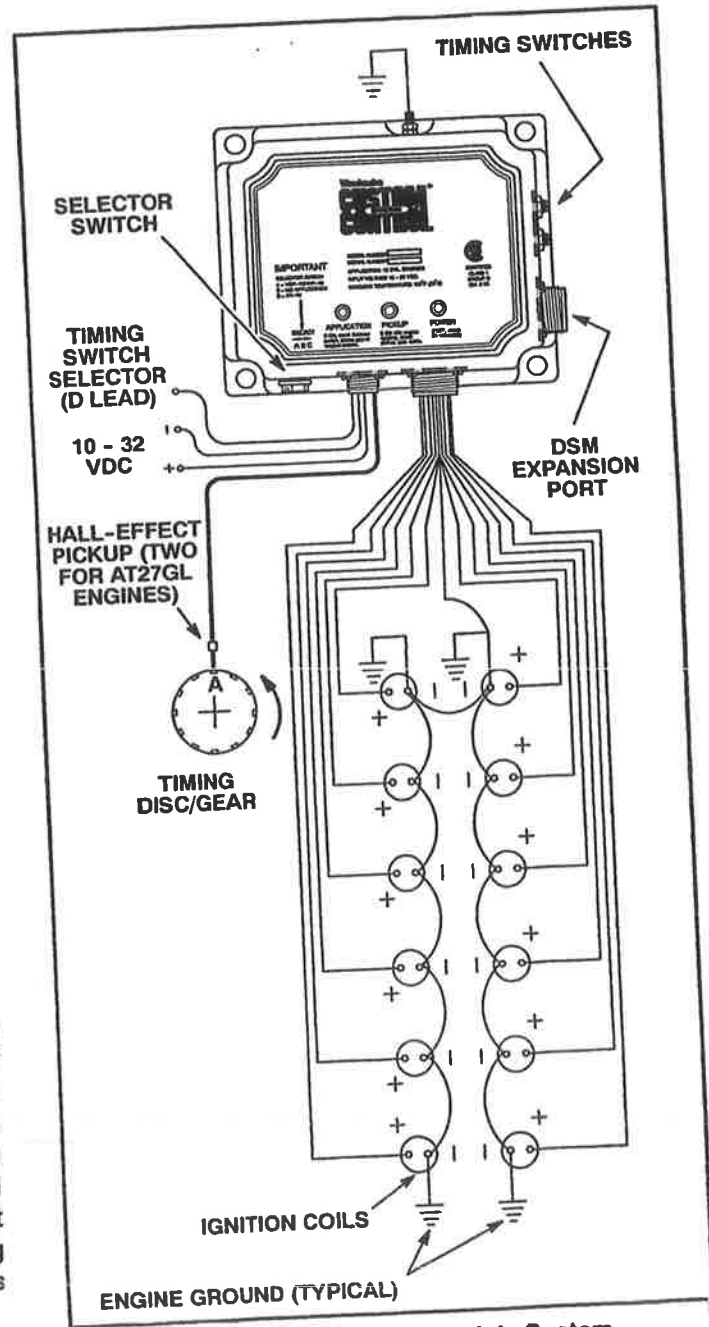


Figure 5.00-2. Ignition Module System



# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

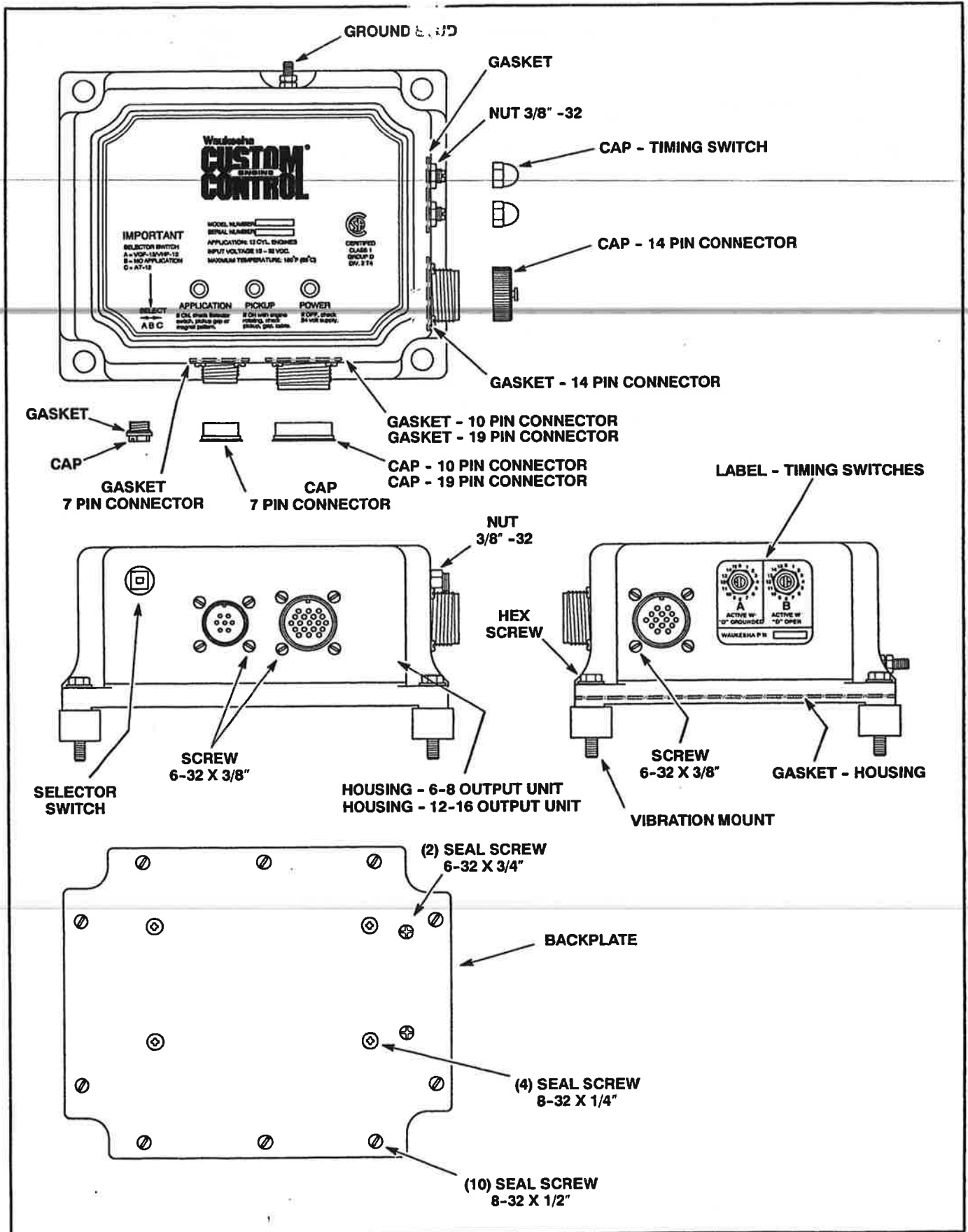


Figure 5.00-3. Ignition Module Components

# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

**Table 5.00-3. Ignition Module Components Part Numbers**

ENGINE MODEL	TIMING DISC	HALL-EFFECT PICKUP	IGNITION MODULE	POWER BOARD ASSEMBLY	LOGIC BOARD ASSEMBLY
VGf 6	305805	295844A	740608	A740819	A740816
VGf 8	305805A	295844A			
VHP 6	305805R	295844A			
8L-AT27GL	305805L and 280513C (Flywheel) with 305509 (Magnets)	295844B 295844	740609	A740820	A740817
VGf 12	302226B (Left Bank Cam Gear) and 305509 (Trigger Magnets)	295844			
VHP 12	305805P	295844A			
VHP 5115GL	305805S	295844A			
12V-AT25GL	305805E	295844			
12V-AT27GL	305805K and 280513C (Flywheel) with 305509 (Magnets)	295844 (Qty. 2)			
VGf 16	303026 (Left Bank Cam Gear) and 305509 (Trigger Magnets)	295844	740610	A740821	A740818
VHP 16	305805N	295844A			
16V-AT27GL	305805K and 280013M (Flywheel) with 305509 (Magnets)	295844 (Qty. 2)			

**Table 5.00-4. Wiring Harnesses Part Numbers**

ENGINE	UNSHIELDED PICKUP AND INPUT HARNESS	SHIELDED INPUT HARNESS	SHIELDED PICKUP HARNESS	UNSHIELDED PRIMARY HARNESS	SHIELDED PRIMARY HARNESS
VGf 6	69796	295841J	295495A	69792 (or) G305628A	H208497
VGf 8	69796	295841J	295495A	69793 (or) V305628	CA208497D
VGf 12	69796	295841B	295495	69794 (or) F305628	V208497D (R.H.) W208497D (L.H.)
VHP 6	69796	485065	485066	69792 (or) C295497B	485064
VHP 12	69796	485065	485066	F69692J	295497
VHP 16	69796	295841N	295495B	69795A (or) 69692V	485073
8L-AT27GL	---	295841A	295495A (or) 295495B	---	295497B
12V-AT25GL	---	295841A	295495	---	295497
12V-AT27GL	---	295841A	295495A (or) 295495D	---	295497
16V-AT27GL	---	295841A	295495B and 295495D	---	295497M

# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

**Table 5.00-5. Ignition Module Internal Parts List**

P/N	QUANTITY	DESCRIPTION
See Table 5.00-3	1	Logic Board Assembly (see Table 5.00-3) (Each Board Assembly Also Contains an IM Gasket/Hardware Kit)
See Table 5.00-3	1	Power Board Assembly (See Table 5.00-3) (Each Board Assembly Also Contains an IM Gasket/Hardware Kit)
A740815 (Ignition Module Gasket/Hardware Kit)	1	Gasket, Timing Potentiometer
	2	Cap, Timing Switch
	1	Gasket, 14 pin connector
	1	Cap, 14 pin connector
	2	Insulators
	1	Cap, 7 pin connector
	1	Cap, 10 pin connector
	1	Cap, 19 pin connector
	1	Gasket, housing
	1	Gasket, 7 pin connector
	1	Gasket, 10 pin connector
	1	Gasket, 19 pin connector
	10	Screw 8-32 x 1/2"
	4	Seal Screw 8-32 x 1/4"
	12	Seal Screw 6-32 x 1/4"
	2	Seal Screw 6-32 x 3/4"
	1	Plug
	1	Gasket, Plug

**Table 5.00-6. Ignition Module Specifications**

ENGINE MODEL	NUMBER OF MAGNETS	TIMING SWITCH INCREMENT ENGINE°	FIRING PATTERN - DISC DEGREES
			A-B-C-D-E-F (@ 6 CYL) A-B-C-D-E-F-H-I (@ 8 CYL) A-B-C-D-E-F-K-L-M-N-P-R (@ 12 CYL) A-B-C-D-E-F-K-L-M-N-P-R-S-T-U-V (@ 16 CYL)
VGf 6	6 + 1	1°	0-60-120-180-240-300
VGf 8	8 + 1	1°	0-45-90-135-180-225-270-315
VHP 6	6 + 1	1°	0-60-120-180-240-300
8L-AT27GL	4 + 1	1°	0-45-90-135-180-225-270-315
VGf 12	12 + 1	1°	0-30-60-90-120-150-180-210-240-270-300-330
VHP 12	12 + 1	1°	0-30-60-90-120-150-180-210-240-270-300-330
VHP 5115GL	12 + 1	1°	0-30-60-90-120-150-180-210-240-270-300-330
12V-AT25GL	12 + 1	1°	0-27-60-87-120-147-180-207-240-267-300-327
12V-AT27GL	6 + 1	1°	0-27-60-87-120-147-180-207-240-267-300-327
VGf 16	8 + 1	1°	0-30-45-75-90-120-135-165-180-210-225-255-270-300-315-345
VHP 16	8 + 1	1°	0-30-45-75-90-120-135-165-180-210-225-255-270-300-315-345
16V-AT27GL	4 + 1	1°	0-27-45-72-90-117-135-162-180-207-225-252-270-297-315-342

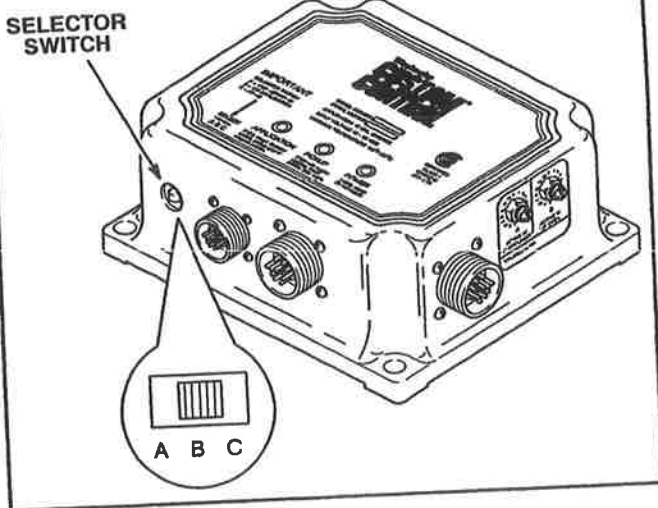
# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

The IM has a three position Selector Switch for setting the engine model (see Table 5.00-7). The Selector Switch is a three position switch (A, B, and C). The Selector Switch must be set during IM timing adjustments. Use your finger or a screwdriver to switch to the proper application.

**NOTE:** The IM is shipped from Waukesha Engine with the Selector Switch in the B (No Application) setting. Refer to Table 5.00-7 for Selector Switch settings.

