

REHS0371 January 1999

CATERPILLAR®

Special Instruction

i01011441

Installation And Initial Start Up Procedures For G3300 And G3400 Engines

SMCS Code: 1000-012

Engines:

G3304 (S/N: 37Y)
G3306 (S/N: 07Y)
G3406 (S/N: 4FD, 1RK)
G3408 (S/N: 6NB, 6FW)
G3408B (S/N: 6RJ)
G3408C (S/N: 3WR, 8YR)
G3412 (S/N: 7DB, 3NK, 8LW)
G3412C (S/N: 6ZM, 9RR)

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Introduction

This Special Instruction includes the installation procedures and the start up procedures for G3300 and G3400 engines. The correct start up adjustment of the engine is essential for the following reasons:

- long engine life
- good fuel economy
- · acceptable emissions

Service technicians should have a thorough understanding of the relationship between the fuel system and the ignition system. The technician must also be familiar with the Service Manual, "Systems Operation Testing And Adjusting" Section and the Service Manual, "Operation And Maintenance" Section.

References

- G3300 Gas Engine Performance, LEBQ4197
- G3400 Industrial Engine Performance, LEBQ6483
- G3400 Generator Set Engine Performance Data Books, LEBQ6484
- G3300 Service Manual
- G3400 Service Manual
- Methane Number Program, LEKQ6378
- EIS Diagnostic Code Card, RENR1234

Table 1

Tools	Tools Needed							
Part Number	Description							
7X - 1400	Electronic Tool Group(1)							
NEXG4511	Electronic Tool Group(1)							
140 - 2304	Electronic Control Programmer ²⁾							
8T - 0452	Manometer Gauge							
156-1060	Emissions Analyzer Group							
8T-5160	Setting Tool Group							

⁽¹⁾ For 3400 EIS engines only. Refer to Using The NEXG4511 Spark Ignited Engine Service Program Module, SEHS8806 for more information on using the Digital Diagnostic Tool. Also refer to Service Program Module For Spark Ignited Engines, NEXG4511. You must have the chip in order for the 7X-1400 Electronic Tool Group to work.

Required Information

Ignition Timing

A complete fuel analysis must be conducted prior to putting the engine into service. Obtain a fuel analysis in order to determine the BTU content and calculate the Methane Number. The BTU content indicates the amount of energy that is available in the fuel. The Methane Number indicates the ability of the fuel to be ignited. The Methane Number is determined when you input the constituents of the fuel into the Methane Number Program, LEKQ6378. Use the Methane Number and the Engine Performance Book, "Fuel Usage Guide" in order to determine the ignition timing.

Obtain several samples of fuel if the quality is expected to change. If the chemistry of the fuel will vary during engine operation, use the lowest expected value in order to determine ignition timing.

Maximum Load

Refer to the Engine Performance Book in order to determine the engine power derates for altitude, temperature, and Methane Number. Use the derate range in order to determine the maximum engine load.

Inlet Manifold Pressure At Full Load

For generator set applications, use the generator power output to determine the engine load. For other applications, use the inlet manifold pressure to estimate the engine load. The Engine Performance Book provides inlet manifold pressures for a specific timing and emissions setting. If the engine power is derated, interpolate the desired inlet manifold pressure between the 100 percent and the 75 percent load ratings.

Note: The inlet manifold pressure may be used if the engine timing and the exhaust oxygen are set properly.

Exhaust Oxygen Level

The 156-1060 Emissions Analyzer or equivalent is required in order to properly set up a gas engine. The engine should be set up at the desired full load with the data that was taken at 100 percent load. Do not exceed the maximum load.

Carburetor Adjustments

The carburetor and the gas pressure regulator require adjustment when the engine is installed. The initial factory settings are based on the following conditions:

- an ambient temperature of 25 °C (77 °F)
- a barometric pressure of 96 kPa (28.4 in Hg)
- the use of a natural gas pipeline with a Low Heating Value of 33.74 kJ/L (905 BTU/cu ft)

The factory ratings comply with SAE J1349 Standards. An engine that does not use natural gas may be shipped with optional orifices and valves. An engine of this type will be run with a catalyst and an air/fuel ratio control. Engine applications that do not use dry pipeline gas may be shipped with carburetor jets and valves for field installation. Contact your Caterpillar dealer for more information.

Gas Pressure Regulator

The gas pressure regulator requires adjustment when the engine is installed. Use only Caterpillar approved regulators in order to avoid problems with performance. A balance line for the regulator is required in all gas engines. This line compensates for changes in boost pressure or air filter restriction. Refer to the Systems Operation Manual for details.

Note: The supply line to the gas pressure regulator must be of adequate diameter in order to provide constant pressure to the regulator from idle to full load. Do not use supply lines that are smaller than the inlet to the pressure regulator.

Governors

It may be necessary to make one or more of the following governor adjustments during start-up:

- low idle speed
- high idle speed
- droop

⁽²⁾ For Engines equipped with ProAct Speed Control.

gain

Refer to the Service Manual for further information.

Hydramechanical

The Hydramechanical Governor is a simple governor for the G3300 and some of the G3400 applications that do not require close speed regulation. The standard Hydramechanical Governor has approximately 7 percent droop at 1800 rpm. Special springs can be ordered in order to lessen the droop.

Pressure Compensated Simple Governor (PSG)

The PSG Governor is a mechanical-hydraulic governor that is capable of isochronous speed control. The speed is controlled by a simple hand lever. A pneumatic control is available for remote speed control. A motor (24 VDC) is also available for remote speed control. Refer to Service Manual, SENR6514, "PSG Governor".

Flo-Tech

The Flo-Tech system is an electronic governor with an electrical actuator for the throttle. The electronic governor control provides a 0 - 200 mA signal to the Flo-Tech actuator in order to position the throttle. The position of the Flo-Tech actuator can not be observed. Instead, a signal voltage that indicates the throttle position is provided. A DC feedback voltage of 0.5 VDC corresponds to a closed throttle position. A signal voltage of 4.5 VDC corresponds to a fully open throttle position. Refer to Service Manual, RENR1356, "Flo-Tech Speed Control" for details.

The EG3P Hydraulic Actuator And The 2301A Electronic Governor

The 2301A electronic governor is used primarily for generator set applications. The EG-3P hydraulic actuator responds to electrical signals from the 2301A governor in order to position the throttle. Refer to Service Manual, SENR1196, "2301A Electric Governors".

ProAct Digital Speed Control

The ProAct digital speed control is an electronic governor that is based on a microprocessor. Adjustment of the ProAct control module requires the 140-2304 Electronic Control Programmer. The ProAct Actuator is electrically driven and connected directly to the throttle shaft. Refer to Service Manual, SENR1196, "ProAct Digital Speed Control".

Connect Gauges And Instruments

7X-1400 Electronic Tool Group

The Digital Diagnostic Tool (DDT) is used only for engines with the Caterpillar Electronic Ignition System (EIS). The DDT is used to program customer specified parameters such as information on the status of the engine and the DDT also reads the diagnostic codes.

Note: The DDT must have the Service Program Module For Spark Ignited Engines, NEXG4511 installed.

Measuring The Fuel/Air Delta Pressure

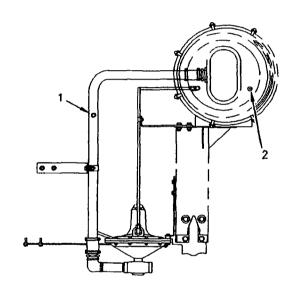
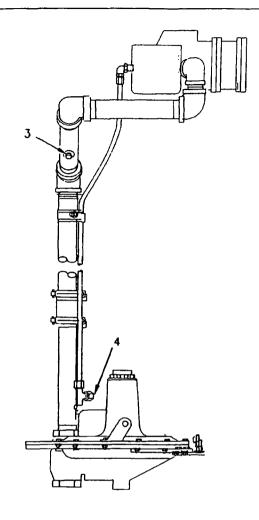


Illustration 1

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Low Pressure Gas Regulator

- (1) Gas Plug
- (2) Air Plug



High Pressure Gas Regulator

(3) Gas Plug

(4) Air Plug

The Water Manometer or the differential pressure gauge is required for the Impco fuel system and the Fisher gas regulator.

- · Turn the main gas valve OFF.
- Remove the plug (1,3) from the gas supply line to the mixer.
- Remove the plug (4) from the balance line on a high pressure system. Remove the plug (2) from the air cleaner on a system that has low pressure.
- Connect an 1U-5470 Engine Pressure Group or a water manometer between the two pressure taps with the proper adapter fittings.

Note: Install a shutoff valve between the carburetor and the manometer for the high pressure systems. Close this valve when you start the engine or you stop the engine.

Emissions Analyzer

Install the 156-1060 Emissions Analyzer in order to monitor the exhaust oxygen levels before the turbocharger. Remove the plug that is located in the exhaust inlet of the turbocharger, or in the exhaust elbow on naturally aspirated engines. Connect the 156-1060 Emissions Analyzer in accordance with the manufacturer's instructions.

Note: The measurements of the NOx and the CO may also be required.

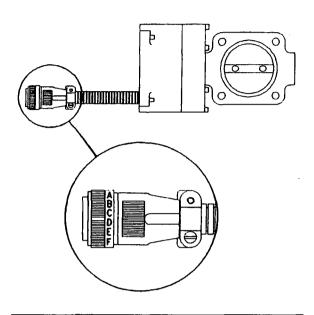
Inlet Manifold Pressure

The inlet manifold pressure is measured below the throttle plate with a pressure gauge. The inlet manifold pressure is used to indicate the engine load.

Gas Supply Line Pressure

Remove the plug from the gas supply line and install a pressure gauge.

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Flo-Tech Actuator

- (A) (Red) Positive Actuator Supply (12 gage)
- (B) (Blue) Negative Position Command (16 gage)
 (C) (Orange) Positive Position Command (16 gage)
- (D) (Black) Negative Actuator Supply (12 gage)
 (E) (White) Position Feedback (16 gage)
- (F) Not Used

The throttle position may be monitored by a DC voltmeter on engines that are equipped with a Flo-Tech actuator. Connect the negative probe of the DC voltmeter to the black terminal "B" of the controller. Connect the positive probe of the DC voltmeter to the white terminal "E". The signal for the position will only be present when the actuator is provided with voltage. The voltage is applied between the terminals "A" and "B" of the actuator.

Adjustment Of The High Pressure And The Low Pressure IMPCO **Carburetor Mixer Systems**

1. Ensure that the throttle linkage is correctly adjusted if the engine has this linkage. Refer to the Service Manual, "Systems Operation Testing And Adjusting * Section.

Note: The angle of the throttle can not be observed on engines that are equipped with a Flo-Tech actuator.