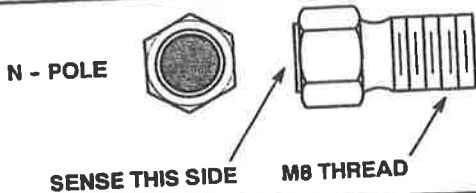
**Table 5.00-7. Ignition Module Selector Switch Settings**

SELECTOR SWITCH SETTING	IGNITION MODULE MODELS		
	Model 811 for 6 & 8 Cylinder Engines	Model 1211 for All 12 Cylinder Engines	Model 1611 for All 16 Cylinder Engines
<b>A</b>	VHP/VGF 6 Cylinder Engines	VHP/VGF 12 Cylinder Engines	VHP/VGF 16 Cylinder Engines
<b>B</b>	No Application	No Application	No Application
<b>C</b>	ATGL/VGF 8 Cylinder Engines	ATGL 12 Cylinder Engines	ATGL 16 Cylinder Engines



**Table 5.00-8. Triggering Magnet**

ENGINE	MAGNET	NUMBER OF MAGNETS
VGF 12	305509	12 + 1
VGF 16	305509	8 + 1
8L-AT27GL	305509	4 + 0
12V-AT27GL	305509	6 + 0
16V-AT27GL	305509	4 + 0



**Table 5.00-9. Hall-effect Pickup Part Numbers**

P/N	LENGTH "L"
295844	4.5 in.
295844A	2.5 in.
295844B	6.0 in.

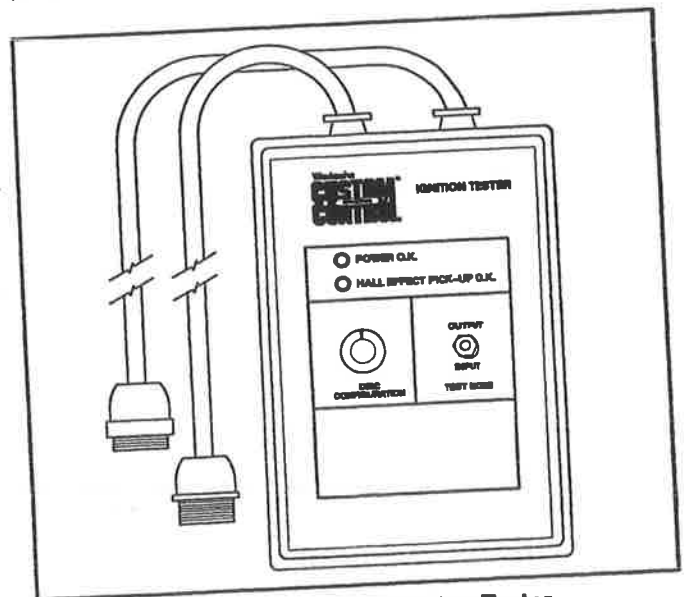
## IGNITION MODULE TESTING

### IGNITION MODULE TESTING - ON ENGINE

#### Testing The IM With The CEC Ignition Tester

The CEC Ignition Tester (P/N 475032) is designed to quickly troubleshoot the various components of the IM system (see Figure 5.00-4).

The Ignition Tester instructions that follow check operation of the IM, power supplied to the IM, wiring to the ignition coils for the primary circuit, and the secondary circuit from the ignition coils to the spark plugs.



**Figure 5.00-4. CEC Ignition Tester**

## ⚠ WARNING

Verify that the engine is purged of all fuel gas prior to using the test unit. Failure to do so may cause the engine to rotate or start which could cause severe personal injury or engine damage.

## ⚠ WARNING

Do not install, set up, maintain or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

**⚠ CAUTION** Disconnect power supply to Ignition Module before completing test with CEC Ignition Tester. Electrical test equipment may be damaged if the tests are not performed properly.

1. Disconnect power from IM.
2. Disconnect the 7 pin Power Pickup Harness from the IM.
3. Position the "OUTPUT/INPUT" switch on the Ignition Tester to the "INPUT" position.
4. Plug the female cable from the Ignition Tester into the IM 7 pin connector.
5. Plug the male cable from the Ignition Tester into the free end of the 7 pin Power Pickup Harness.
6. Apply 10 - 32 VDC power to the IM. The green "POWER O.K." LED on the Ignition Tester will light indicating power is applied to the IM. The LED does not indicate that the power supply is within specification, but that power is applied.
7. Rotate the "DISC CONFIGURATION" selector switch to the proper magnet arrangement for your application. *For example:* If you have a 12 cylinder engine, the knob should be rotated so that the white indicating line is opposite the "12+1" marking.
8. Verify that the Selector Switch on the IM is set for the proper application. Refer to Table 5.00-7 for Selector Switch settings. Use your finger or a screwdriver to switch to the proper setting.

## ⚠ WARNING

Verify that the engine is purged of all fuel gas prior to using the test unit. Failure to do so may cause the engine to rotate or start which could cause severe personal injury or engine damage.

9. Verify that the engine has been properly purged of fuel since the following steps will cause a functioning unit to output a spark to all engine cylinders.

10. Position the "OUTPUT/INPUT" switch on the Ignition Tester to the "OUTPUT" position.

11. The CEC Ignition Tester will send simulated Hall-effect pickup signals to the IM. If errors are detected during this test, the LEDs on the IM will light (see Table 5.00-1, "Ignition Module Diagnostics Chart"). The IM should fire all outputs in sequence at a rate equivalent to a magnet disc speed of 661 rpm. Use any convenient method, such as a spark plug glow indicator, to check that each ignition coil and spark plug are firing.

12. Position the "OUTPUT/INPUT" switch on the Ignition Tester in the "INPUT" position at the end of the test.

**NOTE:** The CEC Ignition Tester can also be used to complete a test of the Hall-effect pickup and Power Pickup Harness. Refer to "Hall-effect Pickup Testing On Engine With CEC Ignition Tester" later in this section to perform the test.

13. After testing is complete, disconnect the Ignition Tester and reconnect the Power Pickup Harness to the IM.

### Ignition Module Testing With Ohmmeter - On Engine

## ⚠ WARNING

Do not install, set up, operate, or maintain any electrical components unless you are a technically qualified individual who is familiar with electrical elements involved. Electrical shock can cause personal injury or death.

**⚠ CAUTION** Disconnect the power supply from the Ignition Module before attempting the ohmmeter tests. Electrical test equipment may be damaged if the tests are not performed properly.

**NOTE:** Use Simpson Model 260 or equivalent analog volt-ohmmeter to perform this test. Some ohmmeters use reverse polarity, which will give incorrect results.

# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

1. Connect the ohmmeter positive and negative leads to the corresponding pin locations listed in Table 5.00-10.
2. Record each reading.

3. If the results comply with Table 5.00-10, proceed to the next test. If the results do not comply with Table 5.00-10, replace the IM's power board assembly and retest. Refer to "Ignition Module Repair" to replace power board assembly.

Table 5.00-10. Ohmmeter Tests

19 PIN CONNECTOR		10 PIN CONNECTOR			
TEST	OHMMETER SCALE	POSITIVE LEAD	NEGATIVE LEAD	READING	
Ignition Module 10 pin or 19 pin connector	R x 10,000	Pin "G"	Pin "A"	Infinite - replace power board assembly and retest if reading is less than 250,000 ohms. <sup>1,2</sup>	
		Pin "G"	Pin "B"		
		Pin "G"	Pin "C"		
		Pin "G"	Pin "D"		
		Pin "G"	Pin "E"		
		Pin "G"	Pin "F"		
		Pin "G"	Pin "H"		
		Pin "G"	Pin "I"		
		Pin "G"	Pin "J"		
		Pin "G"	Pin "K"		
		Pin "G"	Pin "L"		
		Pin "G"	Pin "M"		
		Pin "G"	Pin "N"		
		Pin "G"	Pin "P"		
		Pin "G"	Pin "R"		
		Pin "G"	Pin "S"		
		Pin "G"	Pin "T"		
Pin "G"	Pin "U"				
Pin "G"	Pin "V"				
Pin "G"	Ground Stud				
Ignition Module 7 pin connector	R x 100	Pin "E"	Pin "F"	Infinite - replace power board assembly and retest if reading is less than 1000 ohms. <sup>1,2</sup>	

NOTE: <sup>1</sup> The ohmmeter needle will deflect and then move to a final infinite reading within 5 seconds.  
<sup>2</sup> Refer to "Ignition Module Repair" to replace power board assembly.



## Ignition Timing Testing - On Engine

**NOTE:** For the following tests to be performed the engine must be able to operate at rated speed and no load.

1. Verify proper power supply to IM (see Figure 5.00-5). Correct if necessary.

**NOTE:** The IM system will function properly with a power source as defined in Figure 5.00-5. However, if the supply is capable of providing a pulse current (higher current level for a shorter period of time such that the average current is the same), the ignition will utilize that pulse capability. In this case, the voltage fluctuations on the supply wiring, including the ground return to the power source, may cause erratic operation of other electrical devices. For this reason, it is recommended that the ignition power source wiring, specifically the ground return, be sized for at least 30 amps even though the average current will be less than 6 amps.

**WARNING**

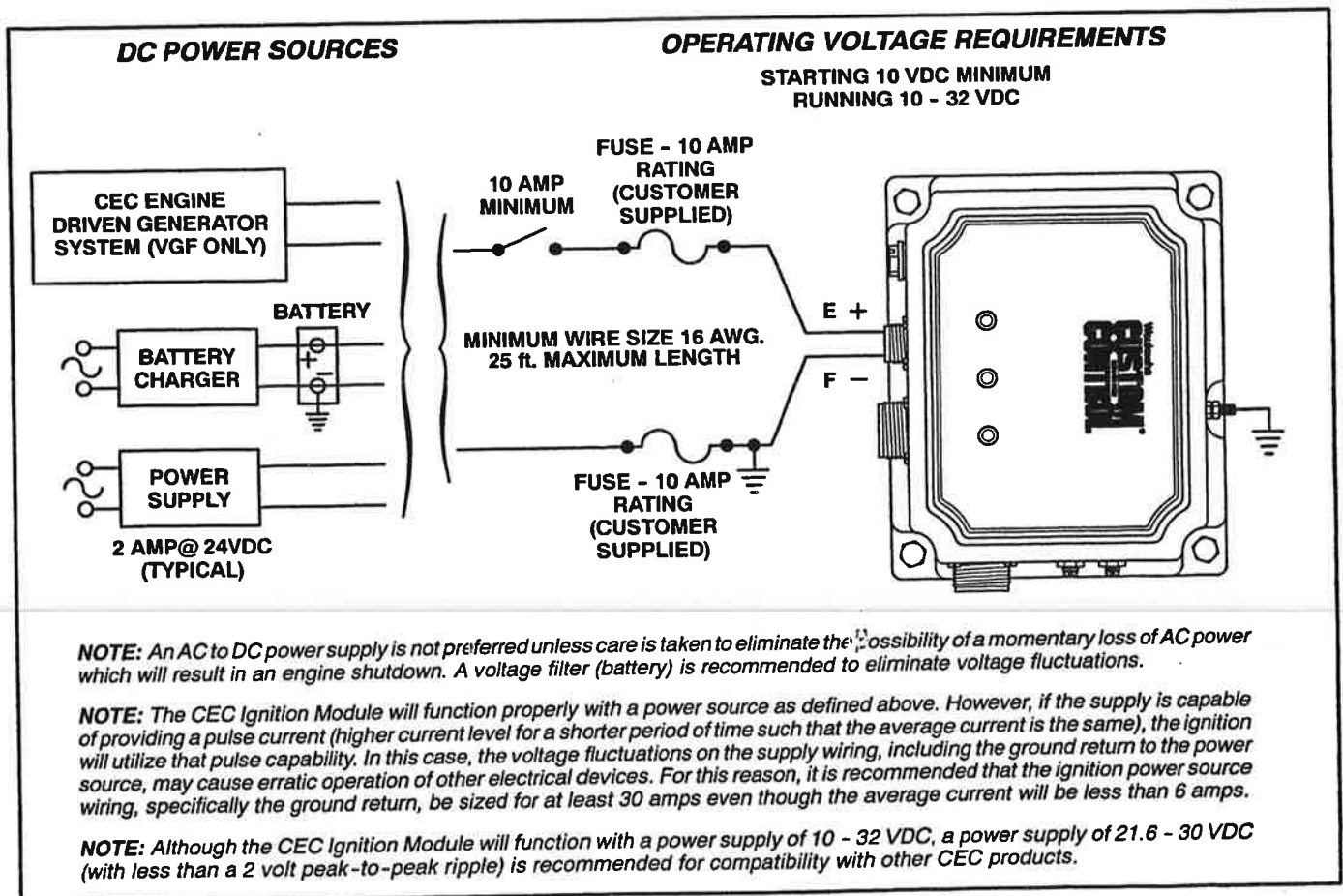
Disconnect the power supply to the Ignition Module when servicing the ignition system. Failure to disconnect the power supply can result in electrical shock, causing personal injury or death.

2. Disconnect the power supply to the IM.

**CAUTION**

Observe correct polarity when connecting power to the Ignition Module. Failure to correctly connect the power supply may damage the Ignition Module.

3. Ground the "D" lead in the Power Pickup Harness to activate timing switch "A" on the IM. Connect the power supply to the IM.
4. Rotate the "A" switch to the "0" position to place the engine in its most retarded setting for this timing switch.



**Figure 5.00-5. Ignition Module Power Supply**

# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

5. Start the engine. Run the engine at rated speed with no load.
6. Use a timing light to check the ignition timing. Record the ignition timing.
7. Use a screwdriver to slowly rotate switch "A" upwards on the dial (0 - 15). Record the ignition timing at each point. The ignition timing should increase one engine (crankshaft) degree for each upward position change of the timing switch.
8. Shut down engine.
9. Disconnect the power supply to the IM.
10. Unground the "D" lead in the Power Pickup Harness to activate timing switch "B" on the IM. Connect the power supply to the IM.
11. Rotate the "B" switch to the "0" position to place the engine in its most retarded setting for this timing switch.
12. Start the engine. Run the engine at rated speed with no load.
13. Use a timing light to check the ignition timing. Record the ignition timing.
14. Use a screwdriver to slowly rotate timing switch "B" upwards on the dial (0 - 15). Record the ignition timing at

each point. The ignition timing should increase one engine (crankshaft) degree for each upward position change of the timing switch.

**NOTE:** An overlap exists between timing switch "A" and "B."

If the IM's timing switches respond correctly proceed to the next test. If the timing switches do not respond in this manner, replace the logic board assembly (see "Ignition Module Repair" in this section).

## 7 Pin And 3 Pin Connector Testing - On Engine

**NOTE:** The following 7 pin and 3 pin tests (see Figure 5.00-6) are performed with the engine running at no load and rated speed. The complete test can only be performed on engines equipped with junction box terminations. Engines without junction boxes will require bench testing or a fabricated test harness to check pins "A," "B," and "C."

1. Connect the voltmeter positive and negative leads to corresponding pin or wire listed in Table 5.00-11.
2. Record each reading.
3. If the results comply with Table 5.00-11, proceed to the next test. Follow the corrective action column of Table 5.00-11 if the readings are out of specification.

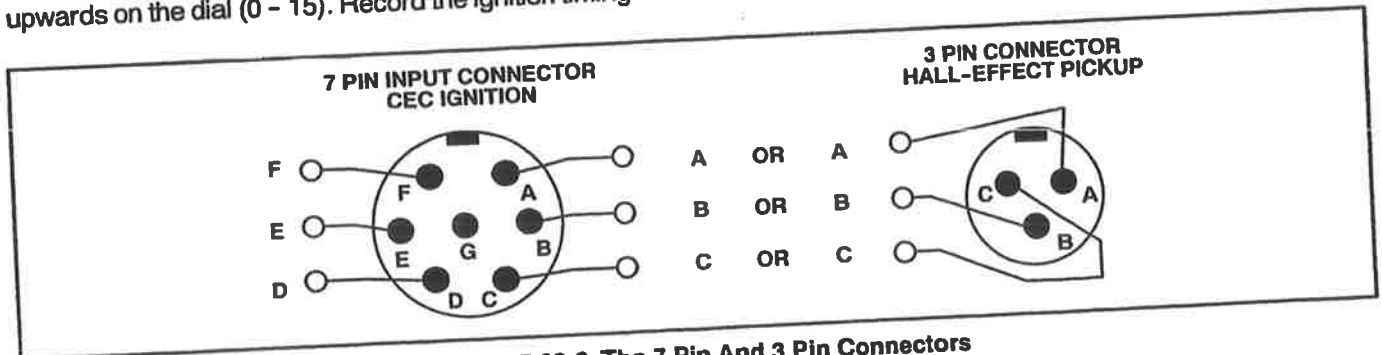


Figure 5.00-6. The 7 Pin And 3 Pin Connectors

Table 5.00-11. Testing The 7 Pin And 3 Pin Connectors

TEST	VOLTMETER SCALE	POSITIVE LEAD	NEGATIVE LEAD	READING	CORRECTIVE ACTION
7 Pin Or 3 Pin Connector	10 VDC	Pin A Or Wire	Ground	4.4 VDC Min. 100 Disc rpm With 10 - 32 VDC Input Voltage	Check Hall-effect Pickup
		Pin B Or Wire	Ground	Approx. 5 VDC	Check Hall-effect Pickup Or Replace IM Power Board Assembly and retest
		Pin C Or Wire	Ground	0 VDC	Correct Ground Lead And/Or Replace Hall-effect Pickup
		Pin D Or Wire	Ground	5 VDC (When Open) 0 VDC (When Grounded)	Replace IM Power Board Assembly and retest
	30 VDC	Pin E Or Wire	Ground	10 - 32 VDC (Positive Input Voltage)	Check Power Supply
	10 VDC	Pin F Or Wire	Ground	0 VDC (Negative Input Voltage)	Check Wire Terminations



## Oscilloscope Testing - On Engine

The oscilloscope test checks the voltage pattern at the ignition coil and the firing position of the cylinder. A malfunctioning SCR or a defective coil will affect the voltage pattern and/or its position.

**NOTE:** An oscilloscope (single channel) and two 10:1 oscilloscope probes are required to perform these tests. The signals being monitored are 150 - 200 VDC, positive polarity. The oscilloscope tests are written for a single channel oscilloscope. The use of dual channel oscilloscope is permitted.

**NOTE:** The VGF series of engines does not include the "G" lead in the Primary Coil Harness. Special pigtail adaptors are available from Waukesha Engine for use with oscilloscope testing (see Table 5.00-12). The pigtail adaptor is installed between the Primary Coil Harness and the IM. The wire that hangs out is the "G" lead and can be connected to the oscilloscope.

**Table 5.00-12. VGF Engine "G" Lead Test Pigtail Adaptors**

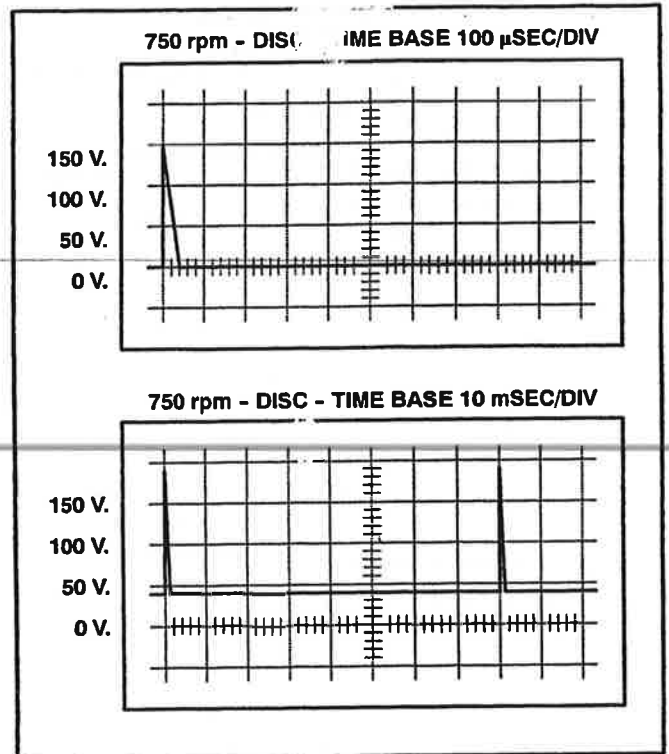
Engine Model	Test Pigtail P/N
F18 - 6 Cylinder	472059
H24 - 8 Cylinder	472060
L36 - 12 Cylinder	472061
P48 - 16 Cylinder	472062

**NOTE:** For the following tests to be performed the engine must be able to operate at rated speed and no load.

1. Connect the oscilloscope trigger input to the positive (+) "A" (first firing) coil terminal.
2. Connect the reading probe to the positive (+) coil terminal of each coil being checked and attach the oscilloscope probe ground to an engine ground.
3. Start the engine. Run the engine at rated speed and no load.
4. View the oscilloscope. Compare with the example patterns shown in Figure 5.00-7.

**NOTE:** The waveform shape displayed on the oscilloscope should be similar in output (140 - 160 VDC) but may differ in the time base because of the timing disc speed, oscilloscope time base setting, or IM model.

5. If the waveforms are not consistent with Figure 5.00-7, replace the IM's power board assembly (see "Ignition Module Repair" in this section).



**Figure 5.00-7. Oscilloscope Test Pattern (6 Cylinder Shown)**

## Storage Capacitor Voltage Pattern Testing - On Engine

The storage capacitor voltage pattern test checks the voltage pattern on the storage capacitor which is affected by the SCRs.

**NOTE:** An oscilloscope (single channel) and two 10:1 oscilloscope probes are required to perform these tests. The signals being monitored are 150 - 200 VDC, positive polarity. The oscilloscope tests are written for a single channel oscilloscope. The use of a dual channel oscilloscope is permitted.

**NOTE:** Refer to Figure 5.00-8 for the scope pattern pertaining to the particular IM being tested.

**NOTE:** For the following tests to be performed the engine must be able to operate at rated speed and no load.

## IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

1. Connect the trigger input of the oscilloscope to the positive (+) "A" primary coil lead.

2. Connect the oscilloscope reading probe to the "G" lead of the Primary Coil Harness and the oscilloscope probe ground to an engine ground.

**NOTE:** The "G" lead pattern displays all firings of the unit.

**NOTE:** With the "G" lead connected DIRECTLY to the scope, the oscilloscope or meter should read 140 - 160 VDC. If voltage is low, check power supply (including power supply to ignition wiring and grounds).

**NOTE:** The VGF series of engines does not include the "G" lead in the Primary Coil Harness. Special pigtail adaptors are available from Waukesha Engine for use with oscilloscope testing.

3. Operate the engine at rated speed and no load. Observe the oscilloscope patterns. The patterns displayed should correspond with those in Figure 5.00-8.

**NOTE:** The patterns displayed on the oscilloscope should be similar in output (140 - 160 VDC) but may differ in the time base because of the timing disc speed, oscilloscope time base setting, or IM model.

4. If the patterns are not consistent with Figure 5.00-8, replace the IM's power board assembly (see "Ignition Module Repair" in this section).

### Firing Pattern Testing - On Engine

**NOTE:** Refer to Table 5.00-6 for the firing pattern and engine model pertaining to the particular IM being tested. Ensure that the IM's cylinder timing matches that of the engine.

**NOTE:** In order to complete this test on engine, the flywheel must be marked with timing marks for all cylinders.

**NOTE:** The engine must be able to operate at rated speed and no load for this test.

1. Start the engine and set to rated speed and no load.
2. Using a timing light, set the ignition timing to zero degrees before top dead center (BTDC) or to the most retarded ignition timing possible.
3. Using the timing light on each cylinder, ensure that the ignition timing is the same for all cylinders. This can be accomplished by using the timing light in conjunction with a fully degreed flywheel. This will check the IM's timing pattern.
4. If the timing pattern does not match the IM and engine combination, replace the IM's logic board assembly (see "Ignition Module Repair" in this section).

# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

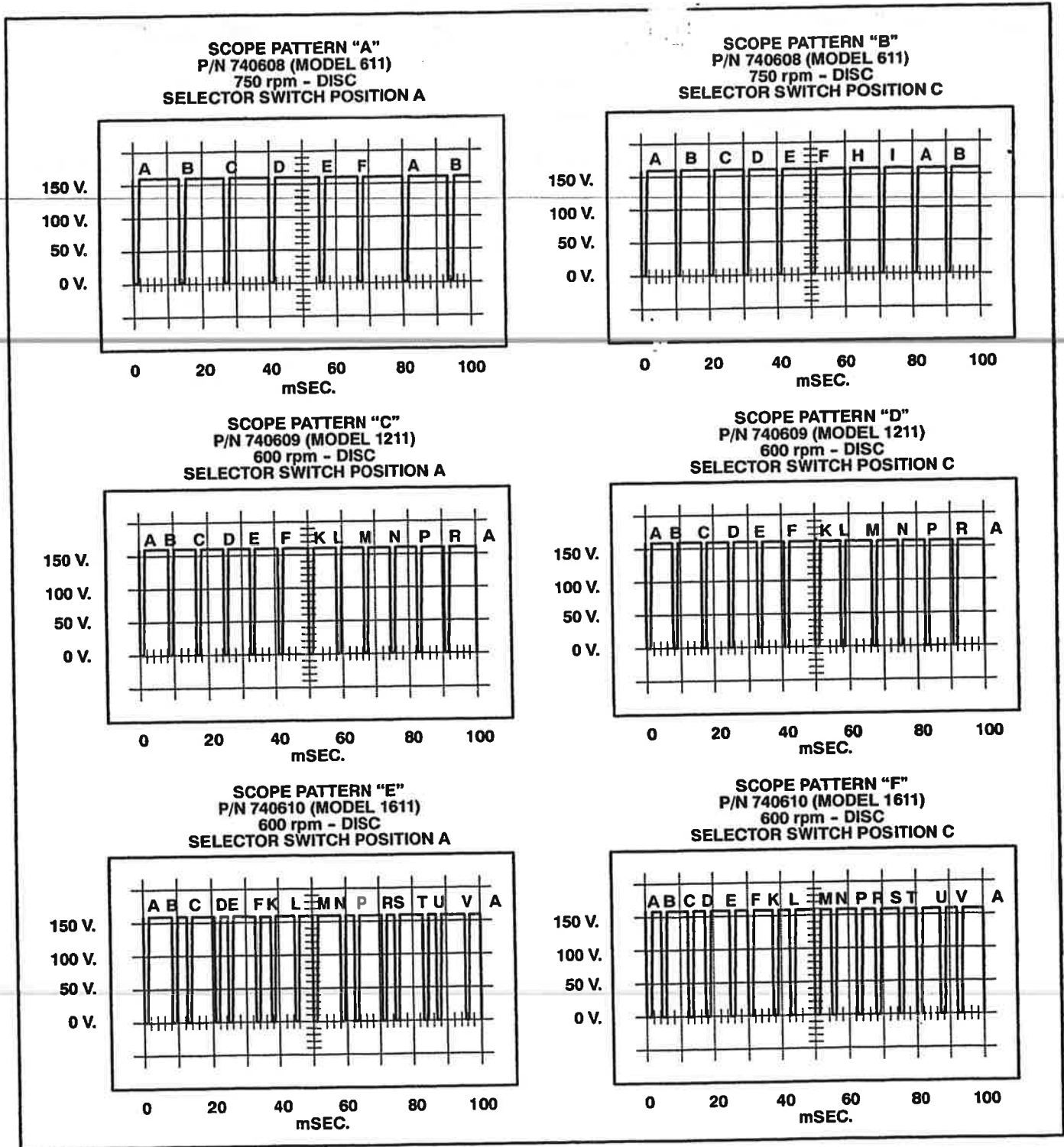


Figure 5.00-8. Oscilloscope Patterns

# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

## IGNITION MODULE TESTING - BENCH TEST

The following five tests require the use of a magneto style bench testing apparatus. In order to ensure accuracy of testing, these procedures should be performed only by those individuals having access to and experience with this type of testing equipment. The following is a list of required materials needed in order to construct a test stand:

- A variable speed motor of 0.25 HP or greater, capable of rotating 1000 rpm.
- A spark degree wheel graduated in 360 increments with the indicator attached to the driving shaft.
- An attachment for the timing discs to be mounted to the motor driving shaft.
- A Hall-effect pickup (P/N 295844A) mounted to sense the rotating magnetic disc.
- Sixteen ignition coils connected to suitable, adjustable spark gaps. Additionally, one coil connected to the indicating degree wheel and an arrangement to connect its positive terminal individually to the positive terminals of all other coils.
- A wiring harness connecting the IM to the ignition coils.
- A wiring harness to connect the Hall-effect pickup to the IM.
- A DC power source capable of supplying 10 - 32 VDC, 6 amps.
- A means to elevate and maintain the IM to a controlled temperature of 150° F (65° C).