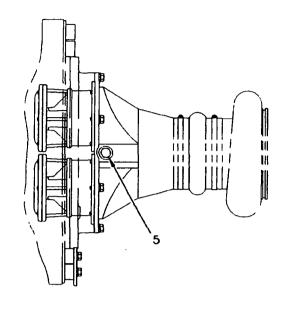


Illustration 4

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(5) Carburetor Adjusting Screw (Low Pressure Gas)

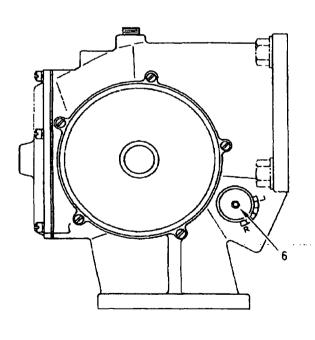
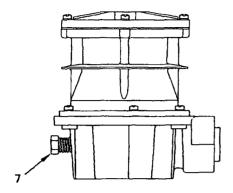


Illustration 5

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(6) Carburetor Adjusting Screw (High Pressure Gas)



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Impco 400 Low And High Pressure Carburetor

(7) Carburetor Adjusting Screw

- 2. Locate the carburetor adjusting screw (5,6). Refer to illustration 4 for carburetors of this type. Turn the screw clockwise until the screw is fully seated. Next, turn the screw 3.5 times in the counterclockwise direction. Refer to illustration 5 for carburetors of this type. Set the screw (6) halfway between the rich "R" setting and the lean "L" setting.
- Set the gas line pressure into the gas pressure regulator. The proper range of the pressure settings follow:
 - 10 kPa (1.5 psi) to 35 kPa (5 psi) for engines with low pressure
 - 138 kPa (20 psi) to 207 kPa (30 psi) for turbocharged engines
 - 10 kPa (1.5 psi) to 138 kPa (20 psi) for naturally aspirated engines

Note: Authorization from the local utility may be required in order to obtain these supply pressures.

4. While the engine is OFF, adjust the gas pressure regulator in order to obtain a differential pressure of 10 cm (4 inch) to 12.7 cm (5 inch) of water. Adjust the differential pressure by removing the cap from the regulator. Turn the threaded disk with the 8T-5160 Gas Regulator Setting Tool. Turning the disk clockwise will increase differential pressure. Turning the disk counterclockwise will decrease the differential pressure.

Note: Check the differential pressure once the engine is started. If necessary, readjust the regulator. Obtain a differential pressure of 10 cm (4 inch) to 12.7 cm (5 inch) of water.

5. If the engine is equipped with a magneto, set the timing with a timing light. Refer to the Service Manual, "Testing And Adjusting " for the correct procedure. Use the DDT to program the desired timing in engines that use the EIS. Refer to "Required Information" and to the Service Manual, "Electronic Troubleshooting". Ensure that the timing is set based on the Fuel Usage Guide.

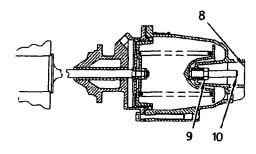
Note: Before you start the engine, be sure that the engine and the driven equipment are ready for operation. Ensure this operation by performing the daily maintenance items.

- 6. Start the engine.
- Allow the engine to reach full operating temperature.
- Gradually increase the load until the engine is carrying the desired full load. Do not exceed the maximum load that is determined in "Required Information".

Slowly adjust the power adjustment screw on the carburetor if the full load can not be reached. This adjustment will increase the gas supply to the carburetor. Monitor the reading on an emissions analyzer such as the 156-1060 Emissions Analyzer, while turning the carburetor adjusting screw. The emissions are monitored in order to prevent adding too much fuel to the fuel air mixture.

Note: It may be necessary to turn the adjustment screw (10) on engines with an adjustable exhaust bypass valve. Perform this adjustment if the engine will not make the full load. This adjustment will increase the boost pressure and this adjustment will allow the engine to operate at full load.

9. While the engine is at full load, adjust the carburetor adjusting screw. Perform this adjustment in order to obtain the exhaust oxygen level that was determined in "Required Information".



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(8) Cap

(9) Locknut

(10) Adjustment Screw

10. For engines with an adjustable exhaust bypass valve, remove the cap (8) and loosen the locknut (9). Turn the adjustment screw (10) in order to obtain a throttle angle of 60° to 70° at full load. It may be necessary to readjust the carburetor adjusting screw and the exhaust bypass valve several times. This adjustment is made in order to obtain the correct angle of the throttle at full load. This adjustment is also made in order to obtain the correct exhaust oxygen level.

Note: The angle of the throttle can not be observed on engines that are equipped with a Flo-Tech actuator. Adjust the exhaust bypass valve until a signal voltage of 4.0 VDC is generated between the terminals "E" and "B" at full load. Refer to the "Flo-Tech Actuator Position" for details.

11. Operate the engine throughout the expected load range. Verify that the engine rpm is stable. Verify that the angle of the throttle and the exhaust oxygen level at full load is correct. If the engine rpm is unstable, verify that the gas line pressures at no load and at full load are within acceptable limits. The pressure must not vary more than 1.7 kPa (0.25 psi) for low pressure fuel systems. The pressure must not vary more than 6.9 kPa (1 psi) for high pressure fuel systems. If the gas line pressure is within acceptable limits, it may be necessary to adjust the governor settings. Refer to the Governor Service Manual for details.

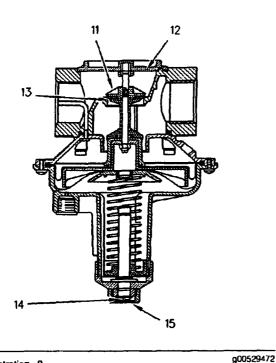
- 12. Check the final adjustments to the engine in order to ensure compliance with the emissions requirement. Use a NOx meter or a CO meter, or use both of these meters together in order to perform this check. In order to obtain desired emission levels, it may be necessary to make slight adjustments to the following settings:
 - · the carburetor adjusting screw
 - the differential pressure
 - the setting of the exhaust bypass valve

These adjustments are particularly important for low emissions engines and for engines that are equipped with a catalyst.

Adjustment Procedure For Deltec Mixer And Zero Pressure Regulators

Note: Gas can leak through the zero pressure regulator into the fuel system when the gas shutoff valve is open. Do not leave the gas shutoff valve open for a longer time than the time necessary to make adjustments. Before starting the engine, purge the inlet system and the exhaust system by disabling the ignition system. Then crank the engine with the gas supply OFF for three to five seconds.

- Ensure that the throttle linkage is adjusted correctly. Refer to the Service Manual, "Systems Operation Testing And Adjusting Section".
- Set the pressure from the gas supply line to the zero pressure regulator at 3 kPa (0.45 psi) to 7 kPa (0.95 psi).
- Remove the cover (12) and the cap (15) from the zero pressure regulator.
- Open the gas shutoff valve in order to supply gas to the zero pressure regulator.
- If gas flows out of the valve (11), turn the screw (14) counterclockwise until the flow stops.
- Turn the screw (14) clockwise in order to begin to lift the regulator valve (11) off the valve seat (13). The flow of gas is now heard in the regulator valve.



Zero Pressure Regulator

- (11) Valve
- (12) Cover
- (13) Seat (14) Screw
- (15) Cap
- 7. De-energize the gas shutoff valve.
- 8. Clean the cover (12) and install the cover.

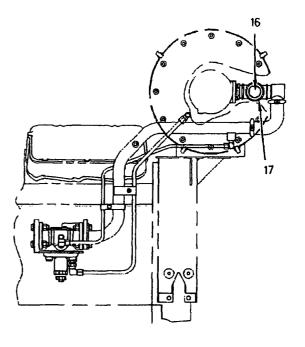


Illustration 9

Deltec Mixer System

- (16) Main Adjusting Screw
- (17) Locknut
- Loosen the locknut (17). Turn the main adjustment screw (16) clockwise until the screw is fully seated.

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- Turn the main adjustment screw (16) four times in the counterclockwise direction. These turns open the fuel passage. Tighten the locknut (17).
- 11. If the engine is equipped with a magneto, set the timing with a timing light. Refer to the Service Manual, "Testing And Adjusting" for the correct procedure. Use the DDT to program the desired timing in engines that have the EIS. Refer to "Required Information" and to the Service Manual, "Electronic Troubleshooting".
- 12. Start the engine. Verify that the supply pressure—to the regulator is within 3 kPa (0.45 psi) to 7 kPa (0.95 psi). Continue to run the engine at low load in order to reach the normal operating temperature.

Note: For the best performance at starting, open the gas shutoff valve after the engine has been cranking for three to five seconds.

- 13. Adjust the exhaust oxygen level with the adjusting screw (16) for the regulator. Make this adjustment while the engine is at low load and high idle. The exhaust oxygen level should be within 3 to 5 percent.
- 14. Increase the load on the engine to approximately 50 percent of the load. Use the main adjusting screw (16) to adjust the exhaust oxygen level. Adjust the level to the 50 percent rating that is given in the Engine Performance Book.
- 15. Gradually increase the load until the engine is carrying the desired full load. Do not exceed the maximum load that was determined in "Required Information". Slowly adjust the main adjustment screw (16), if the engine can not reach full load with the throttle in the wide open position. This adjustment increases the gas supply. Monitor the 156-1060 Emissions Analyzer reading while you turn the main adjustment screw (16). Monitor this reading in order to avoid adding too much fuel to the mixture. For engines with an adjustable exhaust bypass valve, adjustment may be necessary. Turn the adjustment screw (10) for the exhaust bypass valve in order to obtain the inlet manifold pressure at full load. This pressure is determined in the information for the prestart.
- 16. While the engine is at full load, adjust the main adjustment screw (16) in order to obtain the desired NOx level.
- 17. Operate the engine at low load and high idle rpm. Readjust the main adjustment screw (16) in order to obtain a 3 to 5 percent oxygen level and maximum stability.
- 18. Operate the engine at full load and readjust the main adjustment screw (16) in order to obtain the desired NOx level.
- 19. For engines with an adjustable exhaust bypass valve, remove the cap (8) and loosen the locknut (17). Turn the adjustment screw (10) in order to obtain a throttle angle of 60° to 70° at full load. It may be necessary to readjust the main adjustment screw (16) and the exhaust bypass valve several times. This adjustment is made in order to obtain the correct angle of the throttle at full load. This adjustment is also made in order to obtain the correct exhaust oxygen level.

Note: The angle of the throttle can not be observed on engines that are equipped with a Flo-Tech actuator. Adjust the exhaust bypass valve until a signal voltage of 4.0 VDC is generated between the terminals "E" and "B" at full load. Refer to the "Flo-Tech Actuator Position" for details.