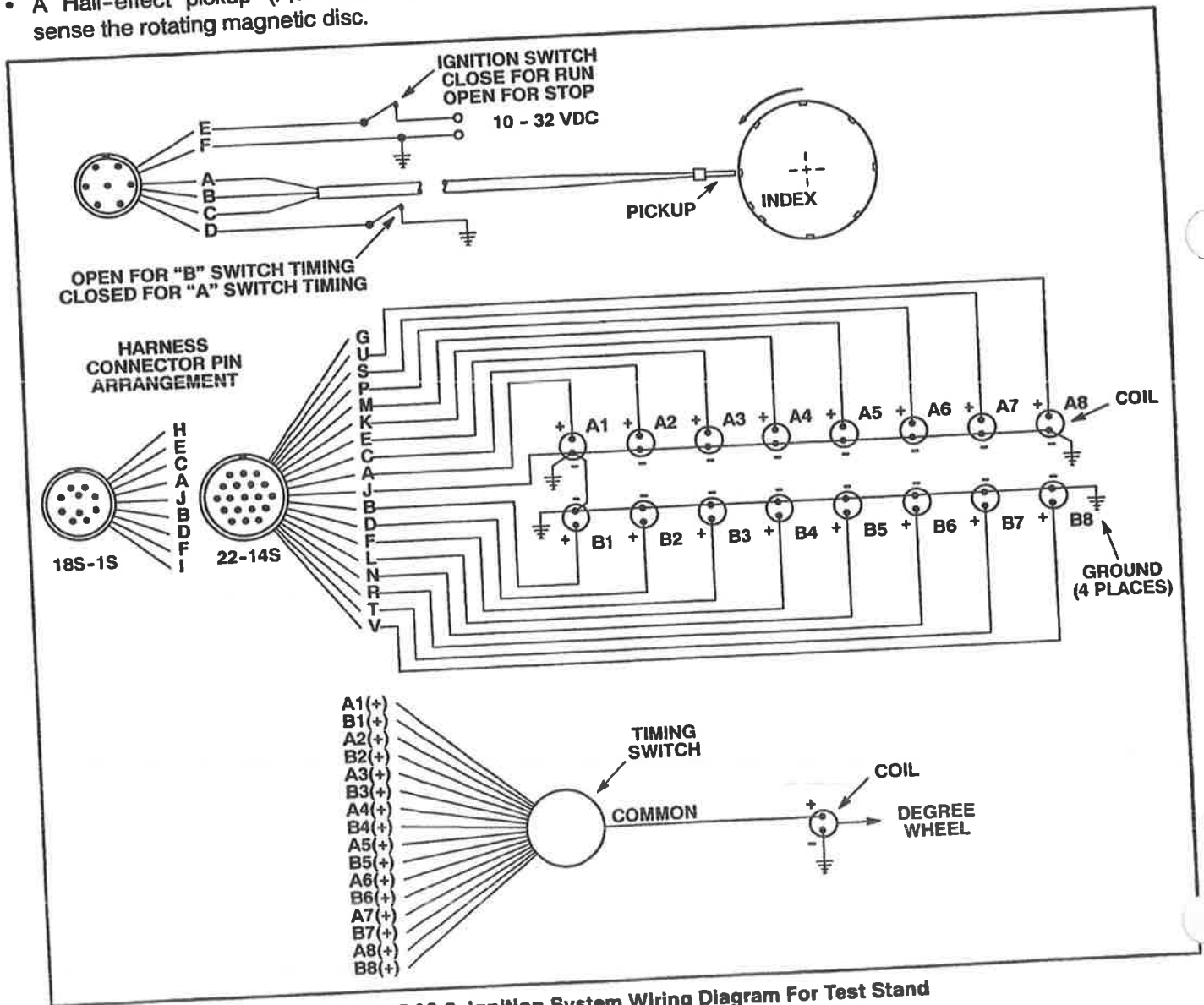


Figure 5.00-9. Ignition System Wiring Diagram For Test Stand

# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

## Performance Testing - Bench Test

**NOTE:** It is required that all bench tests be performed with the IM heated to a temperature of 150° F (65° C).

1. Set each spark gap to 15 mm (0.591").
2. Apply the corresponding input voltage as indicated for each test (see Table 5.00-13). Operate the timing disc at the speed indicated for each test.

**Table 5.00-13. Bench Testing Voltage Output**

DISC rpm	INPUT VOLTAGE	TEST
25	10 VDC	All outputs fire at 15 mm gap
400	24 VDC	All outputs fire at 15 mm gap
900	24 VDC	All outputs fire at 15 mm gap

3. Check all the spark gaps to ensure the IM is firing each gap.
4. Repeat this procedure for each disc rpm (see Table 5.00-13).
5. If the IM fires the gap at all indicated speeds, proceed to the next test. Replace the IM's power board assembly if it does not meet the specifications (see "Ignition Module Repair" in this section).

## Firing Pattern Testing - Bench Test

**NOTE:** Refer to Table 5.00-6 (IM Specification Table) for the firing pattern pertaining to the particular IM being tested.

1. Set the degree wheel at "0" degrees for output "A" of the primary harness.
2. Run the test bench. Record the firing pattern disc degrees for output "A" which should be zero.
3. Record the firing pattern disc degrees for all other outputs used by the particular IM being tested. (Example: IM model P/N 740608 uses firing pattern: A-B-C-D-E-F-H-I = 0-45-90-135-180-225-270-315 firing pattern disc degrees). Use a timing switch to alternate between the remaining outputs.
4. Compare the recorded data with the firing patterns listed in Table 5.00-6. If the timing pattern does not match the table, replace the IM's logic board assembly (see "Ignition Module Repair" in this section).

## Ignition Timing Testing - Bench Test

### **WARNING**

Disconnect the power supply to the Ignition Module when servicing the ignition system. Failure to disconnect the power supply can result in electrical shock causing personal injury or death.

1. Disconnect the power supply to the IM.
  2. Ground the "D" lead in the ignition wiring harness to activate timing switch marked "A" on the IM. Connect the power supply to the IM.
  3. Operate the test bench.
  4. Rotate the "A" switch to the "0" position to place the ignition in its most retarded setting for this timing switch.
  5. Record the firing pattern disc degrees for output "A" of the Primary Coil Harness.
  6. Use a screwdriver to slowly rotate switch "A" upwards on the dial (0 - 15). Record the ignition timing at each point. The ignition timing should increase one half (0.5) disc degrees for each upward position change of the timing switch.
  7. Turn off the test bench.
  8. Disconnect the power supply to the IM.
  9. Unground the "D" lead in the Power Pickup Harness to activate timing switch marked "B" on the IM. Connect the power supply to the IM.
  10. Rotate the "B" switch to the "0" position to place the module in its most retarded setting for this timing switch.
  11. Operate the test bench.
  12. Record the firing pattern disc degrees for output "A" of the Primary Coil Harness.
  13. Use a screwdriver to slowly rotate switch "B" upwards on the dial (0 - 15). Record the ignition timing at each point. The ignition timing should increase one half (0.5) disc degrees for each upward position change of the timing switch.
- NOTE:** An overlap exists between timing switch "A" and "B."

If the IM's timing switches respond correctly, proceed to the next test. If the IM's timing switches do not respond in this manner, replace the logic board assembly and retest (see "Ignition Module Repair" in this section).

# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

## 7 Pin And 3 Pin Connector Testing - Bench Test

1. Connect the voltmeter positive and negative leads to the corresponding pin or wire listed in Table 5.00-11 (see Figure 5.00-6).
2. Record each reading.

3. If the results comply with Table 5.00-11, proceed to the next test. Follow the corrective action column of Table 5.00-11 if the readings are out of specification.

## Oscilloscope Testing - Bench Test

The oscilloscope test checks the voltage pattern at the ignition coil and the firing position of the cylinder. A malfunctioning SCR or a bad coil will affect the voltage pattern and/or its position.

**NOTE:** An oscilloscope (single channel) and two 10:1 oscilloscope probes are required to perform these tests. The signals being monitored are 150 - 200 VDC, positive polarity. The oscilloscope tests are written for a single channel oscilloscope. The use of a dual channel oscilloscope is permitted.

1. Connect the oscilloscope trigger input to the positive (+) "A" coil terminal.
2. Connect the reading probe to the positive (+) coil terminal of each coil being checked and attach the oscilloscope probe ground to an engine ground.
3. Operate the test bench.
4. View the oscilloscope. Compare with the example patterns shown in Figure 5.00-7.

**NOTE:** The waveforms displayed on the oscilloscope should be similar in output (140 - 160 VDC) but may differ in the time base because of the timing disc speed or oscilloscope time base setting.

5. Turn off the test bench.
6. If the waveforms are not consistent with Figure 5.00-7, replace the IM's power board assembly (see "Ignition Module Repair" in this section).

## Storage Capacitor Voltage Pattern Testing - Bench Test

The storage capacitor voltage pattern test checks the voltage pattern on the storage capacitor which is affected by the SCRs.

**NOTE:** An oscilloscope (single channel) and two 10:1 oscilloscope probes are required to perform these tests. The signals being monitored are 150 - 200 VDC, positive polarity. The oscilloscope tests are written for a single channel oscilloscope. The use of a dual channel oscilloscope is permitted.

**NOTE:** Refer to Figure 5.00-8 for the scope pattern pertaining to the particular IM model being tested.

1. Connect the trigger input of the oscilloscope to the positive (+) "A" primary coil lead.
2. Connect the oscilloscope reading probe to the "G" lead of the Primary Coil Harness and attach the oscilloscope probe ground to an engine ground.

**NOTE:** The "G" lead pattern displays all firings of the unit.

**NOTE:** With the "G" lead connected DIRECTLY to the scope, the scope or meter should read 140 - 160 VDC.

**NOTE:** The VGF series of engines does not include the "G" lead in the Primary Coil Harness. Special pigtail adaptors are available from Waukesha Engine for use with oscilloscope testing.

**NOTE:** The patterns displayed on the oscilloscope should be similar in output (140 - 160 VDC) but may differ in the time base because of the timing disc speed or oscilloscope time base setting.

3. Operate the test bench. Observe the oscilloscope patterns. The patterns displayed should correspond with those in Figure 5.00-8.
4. Turn off the test bench.
5. If the patterns are not consistent with Figure 5.00-8, replace the IM's power board assembly (see "Ignition Module Repair" in this section).



## HALL-EFFECT PICKUP TEST

**NOTE:** Use the CEC Ignition Tester (P/N 475032) to test the Hall-effect pickup. If the tool is unavailable, use an ohmmeter and a source of 8 - 12 VDC. The DC source may be a small battery or a commercial power supply.

### Hall-effect Pickup Testing On Engine With CEC Ignition Tester

The CEC Ignition Tester (P/N 475032) is designed to quickly troubleshoot the various components of the IM system (see Figure 5.00-10).

The Ignition Tester instruction that follow check the timing disc/gear magnets, Hall-effect pickup, and the wiring up to the IM.

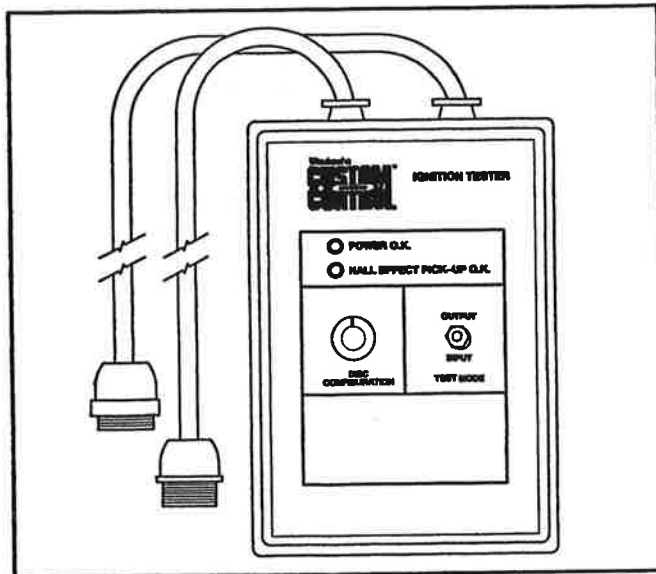


Figure 5.00-10. CEC Ignition Tester

## ⚠ WARNING

Verify that the engine is purged of all fuel gas prior to using the test unit. Failure to do so may cause the engine to rotate or start which could cause severe personal injury or engine damage.

## ⚠ WARNING

Do not install, set up, maintain, or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

**⚠ CAUTION** Disconnect power supply to Ignition Module before completing test with CEC Ignition Tester. Electrical test equipment may be damaged if the tests are not performed properly.

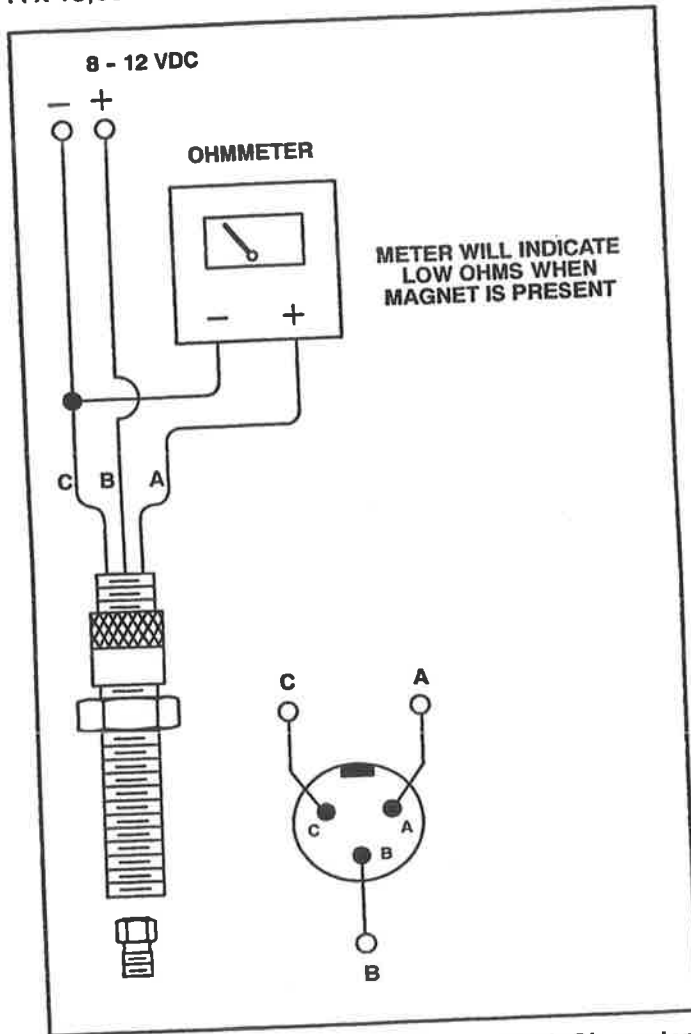
1. Disconnect power from IM.
  2. Place the "OUTPUT/INPUT" switch on the Ignition Tester to the "INPUT" position.
  3. Disconnect the 7 pin Power Pickup Harness from the IM.
  4. Plug the female cable from the Ignition Tester into the IM 7 pin connector.
  5. Plug the male cable from the Ignition Tester into the free end of the 7 pin Power Pickup Harness.
  6. Apply 10 - 32 VDC power to the IM. The green "POWER O.K." LED on the Ignition Tester will light indicating power is applied to the IM. The LED does not indicate that the power supply is within specification, but that power is applied.
  7. Rotate the engine so that one of the timing magnets is opposite the Hall-effect pickup. The "HALL EFFECT PICK-UP O.K." LED should light indicating proper operation of the Hall-effect pickup. If the LED does not light, this indicates that a problem exists with the Hall-effect pickup, the Power Pickup Harness, or the pickup air gap is exceeding gap tolerance.
- NOTE:** The CEC Ignition Tester can also be used to complete a test of the IM. Refer to "Testing The IM With The CEC Ignition Tester" earlier in this section to perform the test.
8. After testing is complete, disconnect the Ignition Tester and reconnect the Power Pickup Harness to the IM.

# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

## Hall-effect Pickup Testing Off Engine With Ohmmeter

**NOTE:** Use Simpson Model 260 or equivalent analog volt-ohmmeter to perform this test.

1. Connect the ohmmeter to the pins "A" and ground "C" (see Figure 5.00-11). Set the ohmmeter scale to  $R \times 10,000$ .



**Figure 5.00-11. Hall-effect Pickup Test With Ohmmeter**

2. Connect the positive lead of an 8 - 12 volt power supply to the "B" pin and the negative lead to the "C" pin.
3. Observe the ohmmeter while moving a magnet (P/N 305509) or timing disc with magnets directly in front of the Hall-effect pickup. The ohmmeter should read low ohms with the magnet in place.
4. If the meter reads infinite ohms (no deflection) with the magnet in place, replace the Hall-effect pickup.

## Hall-effect Pickup Testing On Engine With Ohmmeter

### **WARNING**

Turn the fuel and ignition OFF when performing this test with the Hall-effect pickup on the engine. Failure to shut the fuel and ignition off may result in an exhaust explosion causing severe engine damage and/or personal injury or death.

1. Reset Hall-effect pickup gap prior to test by completing the following steps:
  - A. Thread the Hall-effect pickup into the pickup mounting hole until the pickup comes in contact with the timing disc/gear.
  - B. Scribe a reference mark on the Hall-effect pickup and at the same point mark the housing or pickup bracket.
  - C. Using the reference mark on the pickup as the starting point, turn out the Hall-effect pickup counterclockwise to the amount listed in Table 5.00-14 to set the pickup to timing disc clearance.
  - D. After the clearance is set, snug the locking nut.

**Table 5.00-14. Hall-effect Pickup Air Gap**

ENGINE MODEL	HALL-EFFECT PICKUP GAP
VGF 6 And 8 Cylinder	3/4 Turn Out ( $\pm 1/16$ of a turn)
VGF 12 And 16 Cylinder	3/4 Turn Out ( $\pm 1/16$ of a turn)
VHP 6, 12, and 16 Cylinder	3/4 Turn Out ( $\pm 1/16$ of a turn)
AT25 12 Cylinder	3/4 Turn Out ( $\pm 1/16$ of a turn)
AT27 8 Cylinder (Cam Gear and Flywheel Pickup)	1 Full Turn Out (+0, -1/16 of a turn)
AT27 12 Cylinder (Cam Gear and Flywheel Pickup)	1 Full Turn Out (+0, -1/16 of a turn)

**NOTE:** Use Simpson Model 260 or equivalent analog volt-ohmmeter to perform this test.

2. Connect an ohmmeter to the pins "A" and ground "C" (see Figure 5.00-11). Set the ohmmeter scale to  $R \times 10,000$ .
3. Connect the positive lead of an 8 - 12 volt power supply to pin "B" and the negative lead to pin "C."



4. Observe the ohmmeter while cranking the engine over with the starter (NO fuel or ignition). The ohmmeter should read low ohms every time a magnet passes by the pickup.

5. If the meter reads infinite ohms (no deflection) with a magnet in place, replace the Hall-effect pickup.

### IGNITION COILS TESTING

The following test is to check the resistance of the primary and secondary wiring in the ignition coils. Replace any coils not measured to be within the stated ranges.

**NOTE:** The use of an ohmmeter is required for the following test.

## ⚠ WARNING

**Disconnect the power supply to the Ignition Module when servicing the Ignition system. Failure to disconnect the power supply can result in electrical shock causing personal injury or death.**

1. Disconnect the power supply to the IM.
2. Disconnect the primary electrical wiring from the coil(s) to be tested.
3. Disconnect the secondary wiring (spark plug wire) from the coil(s) to be tested.
4. Connect the ohmmeter probes to the locations listed in Table 5.00-15.

**Table 5.00-15. Coil Resistance**

COIL P/N	PRIMARY	SECONDARY
60615F	0.2 - 0.4 Ohms (Pin A To Pin B)	8000 - 9600 Ohms (Output To Case)
69694	0.1 - 0.2 Ohms (Pin + To Pin -)	5500 - 6900 Ohms (Negative To H.V. Cup)
69694E	0.3 - 0.5 Ohms (Pin A To Pin B)	7500 - 10,200 Ohms (Flange To H.V. Cup)
69694F	0.3 - 0.5 Ohms (Pin A To Pin B)	7500 - 10,200 Ohms (Flange To H.V. Cup)
69694G	0.3 - 0.5 Ohms (Pin A To Pin B)	7200 - 10,200 Ohms (Flange To H.V. Cup)

5. Record the ohmmeter reading and compare results with those in Table 5.00-15.

**NOTE:** Secondary resistance will vary somewhat with temperature.

6. If the readings are acceptable, connect the primary and secondary wiring to the coil. Replace the ignition coil if the readings are not within specification and connect the primary and secondary wiring to the coil.

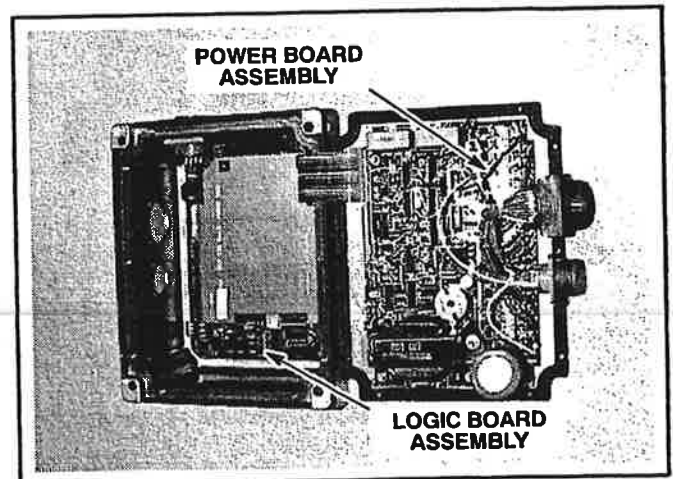
7. Repeat this procedure for all ignition coils tested.

8. Connect power supply to the IM.

### IGNITION MODULE REPAIR

**NOTE:** To retain Canadian Standards Association (CSA) approval for a Custom Engine Control<sup>®</sup> IM, the module **MUST** be returned to the manufacturer for any modifications required to the circuit board (disassembly, board replacement). A circuit board modified by anyone other than the manufacturer will no longer be CSA approved. **This is a CSA requirement!**

This section contains replacement procedures for the circuit board assemblies located inside the IM. The two circuit boards located inside the IM are the power board assembly and logic board assembly (see Figure 5.00-12). Once a failed board is diagnosed, this section is to be used to remove and replace the defective board(s) and gaskets.



**Figure 5.00-12. View Of Circuit Board Assemblies Inside Ignition Module**

# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

The IM must be subjected to the five bench tests (Performance, Firing Pattern, Ignition Timing, Oscilloscope, and Storage Capacitor Voltage Pattern) at elevated, 150° F (65° C) temperature as described previously in this section after repair, to verify that the ignition meets the original specifications. After the troubleshooting section has been used to determine the problem component(s), this section will be used to remove and replace the internal boards. Use the Figure 5.00-3 and Table 5.00-5 to identify the proper part(s) and part number(s).

**NOTE:** Replacement of electrical components located on the circuit boards is not permitted. Each circuit board is to be replaced as an assembly.

Use a IM Gasket/Hardware Kit (P/N A740815) when doing any repair work on a IM. The kit contains all gaskets and insulated pads needed for the IM's re-assembly. See Table 5.00-5 for a list of components found in this kit.

**CAUTION** Use a static mat and an electrical wrist strap when repairing a Ignition Module. Static charges can permanently damage the Ignition Module's internal circuit boards.

## Required Equipment

- Static Mat
- Wrist Strap
- 3/16" Regular Screwdriver
- #2 Phillips Screwdriver
- 1/2" Wrench
- 1/4" Nutdriver

## IGNITION MODULE DISASSEMBLY

**NOTE:** All IMs MUST be retested as described in "Ignition Module Testing" whenever repairs (including assembly and disassembly) take place.

Place the IM on a static mat. The technician must use a wrist strap to reduce the possibility of static charges being applied to the circuit boards.

## Separating Power Board And Logic Board Assemblies

1. Before disassembling IM, check and note the setting of the timing switches "A" and "B" on the side of the IM. If the timing switch position(s) change during disassembly/reassembly, you will know what position they were set to prior to disassembly.
2. Remove the eight 6-32 x 3/8" screws securing the 7 pin and 10 or 19 pin circular connectors to the IM housing (see Figure 5.00-13).