- 20. Stop the engine and start the engine several times. If the engine is difficult to start, it may be necessary to make further adjustments to the regulator adjustment screw (10). Repeat this procedure starting at Step 13 if it is necessary to readjust the zero pressure regulator.
- 21. Operate the engine throughout the expected load range. Verify the following parameters:
 - engine stability
 - · the angle of the throttle at full load
 - the O₂ level

If the engine rpm is unstable, it may be necessary to adjust the governor settings. Refer to the Service Manual for details:

Gas Engine Troubleshooting Data Sheet

This sheet should be completed before you call the local dealer or the Caterpillar Service Engineering Department:

sure to include the units the me	easurements were t	aken in.	
CUSTOMER/INSTALLATION:			
ENGINE MODEL/DRIVEN COMPONENT:		·	·
Engine Serial #	Application		
SMR Compr.Ratio	(circle one)	Industrial other	
	Ignition		
Altitude(ft) (m) a	bove SL Timing	deg	(BTDC) (ATDC)
TUEL:		.	
Type (LHV, methane #)	Gas Reco	_ Fuel Rate	
Pressure (to gas reg.)			
DIL:			
rand & Type			
NGINE: peed Load _	T)	nwartle Buele	
Detonation (Bars on DDT)	Air Inlet	Restriction	
Intake Air		temp probe)
Mainfold: pressure	temperature	location	
urbo: boost ODD	exhaust out (ODD	_
pressure (left bank) EVEN		(left bank) /EN	
(right bank)	2	(right bank	<u>.)</u>
xhaust tack: pressure tem	merature	02 5 201	(wet)
			
NOX (ppm) CO (ppm)Ana	alyzer Brand	
xhaust (1) (3) (5) ort	(7)(9)	_ (11) (13)	(15)
'emps: (2)(4)(6)	(8)(10)	(12)(14)	(16)
Aftercooler IN Ja	icket IN	Engine	IN

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Exhaust Emissions

MODEL	PRICING ARR'T	HP	SPEED	C.R.	%O2	NOX G/BHP-HR	EXH. FLOW lb/hr	CO2 g/BHP-hr
3304 SINA	LA1819	95	1800	10.5:1	3.1	15.8	702	482
3306 SINA	LA1815	145	1800	10.5:1	2.0	20.3	1044	469
3306 SITA	PA4787	203	1800	8:1	2.0	22.8	1492	432
3306 SITA	PA4787	220	1800	8:1	2.0	20.5	1540	
3406 SITA		250	1400	9.4:1	2.0	20.4	1690	
3406 SINA	PA-4728	215	1800	10.3:1	2.0	21.4	1424	317
3406 SITA	PA-4727	325	1800	9.4:1	2.0	21.5	2146	315
3408 SITA		250	1400	9.4:1	2.0	20.4	1690	
3408 SITA	PA-4733	400	1800	9.7:1	2.0	21.3	2806	325
3412 SITA	PA-4742	600	1800	9.7:1	2.0	21.7	4245	325
3412 SITA		465	1400	9.7:1	2.0	21.5	3358	465
3508 SITA	PA4321	515	1200	8:1	7.7	2.0	5236	428
3508 SITA	PA5322	633	1400	8:1	8.0	2.0	6243	440
3512 SITA	PA4936	810	1200	8:1	8.2	2.0	7883	432
3512 SITA		945	1400	8:1	8.2	2.0	9473	444
3512 AFR		860	1200	8:1	8.3	2	8641	
3512 AFR		1004	1400	8:1	8.3	1.5	9944	
3516 SITA	PA4871	1085	1200	8:1	8.0	2.0	10437	423
3516 SITA	PA5319	1265	1400	8:1	7.9	2.0	13043	433
3516 AFR		1150	1200	8:1	8.2	1.5	11217	
3516 AFR		1340	1400	8:1	8.3	1.5	13292	
3606 SITA		1665	1000	9:2	12.3	0.7	19717	259
3608 SITA		2225	1000	9:2	12.3	0.7	26537	259
3612 SITA		3335	1000	9:2	12.3	0.7	39524	259
3616 SITA		4445	1000	9:2	12.3	0.7	52465	259

G3304 NA Gas Industri	al Engine Performa	nce	CA	TERPIL	LAR
Engine Speed (rpm)	1800	Fuel		i	NAT GAS
Compression Ratio	10.5:1	LHV of Fuel (B	tu/SCE\		920
Aftercooler Inlet Temperature (°F)	10.5.1 N/A	Fuel System	narsor /	\$\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\	PG IMPCO
Jacket Water Outlet Temperature (°F)		ruei dysiem		,	a iwi oo
Ignition System	210 MAG	Minimum Fuel	Pressure (psig)	4	1.5
_	WATER COOLED		ber at Conditions S	hown	80
Combustion System Type	STANDARD	Rated Altitude		iiowii	500
Combustion System Type	STANDARD		77°F Design Tempe	rature	500
Engine Rating Data		% Load	100%	75%	50%
Engine Power (w/o fan)		bhp	95	71	48
Engine Data					
Specific Fuel Consumption (BSFC) (1)		Btu/bhp-hr	7640	7917	10073
Air Flow (Wet, @77°F, 28.8 in Hg)		lb/hr	666	533	414
Air Mass Flow (Wet)		scfm	145	116	90
Compressor Out Pressure		N/A	N/A	N/A	N/A
Compressor Out Temperature		N/A	N/A	N/A	N/A
Inlet Manifold Pressure		in. Hg (abs)	27.5	23.5	19.4
Inlet Manifold Temperature (10)		°F	100	100	131
Timing (11)		°BTDC	30	30	30
Exhaust Stack Temperature		°F	1045	1004	988
Exhaust Gas Flow (Wet, @ stack temp	erature, 29.7 in Hg)	CFM	461	351	276
Exhaust Gas Mass Flow (Wet)		lb/hr	702	561	438
Engine Emissions Data		1			
Nitrous Oxides (NOx as NO2) (9)		g/bhp-hr	15.8	16.8	19.7
	(Corr. 15% O2)	ppm	1174	1161	1086
Carbon Monoxide (CO) (9)		g/bhp-hr	1.6	1.7	1.8
	(Corr. 15% O2)	ppm	201	191	160
Total Hydrocarbons (THC) (9)		g/bhp-hr	2.4	2.4	3.2
	(Corr. 15% O2)	ppm	520	473	519
Non-Methane Hydrocarbons (NMHC) (9)	g/bhp-hr	0.36	0.36	0.48
	(Corr. 15% O2)	ppm	78	71	78
Exhaust Oxygen (9)		%	3.1	2.9	1.7
Lambda			1.17	1.18	1.10
Engine Heat Balance Data		i			
Input Energy LHV (1)		Btu/min	12097	9401	7974
Work Output		Btu/min	4029	3022	2014
Heat Rejection to Jacket (2) (6)		Btu/min	4344	3502	3634
Heat Rejection to Atmosphere (Radiate	ed) (4)	Btu/min	484	376	319
Heat Rejection to Lube Oil (5)		Btu/min	0	0	0
Total Heat Rejection to Exhaust (to 77		Btu/min -	3106	2369	1826
Heat Rejection to Exhaust (LHV to 350	^s F) (2)	Btu/min '	2259	1693	1295
				N/A	

Engine Noise Data - at 100% load

Noise - Mechanical @ 1 m

93 dB(A)

Noise - Exhaust @ 1.5 m

106 dB(A)

Fuel Usage Guide

Derate Factor / Engine Timing vs Methane Number

											80 to
<30	30	35	40	45	50	55	60	65	70	75	100
0	1.0/15	1.0/16	1.0/17	1.0/20	1.0/21	1.0/22	1.0/23	1.0/25	1.0/26	1.0/27	1.0/30

Altitude Deration Factors

AIR	70 60	1.00	0.99	0.96	0.92	0.89	0.86	0.83	0.80	0.77 0.78	0.74	0.71	0.68	0.66
N.E.	90 80	0.99	0.96	0.92	0.89	0.86	0.83	0.80	0.77	0.74 0.75	0.71	0.68	0.66	0.63
<u> </u>	100	0.98	0.94	0.91	0.88	0.84	0.81	0.78	0.75	0.73	0.70	0.67	0.65	0.62
ĒΜ	110	0.96	0.93	0.89	0.86	0.83	0.80	0.77	0.74	0.71	0.69	0.66	0.63	0.61
₫.	120	0.94	0.91	0.88	0.84	0.81	0.78	0.76	0.73	0.70	0.67	0.65	0.62	0.60
	130	0.93	0.89	0.86	0.83	0.80	0.77	0.74	0.71	0.69	0.66	0.64	0.61	0.59

ALTITUDE (FEET ABOVE SEA LEVEL)

Aftercooler Heat Rejection Factors

_	130	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EMP	120	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	110	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
⊢	100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Щ	90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Z	80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
AIR	70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
⋖	60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
(°F)	50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	_	0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000

ALTITUDE (FEET ABOVE SEA LEVEL)

TM9744-02 Data is intended to be used with Gas Engine Performance Book Parameters - DM5901-00 on page 8

CATERPILLAR®

Caterpillar Gas Engine Lubricant, Fuel, and Coolant Recommendations

Important Safety Information

Most accidents that involve product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.

Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Safety precautions and warnings are provided in this manual and on the product. If these hazard warnings are not heeded, bodily injury or death could occur to you or to other persons.

The hazards are identified by the "Safety Alert Symbol" and followed by a "Signal Word" such as "DANGER", "WARNING" or "CAUTION". The Safety Alert "WARNING" label is shown below.

A WARNING

The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

The message that appears under the warning explains the hazard and can be either written or pictorially presented.

Operations that may cause product damage are identified by "NOTICE" labels on the product and in this publication.

Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are, therefore, not all inclusive. If a tool, procedure, work method or operating technique that is not specifically recommended by Caterpillar is used, you must satisfy yourself that it is safe for you and for others. You should also ensure that the product will not be damaged or be made unsafe by the operation, lubrication, maintenance or repair procedures that you choose.

The information, specifications, and illustrations in this publication are on the basis of information that was available at the time that the publication was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service that is given to the product. Obtain the complete and most current information before you start any job. Caterpillar dealers have the most current information available.

MARNING

When replacement parts are required for this product Caterpillar recommends using Caterpillar replacement parts or parts with equivalent specifications including, but not limited to, physical dimensions, type, strength and material.

Failure to heed this warning can lead to premature failures, product damage, personal injury or death.

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Foreword

Literature Information

This manual should be stored in the literature storage area.

The information contained in this document is the most current information available for coolants, fuels, and lubricants. Refer to the Operation and Maintenance Manual for any special lubrication requirements for your engine.

Whenever a question arises regarding the engine, this publication, or the Operation and Maintenance Manual, please consult any Caterpillar dealer for the latest available information.

Safety

Refer to the Operation and Maintenance Manual for your engine for all safety information. Read and understand the basic safety precautions listed in the Safety Section. In addition to safety precautions, this section identifies the text and locations of safety signs used on the engine.

Read and understand the basic precautions listed in the Safety Section before operating or performing lubrication, maintenance and repair on this engine.

Maintenance

Refer to the Operation and Maintenance Manual for your engine to determine all maintenance requirements.

Maintenance Intervals

Use the Maintenance Interval Schedule in the Operation and Maintenance Manual for your engine to determine servicing intervals. The actual operating environment of the engine also governs the maintenance interval schedule. Therefore, under extremely severe, dusty, wet or freezing cold operating conditions, more frequent lubrication and maintenance than is specified in the Maintenance Interval Schedule may be necessary.

Extended Engine Oil Drains and Warranty

Failures that result from extended oil drain periods are not Caterpillar factory defects and therefore are not covered by Caterpillar's warranty. In addition, failures that result from not using the recommended oil type are not Caterpillar factory defects and therefore are not covered by Caterpillar's warranty.

Refer to the applicable Operation and Maintenance Manual for standard oil drain periods and to the Maintenance Section, "Lubricant Specifications" of this publication for engine oil type and viscosity grade recommendations.

To reduce the potential risk of failures associated with extended oil drain periods; it is recommended that oil drain intervals only be extended based on oil analysis, and subsequent engine inspections. Oil analysis alone does not provide an indication of the rate of formation of lacquer, varnish and/or carbon on pistons and other engine surfaces. The only accurate way to evaluate specific oil performance in a specific engine and application that utilizes extended oil drain periods is to observe the effects on the engine components. This involves tear-down inspections of engines that have run to their normal overhaul period with extended oil drain intervals. Following this recommendation will help ensure that excessive component wear does not take place in a given application.

NOTICE

Light loads, low hour accumulation, and excessive idling time can contribute to excessive water in the crankcase oil. Corrosive damage, piston deposits and increased oil consumption can also result. If oil analysis is not done or the results are ignored, the potential for corrosive damage and piston deposits increases. Refer to the appropriate Operation and Maintenance Manual for guidance.

Note: Failures that result from extended oil drain periods are not warrantable failures, regardless of use of this recommended procedure. Failures that result from extended engine oil drain periods are considered improper use under the warranty.

Aftermarket Products and Warranty

NOTICE

When auxiliary devices, accessories or consumables (filters, oil, additives, catalysts, fuel, etc.) made by other manufacturers are used on Caterpillar products, the Caterpillar warranty is not affected simply because of such use. Failures that result from the installation or usage of other manufacturers auxiliary devices, accessories or consumables, however, are not Caterpillar factory defects and therefore are NOT covered by Caterpillar's warranty.

Caterpillar is not in a position to evaluate the many auxiliary devices, accessories or consumables promoted by other manufacturers and their effect on Caterpillar products. Installation or use of such items is at the discretion of the customer who assumes ALL risks for the effects that result from this usage.

Furthermore, Caterpillar does not authorize the use of its trade name, trademark, or logo in a manner which implies our endorsement of these aftermarket products.

Maintenance Section

Lubricant Specifications

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General Lubricant Information

SMCS Code: 0645; 1000; 1300; 1348; 7581

NOTICE

Refer to the engine's Operation and Maintenance Manual for any lubricant information that may be specific to that application.

Engine Oil

Engine oil performs several functions:

- Keeping the engine clean
- Preventing rust and corrosion
- Acting as a coolant
- Reducing friction and wear

Engines that use gaseous fuel require oils that are formulated with additives that are specific to these engines. There are no industry standards that define the performance specifications of oils for these engines. Field evaluations must be used in order to determine oils that are acceptable. To aid in oil selection, guidelines are provided in this Special Publication.

Hydraulic Oil

For information on hydraulic oil, see this Special Publication, "Hydraulic Oil" topic.

Lubricating Grease

Grease is classified by the National Lubricating Grease Institute (NLGI). The classification is based on the "ASTM D217-68 Worked Penetration" characteristics. The characteristics have a number for consistency that is defined. For further information on grease, see this Special Publication, "Lubricating Grease" topic.

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Engine Oil

SMCS Code: 1348

The following costs are associated with maintenance of the engine's lubrication system:

- Initial fill
- Consumption
- Analysis of the engine oil
- Replacement of the engine oil and engine oil filter
- Disposal of the used engine oil

Maintaining the engine's lubrication system is usually between 10 and 20 percent of the total cost of the engine's maintenance. This percentage can be affected by the type of fuel, the engine's duty cycle, and the maintenance practices.

The temperature of the cooling system, extended operation at light loads, and the condition of the engine (wear) have an effect on the rate of consumption and on the engine oil's service life.

Maintenance costs can be greatly increased by the wrong engine oil. Inadequate lubrication that destroys moving parts causes expensive unscheduled down time. The following problems can result from the use of incorrect engine oil:

- Buildup of varnish (glazing) in the cylinder liners
- Damage to bearings
- Deposits on the valves that can lead to guttering of the valves
- Oil coking in the turbocharger
- Piston rings and valves that stick

To achieve the lowest maintenance costs for the lubrication system, maintain the engine oil to the minimum standards that are recommended in this Special Publication.

Due to significant variations in the quality and in the performance of commercially available oils, Caterpillar makes the following recommendations:

- Caterpillar Natural Gas Engine Oil (NGEO)
- Caterpillar Natural Gas Engine Oil (NGEO) EL250

Caterpillar NGEO has been tested throughout the world in demanding environments. Caterpillar NGEO has been tested in engines that use all types of gaseous fuel. Caterpillar NGEO is formulated and blended with special additives in order to provide protection against oxidation and nitration. Caterpillar NGEO also has thermal stability. The formulation of the oil has been proven to be superior to many brands of oil that are locally available.

Caterpillar NGEO also provides the following benefits:

- Reduction of the formation of carbon and sludge
- · Resistance to foaming
- Protection against corrosion
- Protection of valves and of valve seats
- Improved cleanliness of pistons
- Protection against scoring of the pistons and scuffing of the pistons
- · Protection against cylinder liner wear

Table 1 lists the oil properties of Caterpillar NGEO. The properties are based on ASTM test specifications.

Table 1

Caterpillar NGEO Properties								
Characteristic	ASTM Test	SAE Viscosity Grade						
		30	40					
API Gravity	"D0287"	28.9	28					
Flash Point	"D0092"	238	252					
Pour Point	"D0097"	-15	-15					
Viscosity (cSt) at 100 °C (212 °F)	"D0445"	10.8	13.2					
Viscosity Index	"D2270"	98	98					
Weight (Percent) of Sulfated Ash	"D0874"	0.52	0.52					
Total Base Number	"D2896"	5.6	5.6					

Table 2 lists the oil properties of Caterpillar NGEO EL250. The properties are based on ASTM test specifications.

Table 2

Caterpillar NGEO EL250 Properties									
Characteristic	ASTM Test	SAE Vis Gra	-						
		30	40						
API Gravity	"D0287"	28.4	27.5						
Flash Point	"D0092"	265	262						
Pour Point	"D0097"	-12	-12						
Viscosity (cSt) at 100 °C (212 °F)	"D0445"	11.0	13.5						
Viscosity Index	"D2270"	99	99						
Weight (Percent) of Sulfated Ash	"D0874"	0.57	0.57						
Total Base Number	"D2896"	6.5	6.5						

Engine Oil and Sour Gas Fuels

Many gaseous fuels contain sulfur compounds. These compounds are primarily composed of hydrogen sulfide (H₂S). Gaseous fuels with less than 0.43 mg H₂S/MJ (.45 µg H₂S/Btu) are considered to be sweet gas.

Gaseous fuels with more than 0.43 mg H_2S/MJ (.45 μ g H_2S/Btu) are considered to be sour gas. Sour gas can reduce the service life of an engine and of the engine oil. When the sulfur compounds are combined with water, acids are produced in the engine oil. These acids attack the metals in the engine crankcase and in other components. This causes corrosive wear. To reduce the effects of these sulfur compounds, Caterpillar recommends the use of devices that treat the fuel. For further information, see this Special Publication, "Hydrogen Sulfide Effects on Engine Maintenance Costs" in the Fuel Specifications section.

Note: Caterpillar does NOT recommend the use of engine oils with a high concentration of sulfated ash in order to reduce the harmful effects of sour gas. High levels of sulfated ash may produce excessive deposits on the valves and on the turbine wheel of the turbocharger. These deposits will reduce the service life of the engine. These deposits will also increase the cost of maintenance.

Engine Oil and Bio-Gas Fuels

Bio-gas fuels that are generated from landfill or digester gas power plants can include contaminants that react with the engine lube oil. This can create varied combustion deposits. Excessive deposits on the piston, the liner, and the cylinder head can occur if the oil is not properly matched for the application. Laquering of the liner may also occur.

Lube oils that are specifically designed for applications that use bio-gas are recommended. These oils should have a concentration of sulfated ash that is not greater than 0.6 percent. When possible, these oils should also be formulated with Group II base stock. Group II base stocks have been shown to provide reduced engine deposit buildup. The use of a lube oil with a high concentration of sulfated ash will result in excessive deposits in the combustion chamber. Because of the inconsistent, variable composition of most bio-gas fuels, the lube oil may react differently to the composition of a particular fuel. Use the S·O·S oil analysis program to determine the proper oil change interval.

For new installations, sample the oil frequently in order to establish a consistent program for oil changes. Initially, sample the oil on a daily basis. The properties of landfill gas can change rapidly. Therefore, it is necessary to continue to monitor the oil on a weekly basis or two times per month in order to ensure adequate protection.

Contact your local Caterpillar dealer or your oil supplier for a recommendation for lube oil for your bio-gas application.

S-O-S Oil Analysis

Caterpillar recommends the S·O·S oil analysis program in order to monitor the condition of the oil. The analysis can help determine the maintenance requirements for the engine. The S·O·S program is part of the preventive maintenance program. For further information about the S·O·S program, see this Special Publication, "S·O·S Oil Analysis" topic.

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Commercial Oils

SMCS Code: 1318; 1348

Commercial oil specifications do not exist for Caterpillar engines that operate on gaseous fuels. The performance of lubrication oil for gas engines is determined by a field evaluation. Successful field operation has been achieved with oils that meet the following guidelines:

- Caterpillar recommends the use of oils that are formulated specifically for heavy-duty gas engines. Do not use oils that are specially formulated for gasoline engines or for diesel engines.
- Caterpillar does not recommend multigrade oils for use in gas engines.

- Caterpillar recommends the use of oils that have a sulfated ash content between 0.40 and 0.60 percent.
- The oil must demonstrate adequate protection for a minimum of 7000 hours in a field evaluation under controlled conditions.

7000 Hour Field Evaluation

Caterpillar recommends oils for gas engines that meet the requirements of the 7000 hour field evaluation. The 7000 hours of field service must be documented. Standard and/or Low Emission engine configurations may be used for the evaluation. The field evaluation must be performed in an engine configuration that is similar to the engine that will use the oil that is proposed. The field evaluation must be performed at a power level that is at least equal to the power that is required by the engine that will use the oil that is proposed.