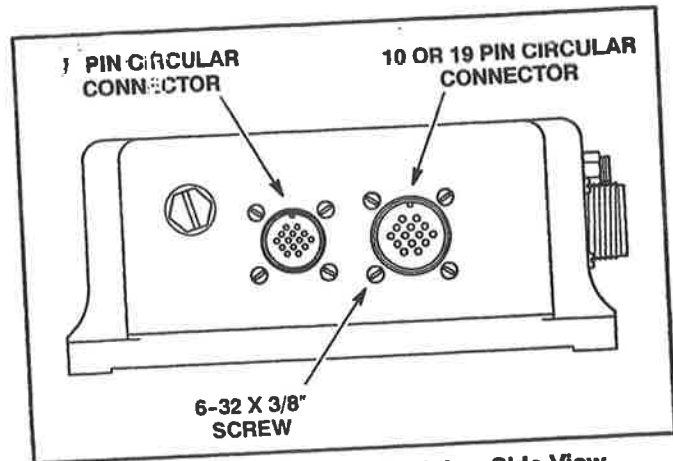


Figure 5.00-13. Ignition Module - Side View

3. Rotate the IM so the backplate is facing upward and place IM onto the static mat.
4. Remove the ten 8-32 x 1/2" seal screws that secure the backplate to the IM housing (see Figure 5.00-14).

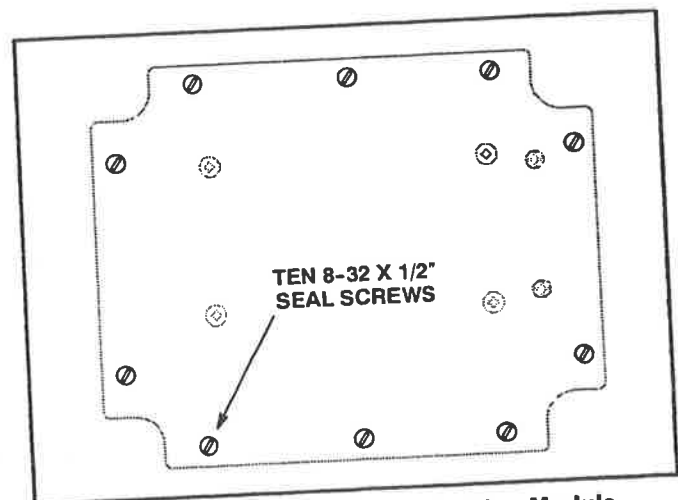


Figure 5.00-14. Backplate Of Ignition Module

## IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

5. Carefully push the two circular connectors (the 7 pin connector and the 10 or 19 pin connector) into the IM housing.

6. **Being careful not to damage any wires**, remove the backplate with the power board assembly still attached. The power board assembly and logic board assembly are connected with a ribbon cable.

7. Disconnect the ribbon cable from the power board assembly.

8. Remove the gasket from IM housing and/or backplate and clean both mounting surfaces.

### Disassembling Power Board Assembly

1. Remove the gaskets from the two circular connectors (the 7 pin connector and the 10 or 19 pin connector).

2. Remove the two screws holding Q1A and Q1B in place from the backside of the backplate (see Figure 5.00-15 and Figure 5.00-16).

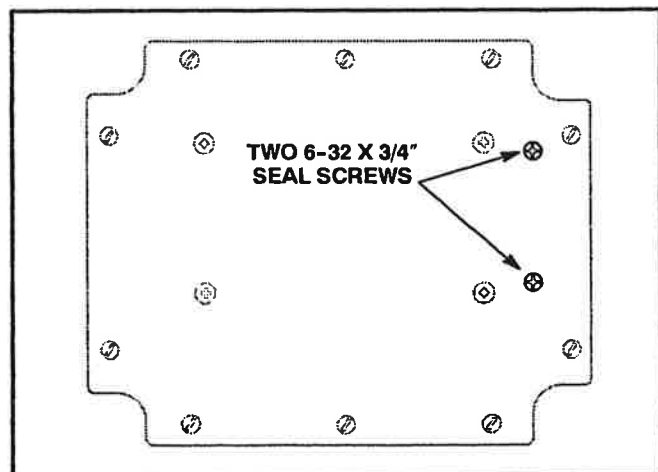


Figure 5.00-15. Backplate Of Ignition Module

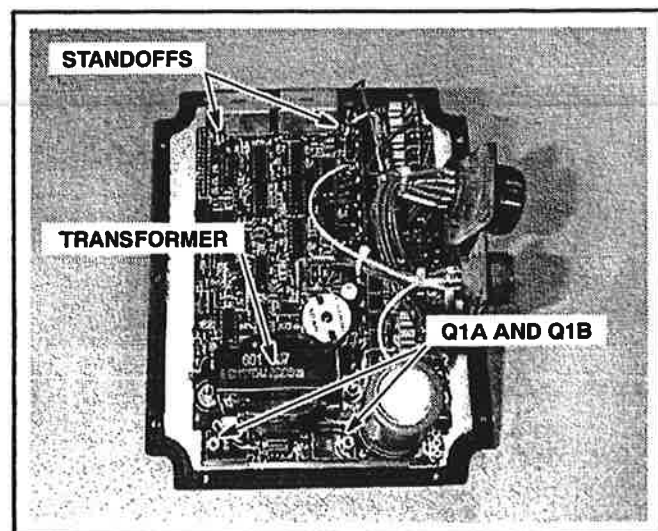


Figure 5.00-16. Power Board Assembly Inside Ignition Module

3. Using a nutdriver, remove the two standoffs on the topside of power board assembly opposite of transformer (see Figure 5.00-16).

4. Remove the two standoffs, flat washers, and lock washers securing transformer to power board assembly.

5. Carefully lift the power board assembly off of the backplate while holding transformer (transformer is NOT mounted to board).

6. Leave remaining four screws and standoffs on backplate (see Figure 5.00-17).

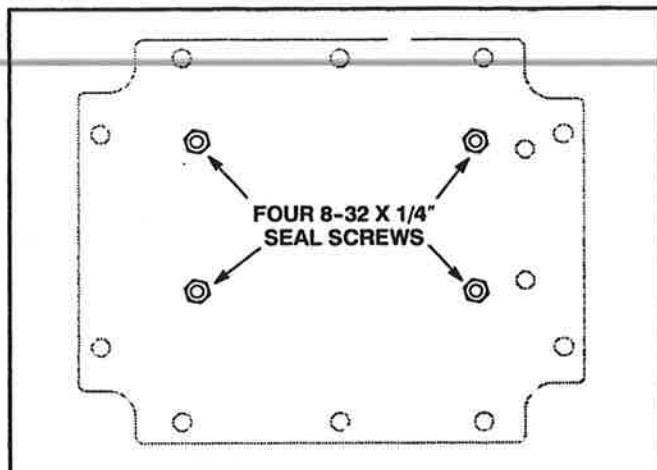


Figure 5.00-17. Remaining Installed Screws And Standoffs On Backplate

### Disassembling Logic Board Assembly

1. Remove the white caps from the timing switches "A" and "B" on side of the IM.

2. Using a wrench, remove the two securing nuts attaching the timing switches to the IM housing.

3. Remove the four screws holding the ground plane to logic board assembly and lift out ground plane (see Figure 5.00-18).

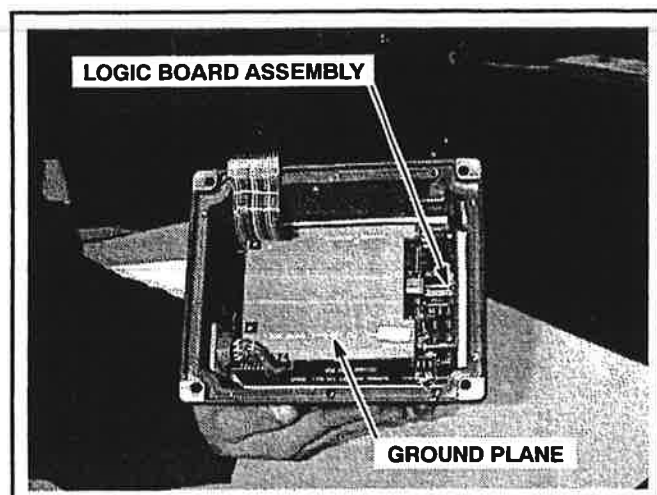


Figure 5.00-18. Logic Board Assembly

## IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING

4. Remove the four 6-32 x 3/8" screws securing the 14 pin circular connector to the IM housing (see Figure 5.00-19).

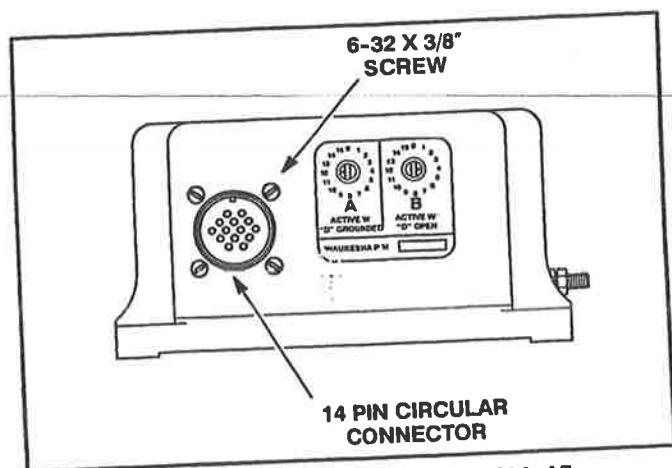


Figure 5.00-19. Ignition Module - Side View

5. Carefully push the 14 pin circular connector into IM housing.
6. Using a nut driver, remove the four standoffs holding the logic board assembly in place.
7. Lift up on the end of the logic board assembly opposite of the timing switches. Carefully remove the logic board assembly by sliding the circuit board up and away from the timing switch holes.
8. Remove the gasket from the timing switch knobs and the gasket from the 14 pin circular connector.

### IGNITION MODULE ASSEMBLY

#### Assembling Logic Board Assembly

1. Install new gasket onto the timing switches.
2. Install new gasket onto the 14 pin circular connector on the logic board assembly.
3. Carefully position the logic board assembly above the open end of the IM housing with the components facing up.
4. Slide the timing switch end of the logic board assembly into the IM housing.
5. Continue to slide the circuit board assembly into the IM housing. Make sure that the timing switches are placed into the appropriate holes in the housing.
6. Verify that the logic board assembly is sitting flat in the IM housing.
7. Place the 14 pin circular connector in hole in IM housing and fasten connector with screws.

8. Install the two securing nuts onto the timing switches securing the timing switches to the housing. Tighten nuts alternately and carefully so standoff holes align with the holes on the logic board assembly.

9. If necessary, adjust timing switches "A" and "B" so that the switches are in the correct/same position they were before disassembly and reassembly of the IM.

10. Install white caps onto timing switches "A" and "B" on IM.

11. Install the four standoffs mounting logic board assembly to housing and tighten with nutdriver (do not over tighten).

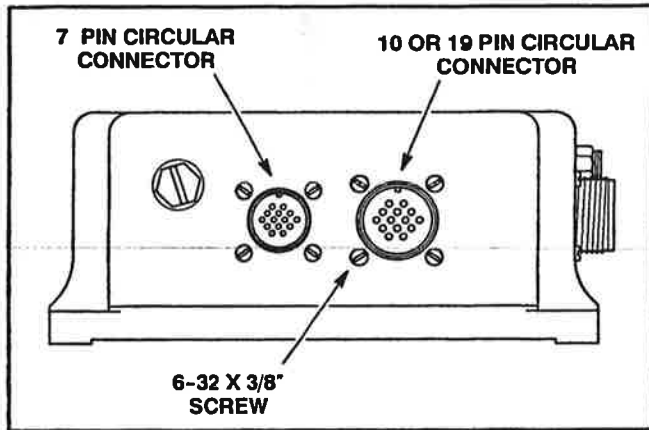
12. Using four screws, mount the ground plane to the standoffs on the logic board assembly.

#### Assembling Power Board Assembly

1. Place power board assembly on backplate with transformer on screws (with mounting screws and standoffs still in position on backplate).
2. Place a flat washer then lock washer on each screw holding transformer.
3. Place a standoff on each of the four screws holding the power board assembly on backplate and tighten standoffs with nutdriver.
4. Install two screws (6-32 x 3/4") through bottom of backplate, mounting Q1A and Q1B.
5. Install new gaskets on the 7 pin circular connector and the 10 or 19 pin circular connector.
6. Install new gasket on IM housing.

#### Completing IM Assembly

1. Plug ribbon cable from logic board assembly into power board assembly (note pin orientation).
2. Place circular connectors (7 pin connector and 10 or 19 pin connector) in holes in IM housing and mount connectors with appropriate screws (make sure gaskets are in place) (see Figure 5.00-20).
3. Screw backplate to housing using appropriate screws.
4. **The IM must be subjected to the five bench tests (Performance, Firing Pattern, Ignition Timing, Oscilloscope, and Storage Capacitor Voltage Pattern) at elevated, 150° F (65° C) temperature to verify that the ignition meets the original specifications.**



**Figure 5.00-20. Ignition Module - Side View**

## TOOL DEFINITIONS

**Analog Volt Ohmmeter (VOM):** An industry standard analog meter such as the Simpson 260 VOM (or equal) used to measure AC voltage, DC voltage, Amperes and Ohms in electrical circuits. Some voltmeters use reverse polarity, which will give incorrect results.

**Crimping Tools, Wire Cutters, And Wire Strippers:** Tools which are useful in making electrical connections. Electrical connections that are soldered after being crimped with ratchet style crimpers offer the best connections possible. Soldering protects the exposed copper of a copper wire from corroding due to H<sub>2</sub>S or oxidation. Ratchet crimpers provide uniform crimps with proper compression regardless of the technician.

**Digital Volt Ohmmeter (VOM) (Optional):** A tool that measures voltages and resistances more accurately than analog VOM meters, but may have problems displaying these readings in high electrical noise environments such as around CD ignition systems. Features that are an advantage over analog meters are: peak hold, peak minimum and maximum storage.