Field evaluations may identify commercial brands of oil with successful results. Caterpillar will not endorse a commercial brand of oil because of the results. The oil company can use the results of the field evaluation as a proof of the oil's performance. The oil company is responsible for the performance and the quality of the oil, and for any changes in the formulation of the oil. Before purchasing a lubrication oil for a gas engine, discuss the claims of performance for the oil with the oil supplier.

For additional details on the 7000 hour field evaluation, refer to this Special Publication, "Field Evaluation of Commercial Oil" topic.

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Field Evaluation of Commercial Oil

SMCS Code: 1348

For gas engines, Caterpillar recommends the use of Caterpillar Natural Gas Engine Oil (NGEO) or Caterpillar NGEO EL250.

Caterpillar Inc. is frequently approached by engine owners and/or oil companies that wish to qualify an oil for use in gas engines. Caterpillar does not recommend the names of other commercial brands of lube oils. However, Caterpillar will evaluate the results of the field evaluation for commercial brands of lube oils. The evaluation can verify that the oil meets the minimum lubrication requirements that are recommended by Caterpillar. Caterpillar has established the following guidelines for the field evaluation of lube oil in gas engines. These guidelines are applicable to the engines that use the following fuels: dry natural gas, sour gas, and bio-gas.

Operating Conditions for the Field Evaluation

Duration – The minimum number of operating hours for a G3300, G3400, and G3500 is 7000 hours. A G3600 requires a minimum of 7000 hours of operation.

Load Factor – The load factor must be representative of the normal engine application at the site. High load factors are preferred.

Lube Oil – The oil must meet the requirements for the oil properties that are described in this Special Publication, "Engine Oil" topic. The oil must also meet the requirement for the formulation for gaseous fuel and the requirement for 0.40 to 0.60% sulfated ash that are described in the "Commercial Oils" topic.

Oil Analysis – Caterpillar recommends the S·O·S oil analysis program. Alternate oil analysis programs must measure oil condition and wear metals. Used oil samples must be obtained for analysis at 250 hour intervals. A baseline analysis of the new oil should also be obtained.

Oil Change Interval – The oil change interval is determined by condemning limits that are established by Caterpillar. The limits are based on analysis of the used oil and the trend lines that are established. For typical oil change intervals, see this Special Publication, "Oil Change Interval" topic.

Fuel Analysis – An analysis of the fuel must be provided by an independent laboratory at the beginning of the field evaluation. The results from the gas analysis must meet the guidelines of the engine models. For the guidelines, see this Special Publication, "Fuel Specifications" section.

Criteria for the Evaluation

Oil Consumption – The oil consumption must not exceed two times the initial oil consumption during the field evaluation. The initial oil consumption is established during the first 1000 hours of operation with the oil that is being evaluated.

Valve Recession – The valves and the valve seats wear over time. This causes the valves to recede into the cylinder head. This condition is called "valve recession". Measure the valve recession at the engine commissioning. This measurement is the baseline. The baseline is a reference for subsequent measurements. Measure the valve recession according to the engine's Operation and Maintenance Manual, "Maintenance Interval Schedule". The valve recession must not exceed the limits that are established for the engine by Caterpillar. Refer to the engine's Operation and Maintenance Manual, "Valve Stem Projection - Measure/Record" topic for the limits for the valve recession.

Parts Requirements – If a new engine is used for the field evaluation, all of the engine's cylinders must be inspected with a borescope. The cylinder that shows the worst deposits or wear and the cylinder that shows average deposits or wear must be used for the visual inspection. If a used engine is used to evaluate the oil, two new sets of these components must be installed before the field evaluation: pistons, piston rings, cylinder liners, and cylinder heads. These new components will be examined during the final inspection.

Final Inspection – At the end of the field evaluation, these components from two cylinders must be removed and inspected:

- Pistons
- Piston rings
- Cylinder liners
- Cylinder heads

None of the following conditions are acceptable:

- Sticking of the piston rings
- Scuffing of the piston rings and/or cylinder liners
- Excessive wear of the piston rings
- Polishing of the cylinder liner bore must be confined to the area that is affected by the uppermost position of the top piston ring.

- The entire circumferences of the inlet valves and the exhaust valves must seal.
- Guttering of the valves is not acceptable.

Close up photographs that show the wear and deposits must be taken in order to document the appearance of these components: pistons, piston rings, cylinder liners, crankcase, top deck of the cylinder head, bottom deck of the cylinder head, inlet valves, and exhaust valves (bottom, face, and stem). In addition, two exhaust valve guides must be removed from two cylinders and sectioned lengthwise. Photographs that show the entire component must also be provided.

Summary – This procedure for a field evaluation provides the oil company and the engine owner with a method of evaluating a lubricating oil for gas engines. If the oil meets these guidelines for the field evaluation, the oil has fulfilled the Caterpillar requirements. Caterpillar will not endorse any oil for use in Caterpillar gas engines as a result of field evaluation. The oil company can use the evaluation as proof of performance.

Responsibilities

Care must be taken in order to define the responsibilities of each party that is involved in the field evaluation. The oil company and the engine owner must recognize the responsibilities if the performance of the oil reduces the service life of the engine. Caterpillar recommends specific definitions of the responsibilities for the oil company and the engine owner in a field evaluation. An agreement should be made before the field evaluation is initiated. Both the oil company and the engine owner must understand that Caterpillar only monitors the field evaluation. The field evaluation is not sponsored by Caterpillar.

Field Evaluation Agreement

The field evaluation agreement is between the engine owner and the oil company. The agreement is a very important part of the field evaluation. The completion and signing of the agreement should occur before the initiation of the field evaluation. The agreement must fully define the field evaluation and the responsibilities of each party. This publication contains the information and guidelines that are necessary to write a detailed agreement. The initial field evaluation involves some risk. Use of the guidelines will minimize the risk. If the guidelines are followed, the probability of a successful field evaluation will be enhanced.

Responsibilities of the Oil Company

Performance – The performance of the oil is the responsibility of the oil company. The oil must maintain stable oil control and the oil must control deposits in the combustion chamber and in the crankcase. Engine service life must be maintained at the predicted stage for the particular engine application.

Supply – The supply of the oil is the responsibility of the oil company. If special storage and/or shipping is required, the oil company should cover the cost of those items.

Oil and Fuel Analysis – During the evaluation, the oil company should pay for the cost of the oil and fuel analyses. Caterpillar recommends the use of the S·O·S oil analysis program in order to monitor the condition of the lube oil. If an independent laboratory is used to analyze the lubricant, refer to this Special Publication, "S·O·S Oil Analysis: Condemning Limits of the Oil" topic. The data that is obtained from the oil analyses must be plotted in order to establish trends. The fuel should be analyzed by an independent laboratory. Results of the oil and fuel analyses must be sent to the engine owner. The owner should review the data. Also, the owner can keep records of the data.

Hardware – If the oil is evaluated in a used engine, two new sets of these components must be installed before the field evaluation: pistons, piston rings, connecting rod bearings, cylinder liners, and cylinder heads. The cost should be covered by the oil company. Those new components will be examined for the final inspection.

Final Inspection – The cost of the final inspection should be paid by the oil company. If the final inspection reveals severe deposits and/or damage to the hardware, the oil company must make the repairs that are necessary for restoring the engine to an acceptable condition.

End of the Evaluation – After completion of the field evaluation, the oil company should work with the engine owner in order to restore the engine to normal operation. The oil company should bear the cost of the restoration. This could include the cost for the removal of storage tanks, special piping, flow meters, and instrumentation.

Final Report – The oil company must prepare a final report that documents the following items:

- The data on oil consumption must be recorded on a minimum schedule of every two weeks. A chart of the data must be included in the final report.
- Results of the oil analysis must be plotted.

- Oil changes
- · Replacement of the oil filters
- Results of fuel analysis
- A histogram for fuel consumption or a histogram for power output
- A histogram for average engine speed
- The typical duty cycle
- Valve recession
- Side clearance for the piston ring
- Valve guide to valve stem clearances
- Close up photographs of the following components from two cylinders must also be included: pistons, piston rings before removal and after removal, piston ring grooves after removal, cylinder liners, crankcase, top deck of the cylinder head, bottom deck of the cylinder head, inlet valves (top and bottom), and exhaust valves (top and bottom).

The final report should be confidential. The final report must be made available to the engine owner and to Caterpillar Inc.

Responsibilities of the Engine Owner

Engine for the Evaluation - The owner must provide access to the engine for the duration of the field evaluation. Special piping and instrumentation may be attached to the engine for the duration of the field evaluation.

Operation and Maintenance – Daily operation and maintenance of the engine is the responsibility of the owner. Operation and maintenance of the engine must follow the guidelines that are published by Caterpillar in the engine's Operation and Maintenance Manual. The daily records of this activity should be made available to the oil company.

Oil Samples and Fuel Samples - Oil samples and fuel samples will be collected by the owner. The samples will be sent to the appropriate laboratory for analysis.

Caterpillar Responsibilities

Advisory — Caterpillar will not assume an active function in the field evaluation. However, Caterpillar will provide technical advice and guidance to the parties that are involved. Caterpillar understands that this function does not satisfy all of the situations that may arise in a field evaluation. Therefore, technical judgments may be required for the initiation of some evaluations.

To provide assistance with the field evaluation, your Caterpillar dealer or district representative can consult the appropriate people at Caterpillar Inc.

Final Inspection – Under some circumstances, Caterpillar is asked to assist with the inspection. This is evaluated on an individual basis. The decision depends on the availability of personnel and on the amount of technical interest.

Guidelines for the Use of A Proven Lubricant In Other Engines (Interchanging)

Interchanging – The information that is obtained from most field evaluations will be applicable to other gas engines at other sites. However, guidelines must be established in order to limit the application of a lubricant that has been evaluated. This is for the protection of the engine and the engine owner. The limit on the application of the lubricant is defined as interchanging.

The interchanging of the lubricant is limited by these factors:

- The oil viscosity grade
- The base stock of the oil
- The engine configuration
- The engine rating

Oil Viscosity Grade

The proper SAE viscosity grade of oil is determined by the minimum ambient temperature during cold engine start-up, and the maximum ambient temperature during engine operation. To determine the oil viscosity that is required for starting a cold soaked engine, refer to the minimum temperature in Table 3. To select the oil viscosity for operation at the highest anticipated ambient temperature, refer to the maximum temperature in Table 3. Use the highest oil viscosity that is available in order to meet the required temperature during start-up.

Table 3

Engine Oil Viscosity				
Caterpillar NGEO Grade of Viscosity	Ambient Temperature			
	Minimum	Maximum		
SAE 30	0 °C (32 °F)	40 °C (104 °F)		
SAE 40	5 °C (41 °F)	50 °C (122 °F)		

Note: Caterpillar NGEO is available in these grades only. Multigrade oils are NOT recommended for use in Caterpillar Gas Engines. If other grades of viscosity are selected, ensure that the oil meets the requirements for Caterpillar Gas Engines. Consult the supplier of the oil.

Note: On G3600 engines, only SAE 40 is recommended. Also, when the ambient temperature is 10 °C (50 °F) or less, an oil heater is recommended.

Base Stock of the Oil

Finished lubricants are made of base stocks and additives. Properly blended lubricants will have base stocks and additives that work together in order to consistently provide the following qualities: adequate control of deposits, adequate control of wear, adequate service life of the oil, stability to oxidation and nitration, and resistance to corrosion.

The quality and performance of a base stock depends on the source of the crude oil and the process that is used to produce the base stock. The performance of the base stock can have a significant effect on the performance of the finished lubricant. A responsible oil company closely controls the quality of the base stock by testing the oil in laboratories and in engines. Through careful testing, the oil company can identify base stocks that provide similar performance levels.

Because of the complex chemistry that is involved with the evaluation of base stocks, Caterpillar cannot establish stringent guidelines for the interchanging of base stocks. However, the following characteristics can be used for identifying differences in the performance of base stocks:

Viscosity index – The viscosity index of a single grade oil is an estimate of the base oil's composition. An oil with a viscosity index that is less than 95 could contain a significant amount of napthenic base stocks. Otherwise, the base stock could have a low level of processing. Napthenic base stocks do not provide the same performance as paraffinic base stocks. A finished lubricant must be specially blended in order to use napthenic base stocks.

i

Oil that has a viscosity index of 95 or more contains paraffinic base stock. If the viscosity index of different shipments of a particular oil increases or decreases by more than 5, the base stock could have been significantly changed. If this occurs, the oil company should be questioned regarding the source and quality of the base stock.

API base oil classification – The API has divided base stocks into five groups. The groups are identified by the viscosity index and by chemical composition. The different groups provide different performance in the finished lubricants. The interchanging of base stocks between those groups is NOT recommended. The API base stock group cannot be easily detected in the finished lubricant. Therefore, the oil company must inform the customer about the type of base stock in the finished lubricant. The oil company must also inform the customer if the base stock is changed to a different API base stock group.

The oil company must accept the responsibility for the performance of the finished oil. This responsibility includes the additives and the base stocks. Any significant changes to the composition of the finished oil must be reported to the customer in order for the risk to be evaluated.

Engine Configuration

Lube oil can be interchanged between engines that use different types of fuel.

Lube oil that is evaluated in G3500 Series Low Emissions Engines may also be used in G3300, G3400, and G3500 engines.

Lube oil for G3600 Series Engines must be evaluated in a G3600 Series Engine.

Lube oil that is evaluated in G3400 Series or G3300 Series Engines may ONLY be used in G3400 Series or G3300 Series Engines.

Engine Rating

The average power output that is produced by the engine during the field evaluation is used to establish the power rating of the field evaluation. The power output must be expressed as Brake Mean Effective Pressure (BMEP). The power output is derived from one of the following sources:

- Output of the generator set
- Torque meter
- Output of the gas compressor
- Displayed load for the engine

To calculate the BMEP, the average engine power output must be expressed in kilowatts. Use the equation in Table 4 to calculate the BMEP.

Table 4

Equation for Calculating the Brake Mean Effective Pressure (BMEP)				
120 000	×	kW		BMFP
L	×	rpm	_ =	DIVIER

kW is the average engine power output during the evaluation.

L is the total displacement of the engine in liters.

Lube oil can be interchanged between engines at different sites that operate with a similar duty cycle. However, the interchanging is limited by a maximum of a ten percent increase in BMEP.

Duty cycles can vary greatly between different sites and between different engine configurations. Therefore, it is difficult to determine an accurate degree of severity for oil in all the various duty cycles. For best results, only use the proven oil in applications with a similar duty cycle. When different duty cycles are introduced, the risk is increased. For cases with different duty cycles, Caterpillar and the engine owner will assess the risk in order to determine if another field evaluation is required. In most cases, an oil with proven performance in a particular duty cycle will be preferred over an oil that has not been proven for that duty cycle.

i01909790

Synthetic Base Stock Oils

SMCS Code: 1300; 1348; 7581

Synthetic base oils are acceptable for use in Caterpillar engines if these oils meet the performance requirements that are specified for the engine.

Synthetic base oils generally perform better than conventional oils in the following two areas:

- Synthetic base oils have improved flow at low temperatures.
- Synthetic base oils have improved oxidation stability at high operating temperatures.

Some synthetic base oils have performance characteristics that enhance the service life of the oil. However, Caterpillar does not recommend the automatic extension of oil change intervals for any type of oil. Oil change intervals for Caterpillar engines can only be adjusted after an oil analysis program that contains the following data: oil condition and wear metal analysis (Caterpillar's S·O·S oil analysis), trend analysis, fuel consumption, and oil consumption.

i01931706

Re-refined Base Stock Oils

SMCS Code: 1300; 1348; 7581

Re-refined base stock oils are acceptable for use in Caterpillar engines if these oils meet the performance requirements that are specified by Caterpillar. Re-refined base stock oils can be used exclusively in finished oil or in a combination with new base stock oils. The US military specifications and the specifications of other heavy equipment manufacturers also allow the use of re-refined base stock oils that meet the same criteria.

The process that is used to make re-refined base stock oil should adequately remove all wear metals that are in the used oil and all additives that are in the used oil. The process that is used to make re-refined base stock oil generally involves the processes of vacuum distillation and hydrotreating the used oil. Just filtering used oil is not adequate for the production of re-refined base stock oils of high quality.

i01895318

Aftermarket Oil Additives

SMCS Code: 1300; 1348; 7581

Caterpillar does not recommend the use of aftermarket additives in oil. It is not necessary to use aftermarket additives in order to achieve the engine's maximum service life or rated performance. Fully formulated, finished oils consist of base oils and of commercial additive packages. These additive packages are blended into the base oils at precise percentages in order to help provide finished oils with performance characteristics that meet industry standards.

- There are no industry standard tests that evaluate the performance or the compatibility of aftermarket additives in finished oil.
- Aftermarket additives may not be compatible with the finished oil's additive package, which could lower the performance of the finished oil.

 The aftermarket additive could fail to mix with the finished oil. This could produce sludge in the crankcase.

To achieve the best performance from a Caterpillar engine, conform to the following guidelines:

- Select the proper Caterpillar oil or commercial oil.
- See the appropriate "Lubricant Viscosities" table in order to find the correct oil viscosity grade for your engine.
- At the specified interval, service the engine. Use new oil and install a new oil filter.
- Perform maintenance at the intervals that are specified in the engine's Operation and Maintenance Manual, "Maintenance Interval Schedule".

i01923478

Oil Change Interval

SMCS Code: 1348

Considerations for the oil change interval include the type of fuel and the engine application. An oil analysis program will provide an evaluation of the used oil. Caterpillar recommends the S·O·S oil analysis program in order to monitor the condition of the oil and the maintenance requirements of the engine. The evaluation can be used to determine the oil change interval that is suitable for your specific engine. Change the engine oil when oil analysis determines that the oil has reached the condemning limit.

Obtain an oil analysis after every 250 service hours. If the analysis indicates that an oil change is necessary, the oil must be changed regardless of the number of service hours.

Refer to the engine's Operation and Maintenance Manual for any information that may be specific to that application.

Increasing the Oil Change Interval

The time between oil changes can only be increased under the following conditions:

- The results of the oil analysis indicate that the oil has not reached the condemning limit.
- The trend lines of the S·O·S oil analysis program indicate a constant slope that is stable.

The maximum increment for increasing the oil change interval is 250 service hours. This is particularly important if a long amount of time is required to obtain results of oil analysis.

Illustration 1 is a graphic representation of adjusting the oil change interval.

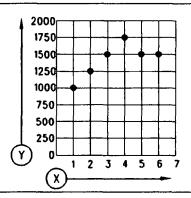


Illustration 1

g00585368

Adjustment of oil change intervals

- (Y) Service hours
- (X) Numbers of oil changes

In Illustration 1, the initial oil change was performed after 1000 service hours. The interval was increased in 250 hour increments. At the fourth oil change interval, the oil had reached the condemning limit after 1750 service hours. Therefore, the interval was reduced to 1500 service hours. The results of the oil analysis was acceptable when the oil was used for 1500 service hours.

i01895339

S-O-S Oil Analysis

SMCS Code: 1000; 7542

Caterpillar recommends the S·O·S oil analysis program in order to monitor the condition of the oil and the maintenance requirements of the engine. The S·O·S program is part of the preventive maintenance program.

The S·O·S oil analysis includes these tests:

- The Wear Rate Analysis monitors wear by detecting, identifying and assessing the amount and the type of wear metal that is in the oil. The increase in the rate of engine wear metal in the oil is as important as the quantity of engine wear metal in the oil. For this reason, regular sampling at specified intervals is necessary in order to establish wear rates. Intermittent sampling does not allow wear rate trend lines to be established. Engine wear metals in the oil sample are compared to established Caterpillar norms in order to determine acceptability. Potential failures can be identified when the wear rate and/or the contaminants exceed the established trend.
- Tests are conducted in order to detect contamination of the oil by water and/or glycol.
- The Oil Condition Analysis determines the loss of the oil's lubricating properties. An infrared analysis is used to compare the properties of new oil to the properties of the used oil sample. This analysis allows technicians to determine the amount of deterioration of the oil during use.

The test results of the oil samples will then be used as a basis for determining the oil change interval for the engine. The results of the S·O·S oil analysis may enable the engine to operate longer between oil changes without the risk of damage.

Obtain each oil sample when the oil is warm and well mixed in order to ensure that the sample is representative of the oil in the engine crankcase.

Oil analysis is essential in order to determine satisfactory performance of the oil.

Refer to Special Publication, PEDP7036, "S·O·S Fluid Analysis" for more information.

Consult your Caterpillar dealer for complete information and assistance about the program.

Condemning Limits of the Oil

Oil analysis is the only method of determining if an oil is protecting the engine. The oil analysis is compared to limits that have been established through experience.

The condemning limits for lubrication oil were developed from experience with engine operation and from the analysis of used oil. The limits provide guidelines for determining the useful service life of the engine oil. Table 5 lists the limits for the service life of the oil.

Table 5

S·O·S Oil Analysis Condemning Limits				
Parameter	Limit			
Oxidation	100% defined by the S·O·S Oil Analysis			
Nitration	100% defined by the S.O.S Oil Analysis			
Water	0.5% maximum			
Glycol	0%			
Silicon (Bio-gas)	25 ppm			
Wear Metals	Based on Caterpillar norms and on the trend of the Wear Rate Analysis ⁽¹⁾			
Additional (Oil Analysis			
Viscosity at 100 °C (212 °F) by "ASTM D445"	Increase of 3 cSt from new oil			
Total acid number (TAN) by "ASTM D664"	3.0 maximum TAN or 2.0 greater TAN than the new oil			
Total base number by "ASTM D2896"	50% of new oil TBN			

⁽¹⁾ A trend can be established from the results of three oil analyses.