**Megger:** A useful tool to help find voltage leakage between wires or ground when an ohmmeter does not detect a short. Meggers use a 500 volt signal to test for short circuits that may only occur under conditions of high voltage. This voltage is similar to the Capacitor Discharge (CD) ignition voltage and will help to detect moisture problems in conduits, connectors, and ignition primary harnesses.

**Oscilloscope:** An instrument in which the variations in voltage appear and can be measured by reading a visible wave form. A single or dual channel with external trigger capabilities and two 10:1 probes are required (100:1 probes are also acceptable). A 10 MHz oscilloscope is fast enough for field requirements (digital scope is not required).

**Timing Light:** A tool which is used to measure an engine's ignition timing. An inductive type timing light functions by clamping the inductive pickup over the spark plug wire and pointing the light emitting end of the timing light onto a timing strip usually located on the engine's flywheel. It can also be used to determine if energy stored in the storage capacitor is being delivered to the primary of the coil. Battery power types (two "D" cells) are the most convenient.

# IGNITION MODULE DIAGNOSTICS AND TROUBLESHOOTING



## ALPHABETICAL DEX

## A

Analog Volt Ohmmeter .....	5.00 - 25
AT Ignition Module Operation .....	3.00 - 1

## C

Capacitive Discharge And Grounding .....	1.05 - 3
CEC Ignition Tester - Hall-effect Pickup Testing .....	5.00 - 19
CEC Ignition Tester - Ignition Module Testing .....	5.00 - 8
Commercial Quality Natural Gas .....	1.10 - 5
Components .....	1.10 - 3
Conversion Tables .....	1.05 - 1
Crimping Tools .....	5.00 - 25

## D

Definitions .....	1.10 - 5
Commercial Quality Natural Gas .....	1.10 - 5
Detonation .....	1.10 - 5
Digester Gas .....	1.10 - 5
Field Gas .....	1.10 - 5
Hall-effect Pickup .....	1.10 - 5
HD-5 .....	1.10 - 5
Landfill Gas .....	1.10 - 5
LED .....	1.10 - 5
Low Btu Fuel .....	1.10 - 5
Magnetic Pickup .....	1.10 - 5
Natural Gas .....	1.10 - 5
Propane .....	1.10 - 5
Sinking Output .....	1.10 - 5
Sourcing Output .....	1.10 - 5
WKI .....	1.10 - 5
Definitions - Tools .....	5.00 - 25
Analog Volt Ohmmeter .....	5.00 - 25
Digital Volt Ohmmeter .....	5.00 - 25
Megger .....	5.00 - 25
Oscilloscope .....	5.00 - 25
Timing Light .....	5.00 - 25
Wire Cutters .....	5.00 - 25
Wire Strippers .....	5.00 - 25

Detonation .....	1.10 - 5
Detonation Sensing Module Interface .....	1.10 - 2
Diagnostics .....	5.00 - 1
Diagnostics Chart .....	5.00 - 2
Crimping Tools .....	5.00 - 25
Digester Gas .....	1.10 - 5
Digital Volt Ohmmeter .....	5.00 - 25

## E

Electrical Connections - AT .....	3.05 - 2
Grounding .....	3.05 - 2
Ignition Module Wiring .....	3.05 - 4
Power Requirements .....	3.05 - 2
Power Source Wiring .....	3.05 - 2
Wiring Diagrams .....	3.05 - 4
Wiring Harness Connections .....	3.05 - 2
Electrical Connections - VGF .....	4.05 - 2
Grounding .....	4.05 - 2
Ignition Module Wiring .....	4.05 - 4
Power Requirements .....	4.05 - 2
Power Source Wiring .....	4.05 - 2
Wiring Diagrams .....	4.05 - 4
Wiring Harness Connections .....	4.05 - 2
Electrical Connections - VHP .....	2.05 - 2
Grounding .....	2.05 - 2
Ignition Module Wiring .....	2.05 - 4
Power Requirements .....	2.05 - 2
Power Source Wiring .....	2.05 - 2
Wiring Diagrams .....	2.05 - 4
Wiring Harness Connections .....	2.05 - 2
Engines Served .....	1.10 - 3

## F

Field Gas .....	1.10 - 5
-----------------	----------

## G

Grounding .....	1.05 - 3
-----------------	----------

## H

Hall-effect Pickup .....	1.10 - 5
HD-5 .....	1.10 - 5
How To Use This Manual .....	vii



# APPENDIX A

## I

Ignition Module .....	1.10 - 1
AT Engines .....	3.00 - 1
Components .....	1.10 - 3
Definitions .....	1.10 - 5
Description .....	1.10 - 1
Detonation Sensing Module Interface .....	1.10 - 2
Diagnostics .....	5.00 - 1
Electrical Connections - AT .....	3.05 - 2
Electrical Connections - VGF .....	4.05 - 2
Electrical Connections - VHP .....	2.05 - 2
Engines Served .....	1.10 - 3
Mounting - AT .....	3.05 - 1
Mounting - VGF .....	4.05 - 1
Mounting - VHP .....	2.05 - 1
Operator Interface .....	1.10 - 3
Repair .....	5.00 - 21
Theory Of Operation .....	1.10 - 4
Timing Adjustments - AT .....	3.10 - 1
Timing Adjustments - VGF .....	4.10 - 1
Timing Adjustments - VHP .....	2.10 - 1
Troubleshooting .....	5.00 - 1
VGF Engines .....	4.00 - 1
VHP Engines .....	2.00 - 1
Repair .....	5.00 - 21
Ignition Module Assembly .....	5.00 - 24
Assembling Logic Board Assembly .....	5.00 - 24
Assembling Power Board Assembly .....	5.00 - 24
Completing	
Ignition Module Assembly .....	5.00 - 24
Ignition Module Disassembly .....	5.00 - 22
Disassembling	
Logic Board Assembly .....	5.00 - 23
Disassembling	
Power Board Assembly .....	5.00 - 23
Separating Power Board And	
Logic Board Assemblies .....	5.00 - 22
Ignition Module Operation - AT .....	3.00 - 1
12V-AT25GL .....	3.00 - 3
Air Gap Setting .....	3.00 - 4
Location Of Hall-effect Pickup .....	3.00 - 3
12V-AT27GL .....	3.00 - 2
Air Gap Setting .....	3.00 - 3
Location Of Hall-effect Pickups .....	3.00 - 2
8L-AT27GL Engines .....	3.00 - 1
Air Gap Setting .....	3.00 - 2
Location Of Hall-effect Pickup .....	3.00 - 1

Ignition Module Operation - VGF .....	4.00 - 1
12 Cylinder .....	4.00 - 1
Air Gap Setting .....	4.00 - 2
Location Of Hall-effect Pickup .....	4.00 - 2
16 Cylinder .....	4.00 - 1
Air Gap Setting .....	4.00 - 2
Location Of Hall-effect Pickup .....	4.00 - 2
6 Cylinder .....	4.00 - 1
Air Gap Setting .....	4.00 - 1
Location Of Hall-effect Pickup .....	4.00 - 1
8 Cylinder .....	4.00 - 1
Air Gap Setting .....	4.00 - 1
Location Of Hall-effect Pickup .....	4.00 - 1
Ignition Module Operation - VHP .....	2.00 - 1
12 Cylinder	
Air Gap Setting .....	2.00 - 2
Location Of Hall-effect Pickup .....	2.00 - 1
Timing Disc Alignment .....	2.00 - 2
16 Cylinder	
Air Gap Setting .....	2.00 - 4
Location Of Hall-effect Pickup .....	2.00 - 4
Timing Disc Alignment .....	2.00 - 4
5115GL	
Air Gap Setting .....	2.00 - 4
Location Of Hall-effect Pickup .....	2.00 - 4
Timing Disc Alignment .....	2.00 - 4
6 Cylinder	
Air Gap Setting .....	2.00 - 2
Location Of Hall-effect Pickup .....	2.00 - 1
Timing Disc Alignment .....	2.00 - 2

## L

Landfill Gas .....	1.10 - 5
LED - Definition .....	1.10 - 5
Low Btu Fuel .....	1.10 - 5

## M

Magnetic Pickup .....	1.10 - 5
Megger .....	5.00 - 25
Mounting Ignition Module - AT .....	3.05 - 1
Mounting Ignition Module - VGF .....	4.05 - 1
Mounting Ignition Module - VHP .....	2.05 - 1

## N

Natural Gas .....	1.10 - 5
-------------------	----------



**O**

Operator Interface ..... 1.10 - 3  
 Oscilloscope ..... 5.00 - 25

**P**

Power Requirements ..... 1.05 - 3  
 Propane ..... 1.10 - 5

**S**

Safety Introduction ..... 1.00 - 1  
 Acids ..... 1.00 - 2  
 Batteries ..... 1.00 - 2  
 Body Protection ..... 1.00 - 2  
 Chemicals ..... 1.00 - 2  
     Cleaning Solvents ..... 1.00 - 2  
     General ..... 1.00 - 2  
     Liquid Nitrogen/Dry Ice ..... 1.00 - 2  
 Components ..... 1.00 - 2  
     Heated Or Frozen ..... 1.00 - 2  
     Interference Fit ..... 1.00 - 2  
     Cooling System ..... 1.00 - 3  
     Electrical ..... 1.00 - 3  
         General ..... 1.00 - 3  
         Ignition ..... 1.00 - 3  
     Equipment Repair And Service ..... 1.00 - 1  
     Exhaust ..... 1.00 - 3  
     Fire Protection ..... 1.00 - 3  
     Fuels ..... 1.00 - 4  
         Gaseous ..... 1.00 - 4  
         General ..... 1.00 - 4  
         Liquid ..... 1.00 - 4  
     Intoxicants And Narcotics ..... 1.00 - 4  
     Pressurized Fluids/Gas/Air ..... 1.00 - 4  
     Protective Guards ..... 1.00 - 4  
     Safety Tags And Decals ..... 1.00 - 1  
     Springs ..... 1.00 - 4  
     Tools ..... 1.00 - 5  
         Electrical ..... 1.00 - 5  
         Hydraulic ..... 1.00 - 5  
         Pneumatic ..... 1.00 - 5  
     Weight ..... 1.00 - 5  
     Welding ..... 1.00 - 5  
         General ..... 1.00 - 5  
         On Engine ..... 1.00 - 5

Sinking Output ..... 1.10 - 5  
 Sourcing Output ..... 1.10 - 5

**T**

Theory Of Operation ..... 1.10 - 4  
     Hall-effect Pickup ..... 1.10 - 4  
     Ignition Module ..... 1.10 - 4  
     Magnetic Pickup ..... 1.10 - 4  
 Timing Adjustments - AT ..... 3.10 - 1  
     Ignition Timing Set ..... 3.10 - 1  
     Pre-start Checklist ..... 3.10 - 1  
     Steps To Adjust Timing ..... 3.10 - 2  
 Timing Adjustments - VGF ..... 4.10 - 1  
     Ignition Timing Set ..... 4.10 - 1  
     Pre-start Checklist ..... 4.10 - 1  
     Steps To Adjust Timing ..... 4.10 - 2  
 Timing Adjustments - VHP ..... 2.10 - 1  
     Discharging The Storage Capacitor ..... 2.10 - 3  
     Ignition Timing Set ..... 2.10 - 1  
     Pre-start Checklist ..... 2.10 - 1  
     Steps To Adjust Timing ..... 2.10 - 2  
 Timing Light ..... 5.00 - 25  
 Troubleshooting ..... 5.00 - 4  
     Components Part Numbers ..... 5.00 - 6  
     Hall-effect Pickup Testing ..... 5.00 - 19  
         CEC Ignition Tester ..... 5.00 - 19  
         Ohmmeter Testing - Off Engine ..... 5.00 - 20  
         Ohmmeter Testing - On Engine ..... 5.00 - 20  
         Ignition Coils Testing ..... 5.00 - 21  
     Ignition Module - Bench Test ..... 5.00 - 16  
         7 Pin And 3 Pin Connector Testing ..... 5.00 - 18  
         Firing Pattern Testing ..... 5.00 - 17  
         Ignition Timing Test ..... 5.00 - 17  
         Oscilloscope Testing ..... 5.00 - 18  
         Performance Testing ..... 5.00 - 17  
         Storage Capacitor Voltage  
             Pattern Testing ..... 5.00 - 18  
     Ignition Module - On Engine ..... 5.00 - 8  
         7 Pin And 3 Pin Connector Testing ..... 5.00 - 12  
         CEC Ignition Tester ..... 5.00 - 8  
         Firing Pattern Testing ..... 5.00 - 14  
         Ignition Timing Testing ..... 5.00 - 11  
         Ohmmeter Testing ..... 5.00 - 9  
         Oscilloscope Testing ..... 5.00 - 13  
         Storage Capacitor Voltage  
             Pattern Testing ..... 5.00 - 13  
     Ignition Module Components ..... 5.00 - 4  
     Ignition Module Repair ..... 5.00 - 21  
         Assembly ..... 5.00 - 24  
         Disassembly ..... 5.00 - 22

## APPENDIX A

Tool Definitions .....	5.00 - 25
Analog Volt Ohmmeter .....	5.00 - 25
Crimping Tools .....	5.00 - 25
Digital Volt Ohmmeter .....	5.00 - 25
Megger .....	5.00 - 25
Oscilloscope .....	5.00 - 25
Timing Light .....	5.00 - 25
Wire Cutters .....	5.00 - 25
Wire Strippers .....	5.00 - 25
Wiring Harnesses Part Numbers .....	5.00 - 6
Troubleshooting Chart .....	5.00 - 3

### V

VGF Ignition Module Operation .....	4.00 - 1
VHP Ignition Module Operation .....	2.00 - 1
VHP Timing Disc Alignment .....	2.00 - 1
12 Cylinder .....	2.00 - 1
16 Cylinder .....	2.00 - 4
5115GL .....	2.00 - 4
6 Cylinder .....	2.00 - 1

### W

Wire Cutters .....	5.00 - 25
Wire Strippers .....	5.00 - 25
Wiring - AT .....	3.05 - 2
Grounding .....	3.05 - 2
Ignition Module Wiring .....	3.05 - 4
Power Requirements .....	3.05 - 2
Power Source Wiring .....	3.05 - 2
Wiring Diagrams .....	3.05 - 4
Wiring Harness Connections .....	3.05 - 2
Wiring - VGF .....	4.05 - 2
Grounding .....	4.05 - 2
Ignition Module Wiring .....	4.05 - 4
Power Requirements .....	4.05 - 2
Power Source Wiring .....	4.05 - 2
Wiring Diagrams .....	4.05 - 4
Wiring Harness Connections .....	4.05 - 2
Wiring - VHP .....	2.05 - 2
Grounding .....	2.05 - 2
Ignition Module Wiring .....	2.05 - 4
Power Requirements .....	2.05 - 2
Power Source Wiring .....	2.05 - 2
Wiring Diagrams .....	2.05 - 4
Wiring Harness Connections .....	2.05 - 2
Wiring Requirements .....	1.05 - 2
WKI - Definition .....	1.10 - 5

**WAUKESHA ENGINE DIVISION, DRESSER EQUIPMENT GROUP, INC.  
EXPRESS LIMITED WARRANTY FOR CUSTOM ENGINE CONTROLS®**

**INTRODUCTION**

The Custom Engine Control® are sold as standard, or as options on new Engines or as Genuine Service Parts, and includes the Detonation Sensing Module (DSM), Air Fuel Module (AFM), Turbocharger Control Module (TCM), and Ignition Module (IM), or any other control device identified as a CEC product.