Trend Analysis

Illustration 2 is an example of a graph for the trends of wear metal analysis and of infrared analysis.

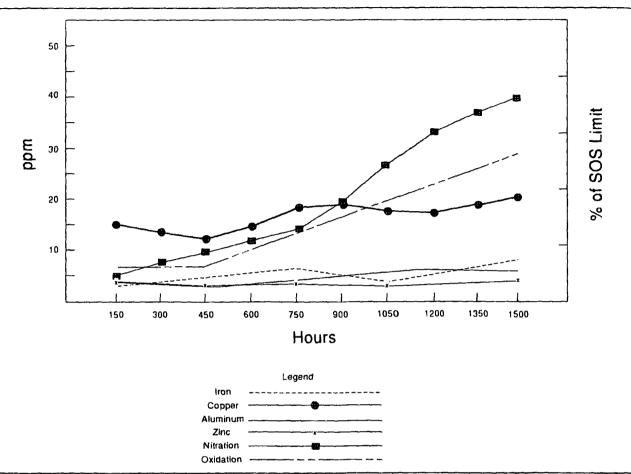


Illustration 2 g01009320

The analysis of the wear metals in Illustration 2 show typical normal levels. However, the level of nitration has exceeded the acceptable limit. The oxidation is also increasing. In conclusion, this analysis indicates that the engine oil must be replaced.

In the absence of analysis, change the engine oil according to the engine's Operation and Maintenance Manual, "Maintenance Interval Schedule".

iO1877561

Hydraulic Oil

SMCS Code: 1348; 4250; 5050; 5095; 7581

Caterpillar Hydraulic Oil (HYDO)

Caterpillar Hydraulic Oil is formulated with a balanced additive system. The system includes the following agents: detergents, rust inhibitors, antiwear agents, and defoamers. Caterpillar Hydraulic Oil offers the following benefits: protection against mechanical wear, rusting, and corrosive wear in hydraulic systems. Caterpillar Hydraulic Oil should be used to achieve maximum life and maximum performance from hydraulic system components. Caterpillar Hydraulic Oil is recommended in most hydraulic systems.

Commercial Oils

If Caterpillar oils cannot be used, the following commercial classifications can be used in hydraulic systems:

- CH-4 engine oils that have a minimum zinc additive of 0.09 percent (900 ppm)
- CG-4 engine oils that have a minimum zinc additive of 0.09 percent (900 ppm)
- CF-4 engine oils that have a minimum zinc additive of 0.09 percent (900 ppm)
- CF engine oils that have a minimum zinc additive of 0.09 percent (900 ppm)

Note: Industrial hydraulic oils are not recommended for service fill in Caterpillar hydraulic systems.

Caterpillar Biodegradable Hydraulic Oil (HEES)

Caterpillar has a biodegradable hydraulic oil that is available for use in hydraulic systems. This fluid is recommended for the hydraulic systems when environmental compliance is required or desired.

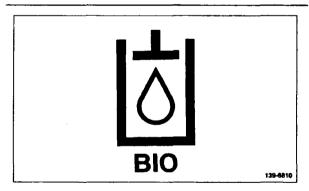


Illustration 3

g00103844

Systems with this symbol are filled with biodegradable hydraulic oil. This symbol is located on the hydraulic tank.

This fluid is formulated with the following components: a saturated HEES (Hydraulic Environmental Ester Synthetic), synthetic base stock, and selected additives.

Note: Use this oil only in hydraulic systems.

Caterpillar Biodegradable Hydraulic Oil (HEES) may become darker in color throughout the service life of the oil. Analysis is required to determine the quality of the oil.

The maximum recommended water content for hydraulic systems that are filled with Caterpillar Biodegradable Hydraulic Oil (HEES) is 0.10 percent. If the water levels exceed 0.10 percent, the water should be removed or the oil should be replaced.

Consult your Caterpillar dealer for additional information on this product and on the potential use.

NOTICE

Do not use Caterpillar Biodegradable Hydraulic Oil (HEES) or commercial oils that meet the BF-1 specification in compartments containing friction material. Refer to the Operation and Maintenance Manual or contact your local Caterpillar dealer for guidance before using Caterpillar Biodegradable Hydraulic Oil (HEES) or commercial oils that meet the BF-1 specification.

Commercial Biodegradable Hydraulic Oil (HEES)

If Caterpillar Biodegradable Hydraulic Oil (HEES) is not used, commercial oils that meet the Caterpillar BF-1 specifications may be used.

i01923521

Lubricating Grease

SMCS Code: 1000; 7581

Caterpillar provides greases in order to cover a variety of applications and extreme temperature conditions. Consult your Caterpillar dealer for part numbers and for available sizes of containers.

Note: Some greases may not be used with other greases. When a commercial grease is used, ensure that the grease is compatible with the grease that is currently used in the system. If the commercial grease is not compatible, the system must be purged. If any questions arise concerning the compatibility of a grease, consult the supplier.

Multipurpose Greases

Multipurpose Lithium Complex Grease (MPGL)

Multipurpose Lithium Complex Grease (MPGL) is a general purpose lithium complex grease for medium-duty applications. This product has good characteristics at high temperatures such as a dropping point of 260 °C (500 °F). MPGL contains unleaded extreme pressure additives, antiwear inhibitors, and corrosion inhibitors that provide extra protection in the following applications:

- Construction
- Agricultural
- Automotive

MPGL meets the National Lubricating Grease Institute (NLGI) certification of "GC-LB". MPGL is also available in a NLGI No. 2 grade. Normal operating temperatures for this product are –28 to 149 °C (–18 to 300 °F). This product is also available as a white lithium complex grease.

Multipurpose Lithium Complex Grease with Molybdenum (MPGM)

Multipurpose Lithium Complex Grease with Molybdenum (MPGM) is a general purpose lithium complex grease that is used for light-duty applications and for medium-duty applications. The MPGM is available in the following grades: NLGI No. 2 grade and NLGI No. 0 grade. The MPGM is strengthened with a molybdenum disulfide and a polymer for extra lubrication and protection. MPGM contains unleaded additives. MPGM also contains antiwear inhibitors, rust inhibitors, and corrosion inhibitors that are for protection and lubrication in many environments. The MPGM is formulated with a base fluid that has high viscosity.

The MPGM has the following features:

- Increased protection against water washout
- Increased retention
- Resistance to heavy loads

This product is recommended for heavily loaded pin joints and for journal bearings. This product meets the certification of "GC-LB". Normal operating temperatures for this product are -28 to 149 °C (-18 to 300 °F) for the NLGI No. 0 grade. Normal operating temperatures for this product are -18 to 149 °C (0 to 300 °F) for the NLGI No. 2 grade.

Note: If MPGM is not available, use a multipurpose type grease which contains three to five percent molybdenum.

Special Purpose Grease (SPG)

Bearing Lubricant (SPG)

Bearing Lubricant (SPG) is available in a NLGI No. 2 grade with a polyurea thickener. This grease is recommended for high temperature antifriction bearings in the following applications: electric starting motors, alternators, fan drives, and generators. The Bearing Lubricant (SPG) has an effective operating range of -29 to 177 °C (-20 to 350 °F).

Water and Temperature Resistant Grease (WTR)

The Water and Temperature Resistant Grease is designed for use whenever the following conditions are a concern: water washout, severe corrosion, and high operating temperatures. The Water and Temperature Resistant Grease provides extreme pressure protection, antiwear protection, rust protection and corrosion protection. The Water and Temperature Resistant Grease is an environmentally friendly grease which does not contain the following materials: antimony, sulfur, barium, zinc, lead, and phosphorous materials. The Water and Temperature Resistant Grease has excellent shear stability. Water and Temperature Resistant Grease can also resist breakdown in the presence of water.

This product meets the NLGI certification of "GC-LB". Normal operating temperatures for this product are -40 to 204°C (-40 to 400°F).

Caterpillar Premium Grease (CPG)

Desert Gold (CPG)

Desert Gold is a heavy-duty, premium synthetic grease that is developed for the most extreme operating environments. This grease is formulated with a high viscosity, synthetic base fluid, polymers, and molybdenum disulfide. Desert Gold has a high viscosity index and a high dropping point.

Desert Gold will protect equipment against heavy shock loads. Desert Gold protects against corrosion in extreme heat, in moist conditions, or in dusty conditions. This product has excellent characteristics of adhesion and of stability. Desert Gold provides longer protection than other greases. Desert Gold is an environmentally friendly grease which does not contain the following materials: antimony, sulfur, barium, zinc, lead, and phosphorous materials. Normal operating temperatures are –6 to 230 °C (21 to 450 °F). Desert Gold can operate at higher temperatures for short time periods.

Arctic Platinum (CPG)

Arctic Platinum is a super-premium extreme pressure lubricating grease that is developed for lubrication in temperatures that are below zero to moderate operating temperatures. Arctic Platinum is available in grades 000, 00, 0, 1, and 2. These grades are sure to pump in central lube systems in a variety of ambient temperatures from -60 to 18 °C (-76 to 65 °F). Arctic Platinum has a high dropping point. Arctic Platinum contains a five percent concentrate of molybdenum disulfide for protection against extra heavy loads. Arctic Platinum provides excellent corrosion protection and rust protection. Arctic Platinum is an environmentally friendly grease which does not contain the following materials: antimony, sulfur, barium, zinc, and phosphorous.

Fuel Specifications

i01877340

General Fuel Information

SMCS Code: 1250; 1280

NOTICE

Refer to the engine's Operation and Maintenance Manual for any fuel information that may be specific to that application.

Gaseous fuels consist primarily of hydrocarbons (combinations of hydrogen and carbon) and some inert gases. Pipeline natural gas has been used for many years. Other types of fuels such as wellhead gas, bio-gas, and manufactured gas need to be reviewed for acceptability.

Each commercial fuel gas is a mixture of gases. Some of the gases are combustible and some of the gases are inert. The compositions of these gas mixtures have extreme variations.

Caterpillar gas engines will operate successfully on a broad range of gaseous fuels. Adjustments must be made to the fuel system when the engine is commissioned or when the fuel is changed. Consult your Caterpillar dealer about the proper adjustments.

Permissible fuels must be analyzed in order to determine the following characteristics:

- Composition
- Contaminants
- Heat value
- Methane number
- Specific gravity

Field gas can have varying characteristics of combustion. Field gas can contain numerous harmful impurities. The impurities can alter the BTU value. The impurities can also alter the methane number. The impurities include everything from water up to complex hydrocarbons that can lead to detonation and severe engine damage. To minimize these effects, Caterpillar recommends the following guidelines:

 Evaluate the fuel with the Caterpillar Methane Number Program, LEKQ6378.

- Methane values below 30 are not recommended for use in a Caterpillar engine. Fuels with a methane number that is below 30 must first be processed in order to remove harmful impurities in the fuel and raising the methane number into the acceptable range.
- If necessary, use an engine that is configured for a fuel that has a high energy. Consult the appropriate manual for the engine in order to determine the recommended engine timing.
- Reduce the oil change interval according to the results of the oil analysis.