**I. TERMS OF EXPRESS LIMITED WARRANTY**

Waukesha Engine Division warrants that it will repair or replace, AT ITS ELECTION AND EXPENSE, any CEC installed on an engine, or Enginator®, or product (hereinafter referred to as "Products") manufactured by Waukesha, or purchased as a Genuine Service Part, which proves to have had a defect in material or workmanship.

**II. TERM LIMITATIONS OF EXPRESS LIMITED WARRANTY**

- A. This coverage shall commence upon initial new Products start-up date or the purchase date, in the case of service parts sales, and shall expire upon the earlier of the following:
1. New Products
    - A. 12 months after the initial new Product start-up date; or
    - B. 24 months after the original shipment date of the covered Products by Waukesha Engine Division.
  2. Genuine Service Parts
    - A. 12 months from the date the CEC is put into service; or
    - B. 18 months from the purchase date.
- B. Notwithstanding the foregoing, Waukesha further warrants that it will repair or replace, AT ITS ELECTION AND EXPENSE, any component of the Waukesha Product damaged as the direct result of a warrantable defect in a CEC product.

**III. WAUKESHA'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY**

Waukesha shall be responsible for:

- A. The repair or replacement, at Waukesha's election, of covered defective parts and all reasonable labor required regarding a warranted failure during the express limited warranty term. All such labor shall be provided by Waukesha's authorized contractor or distributor.
- B. For the repair of CECs installed on Products shipped from Waukesha, reasonable and necessary travel and expenses incurred by Waukesha's authorized contractor or distributor.
- C. Replacement of lubricating oil, coolant, filter elements, Waukesha supplied engine components, or other normal maintenance items that are contaminated and/or damaged as a direct result of a warranted failure.

**IV. OWNER'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY**

Owner shall be responsible for:

- A. The operation and maintenance of the Products within the guidelines established by Waukesha.
- B. Making the Products available to Waukesha or Waukesha's authorized contractors or distributors for any warranty repair, during normal business hours.
- C. All additional costs incurred for premium or overtime labor, should owner request that repairs be made on a premium or overtime schedule.
- D. All costs incurred as the result of removal or reinstallation of the Products as may be required to effect any warranted repair.
- E. All administrative costs and expenses resulting from a warranted failure.
- F. Any costs of transportation, towing, repair facilities, or associated costs.
- G. All travel, mileage, and other related Distributor costs and expenses associated with repair under the terms of the Service Parts Warranty.
- H. All additional labor time in excess of Waukesha's Labor Guide for the warrantable repair.
- I. Loss of revenue and loss of/or damage to real and/or personal property.

**V. LIMITATION OF WAUKESHA'S OBLIGATIONS**

The obligations of Waukesha under this express limited warranty shall be waived and voided, and Waukesha shall not, thereafter, be responsible for:

- A. Any failure resulting from owner or operator abuse or neglect, including but not by way of limitation, any operation, installation, application, or maintenance practice not in accordance with guidelines or specifications established by Waukesha; or
- B. Any failure resulting from unauthorized modifications or repairs of the Products; or
- C. Any failure resulting from overload, overspeed, overheat, accident, improper storage; or
- D. Failure of owner to promptly provide notice of a claimed defect; or
- E. Failure of Products for which Waukesha did not receive properly completed start-up reports; or
- F. Repairs of a covered failure performed with non-genuine Waukesha parts; or
- G. Repairs of a covered failure performed by non-authorized contractors or distributors; or
- H. Failure to make Products available to Waukesha or its authorized representatives; or
- I. Failure to supply documents such as drawings and specifications relating to the specific application of the Products; or
- J. Improper diagnosis of a Product problem for which a CEC product is replaced.
- K. Failure of Service Parts for which Waukesha did not receive proper documentation concerning the Service Parts purchase date from an authorized Waukesha Engine Distributor; or
- L. Any failure of a Service Part resulting from misapplication or improper repair procedures; or
- M. Any failure or damage resulting from the improper or extended storage of a Service Part; or
- N. Freight, Customs, Broker Fees, and Import Duties if appropriate documentation is not provided.

**VI. APPLICABILITY AND EXPIRATION**

The warranties set out above are extended to all owners in the original chain of distribution. The warranties and obligations of Waukesha shall expire and be of no further effect upon the dates of expiration of the applicable warranty periods.

**VII. WARRANTY ADMINISTRATION**

This warranty is administered exclusively by an authorized Waukesha Distributor. The invoice for the failed Service Parts must be provided to the Distributor to determine whether the warranty is applicable.

Contact the nearest authorized Waukesha Distributor for assistance with warranty matters or questions. The location of the nearest authorized Distributor is available by contacting Waukesha Engine Division at (414) 547-3311.

**THE FOREGOING SETS FORTH WAUKESHA'S ONLY OBLIGATIONS AND OWNERS' EXCLUSIVE REMEDY FOR BREACH OF WARRANTY, WHETHER SUCH CLAIMS ARE BASED ON BREACH OF CONTRACT, TORT (INCLUDING NEGLIGENCE AND STRICT LIABILITY), OR OTHER THEORIES, AND THE FOREGOING IS EXPRESSLY IN LIEU OF OTHER WARRANTIES WHATSOEVER EXPRESSED, IMPLIED, AND STATUTORY, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS.**

Notwithstanding the preceding, in no event shall Waukesha be liable for any direct, special, incidental, or consequential damages (whether denominated in contract, tort strict liability, negligence, or other theories) arising out of this Agreement or the use of any Products provided under this Agreement.

Any action arising hereunder or relating hereto, whether based on breach of contract, tort (including negligence and strict liability), or other theories must be commenced within two (2) years after the cause of action accrues or it shall be barred.

**BINDING ARBITRATION**

- (a) Buyer and Seller shall attempt, in good faith, to resolve any dispute arising out of or relating to this agreement, or the products and/or services provided hereunder, promptly by negotiation between executives. If the matter has not been resolved within sixty (60) days of a party's request for negotiation, either party may initiate arbitration as herein after provided.
- (b) Any dispute arising out of or related to this agreement or the products and/or services provided hereunder which has not been resolved by the negotiation procedure described above, shall be settled by binding arbitration administered by the American Arbitration Association in accordance with its Commercial Arbitration Rules and judgment on the award rendered by the arbitrator(s) may be entered in any court having jurisdiction thereof.
- (c) Unless Buyer and Seller otherwise agree in writing, the arbitration panel shall consist of three arbitrators. The arbitrator(s) shall have no authority to award punitive or other damages not measured by the prevailing party's actual damages and may not, in any event, make any ruling, finding or award that does not conform to the terms and condition of this agreement. The law of Texas shall govern.
- (d) The arbitration proceeding shall be conducted in English, in Dallas, Texas.

See Form M-462 for the most current warranty terms. Effective April 1, 1999

12

12





**Waukesha Engine Division**

# We welcome your comments

In order to continue bringing the best in Waukesha product information, we ask that you take a moment to let us know about any errors or omissions in this publication. Comments and suggestions are also welcome. Please use the self addressed, postage paid card attached.

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Please rate the manual by checking one.

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Very Good

Good

Fair

Poor



You can receive a **Free Gift** by simply filling out the self addressed, postage paid card attached below. Your engine's location and application are important to Waukesha Engine. This information will aid Waukesha's efforts in field campaigns and product promotions.

## Engine Information



Name / Title \_\_\_\_\_ Purchased from \_\_\_\_\_

Company \_\_\_\_\_

Address \_\_\_\_\_

City, State, Zip, Country \_\_\_\_\_

Phone / Fax / Email \_\_\_\_\_

Model# \_\_\_\_\_ Serial# \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

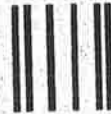
Please circle applicable codes below.

G - Gas Compression  
P - Power Generation  
M - Mechanical Drive

C - Continuous  
I - Intermittent  
S - Standby

G	P	M	C	I	S
G	P	M	C	I	S
G	P	M	C	I	S
G	P	M	C	I	S



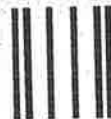


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Dresser Equipment Group, Inc.  
1000 West St. Paul Avenue  
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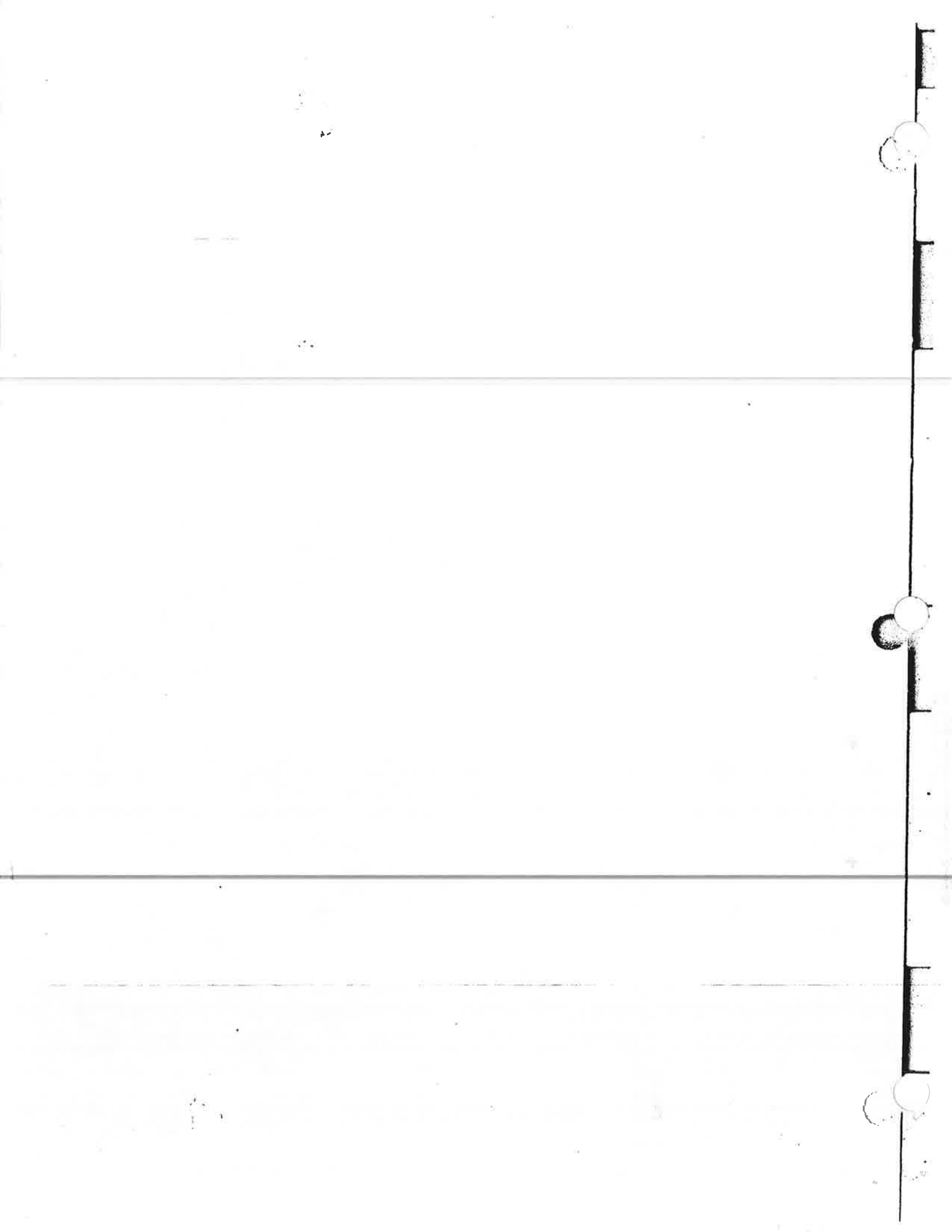
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