Before the engine arrangement is ordered, use the methane number to determine the following characteristics for the new engine:

- Compression ratio
- Fuel system components
- Ignition timing
- Rated load

For a detailed explanation of methane numbers, refer to Application and Installation Guide, LEKQ7256, "Fuels, Fuel Systems".

The High Heat Value (HHV) is a measurement of the total heat that is generated by combustion of a fuel. When any hydrocarbon is used as a fuel in an internal combustion engine, water is one of the products of combustion. The water is converted into steam before leaving the engine. The conversion requires heat. The steam removes the heat and the energy is not used by the engine. The HHV minus the heat that is used to vaporize the water equals the Low Heat Value (LHV) of the fuel. The LHV is sometimes known as the fuel energy content. Generally, fuel with a lower LHV releases heat less rapidly.

iO1931763

Fuel Effects on Maintenance Costs

SMCS Code: 1280

There are many sources of the fuel that is used in gas engines. These different sources may have an effect on the engine's maintenance intervals. These sources include pipeline natural gas, wellhead gas, bio-gas, and propane.

With pipeline natural gas, maintenance intervals might be extended. Due to the harmful effects of impurities that contaminate gases such as bio-gas, shorter maintenance intervals would be expected. These maintenance intervals can be improved by processing the gas in order to remove damaging impurities.

For more information on types of fuels, see the appropriate topics in the Fuel Specifications section of this manual. For specific information on the maintenance intervals, see the Operation and Maintenance Manual for the engine.

i01895409

Dry Natural Gas (Pipeline)

SMCS Code: 1280-G6

Dry natural gas is a mixture of methane and traces of heavier hydrocarbons. Dry natural gas has been processed in order to remove liquids. This gas has a low tendency to detonate.

For dry natural gas, the acceptable limit of hydrogen sulfide is 0.43 mg/MJ (0.45 µg/Btu).

The heat value of dry natural gases may vary. This depends on the composition of the gas. Dry natural gas usually has an LHV that is between 33.53 to 34.65 kJ/L (900 to 930 Btu/cu ft). Caterpillar Gas Engines are adjusted at the factory with a dry natural gas that is within this range.

i01925600

Propane

SMCS Code: 1280

NOTICE

Propane and blends of propane may cause detonation in high compression engines.

Propane is transported to a site as a liquid. The liquid is converted into a gas at the site.

For the guidelines in this Special Publication, propane must meet these HD-5 specifications:

- 95 percent propane
- Remaining 5 percent is not heavier than butane.

The engine must be properly equipped for the use of propane. The use of pistons with a low compression ratio and a derating is required.

HD-5 propane has a Low Heat Value (LHV) between 2427 to 2532 kJ/0.305 m³ (2300 to 2400 Btu/ft³). Due to the higher heat of combustion that is produced by propane, engines that use this fuel will have higher exhaust port temperatures than engines that use dry natural gas.

The higher exhaust temperatures tend to reduce the service life of the cylinder head, of the exhaust manifold, and of the turbocharger.

i01931751

Wellhead Gas

SMCS Code: 1280-G6

Wellhead gas (field gas) is a mixture of hydrocarbons and inert gases that is drawn directly from the wellhead in the gas field. Wellhead gas has minimal processing before entering the fuel manifold. This fuel is commonly used in engines that power gas compressors.

The composition of gas from the wellheads in different gas fields varies, and the composition of the gas from different wellheads within the same gas field can vary. Different compositions have different characteristics of combustion. As a result, the gas from one source may be acceptable for use but the gas from a different source may not be acceptable. Heavier hydrocarbons such as pentane and butane can cause detonation and other problems. For these reasons, a fuel analysis is required to determine if the fuel is acceptable for a particular Caterpillar Engine.

Note: The composition of the gas from a field can change over time. Allow some adaptability for this change during the life of the project.

Some gas fields contain significant amounts of hydrogen sulfide. In these cases, follow the precautions that are recommended in this Special Publication, "Sour Gas" topic.

The site may have equipment such as scrubbers, liquid separators, and heat exchangers that remove water and liquid hydrocarbons from the gas. However, vapor can still be drawn into the engine.

The maintenance costs are variable for engines that use wellhead gas. Sometimes, overhauls are needed at intervals that are sooner than the expected time. However, the practices and factors at many sites enable overhaul intervals that are longer than the expected times: efficient preventive maintenance, proper engine oil, and operation below the rated load.

Follow the guide for fuel usage that is in the engine's Engine Performance publication. These publications are available from your Caterpillar dealer.

Consult your Caterpillar dealer before operating the engine with fuel that has more than one percent of hydrocarbons that are heavier than butane.

i01925577

Sour Gas

SMCS Code: 1280

Many gaseous fuels contain sulfur compounds. These compounds are primarily composed of hydrogen sulfide (H₂S). Gaseous fuels with more than 0.43 mg H₂S/MJ (.45 µg H₂S/Btu) are considered to be sour gas. The following gases are within this category:

- Some wellhead gases
- Landfill gas
- Digester gas

Required maintenance is increased by the introduction of hydrogen sulfide into the engine's fuel. For sour gas, Caterpillar recommends engine arrangements for landfill gas.

The use of gases that have hydrogen sulfide can damage the engine. Products of combustion (water vapor and sulfur oxides) form sulfurous acid and sulfuric acid.

Analyze the gas before use. If the gas has more than 0.43 mg of H₂S/MJ (.450 µg of H₂S/Btu), treat the gas in order to reduce the content of hydrogen sulfide. For more information, see this Special Publication, "Hydrogen Sulfide Effects on Engine Maintenance Costs".

i01877399

Bio-Gas

SMCS Code: 1280-G5

Bio-gas is generally classified as gas that is obtained from these sources:

- Landfills
- Facilities that produce digester gas

Although these gases are both the result of organic decomposition, the compositions are different.

Landfill Gas

The decomposition of organic material produces landfill gas. The composition of landfill gas depends on the materials that are in the landfill. The gas is collected through a grid of pipes that are laid out within the landfill.

Landfill gas may contain contaminants that can cause harmful effects on engines:

- Chlorine
- Fluorine
- Siloxanes
- Sulfur
- Water vapor

Fuel analysis is required in order to provide guidelines for treatment of the fuel.

The sulfur compounds in landfill gas cause the same engine problems as sulfur in sour gas. When landfill gas is used, follow the precautions that are recommended for sour gas.

Landfills can also contain chlorine and fluorine compounds in the form of volatile organic compounds and chlorofluorocarbons. When these substances are burned in engines, corrosive hydrochloric acid and hydrofluoric acid can be produced.

Landfill gas can corrode both the equipment that handles the gas and the engine. Vapor is produced by combustion. If that vapor condenses in the crankcase, a solution that is potentially corrosive to the engine can form.

Landfill gas and digester gas can contain siloxanes. Siloxanes are formed when silica ions attach to the methane hydrocarbon chain. These gaseous compounds enter the combustion chamber with the fuel. This creates deposits in the cylinders.

Because the engine oil contains some calcium, deposits in the combustion chamber are generally a combination of these materials: silicon, calcium, and some traces of other elements.

The particles can be abrasive to exhaust valve faces and to valve seats. This causes the valves to become pitted and indented. The particles can also build up on the valve seat. The buildup can cause guttering of the valves.

Deposits also form on the pistons and on the bottom deck of the cylinder heads. These deposits can increase the compression ratio, which can lead to detonation. Detonation can loosen the deposits. The deposits that are loosened can be trapped between the valve and the valve seat. The valve will be held open. Guttering of the valve will result.

The formation of deposits depends on the following factors:

- Composition of the fuel
- Operating conditions
- Type of lubrication oil

Most landfill applications will generate some deposits in the combustion chamber and in the turbocharger. Siloxanes are a major contributor to these deposits. The fuel requires treatment in order to remove the siloxanes. For information on equipment for processing landfill gas, refer to Application and Installation Guide, LEKQ7260, "Low Energy Fuels".

Note: The amount of silicon in the fuel can be measured with a test that was developed by Caterpillar and by Bio-Engineering Services. The test kit enables a sample of the fuel to be analyzed. The fuel can also be analyzed for other harmful contaminants such as chlorines, fluorines, sulfur, and halides. Details can be obtained from the following address:

Bio-Engineering Services 36 Virginia Street Southport, Merseyside PR8 6RU England Telephone: 44 (0) 1704-539094 Fax: 44 (0) 1704-501660

During normal combustion, some exhaust gas is forced past the piston rings and into the crankcase. The contaminants in this blowby are vented away from the crankcase by positive crankcase ventilation. The contaminants are diluted and purged.

The formation of water in the crankcase and in the valve mechanisms can result in an acid solution which allows corrosion to occur. A high jacket water coolant temperature helps to prevent the condensation of water in the crankcase. Engines that are used for landfill gas have a high temperature jacket water cooling system as standard equipment.

To protect the service life of the engine, it is necessary to follow the guidelines for operation and maintenance that are recommended by Caterpillar. Landfill gas also requires regular, careful maintenance of the spark plugs. Misfire causes the engine to run rough. The cylinder temperatures are reduced. Cooler cylinders allow deposits to build up faster in the combustion chamber, in the exhaust manifold, and in the turbocharger. Exhaust port temperatures can indicate the performance of the spark plugs. An exhaust port temperature that decreases more than 66 °C (150 °F) below the average operating temperature may indicate the misfire of a spark plug. Inspect the spark plug in accordance with the engine's Operation and Maintenance Manual, "Ignition System Spark Plug Inspect/Adjust/Replace" article.

Note: For more information on bio-gas, refer to Application and Installation Guide, LEKQ7260, "Low Energy Fuels".

Digester Gas

A variety of materials can produce digester gas:

- Sewage
- Animal waste

Digester gas has properties that are similar to the properties of landfill gas. Digester gas usually has some sulfur and siloxanes. However, the chlorofluorocarbons that are commonly found in landfill gas are not usually found in digester gas. The same precautions for treatment of the fuel and protecting the engine are required. Until experience proves otherwise, the same maintenance recommendations are used.

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Hydrogen Sulfide Effects on Engine Maintenance Costs

SMCS Code: 1280

The use of gases that have hydrogen sulfide can damage the engine. Products of combustion (water vapor and sulfur oxides) form sulfurous acid and sulfuric acid. Sulfur reacts easily with bright metals such as copper. Therefore, oil coolers are usually the first components that are affected by the acids. Other engine parts that are attacked by the acids include the following components:

- Fuel valves
- Valve mechanisms

- Piston pin bushings
- Piston rings
- Cylinder liners
- Exhaust manifolds
- Aftercoolers

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Various devices can reduce the content of hydrogen sulfide. Examples are chemically active filters, reactive beds, and solutions. The performance of the devices deteriorates as the reactive chemicals are depleted. The devices must be serviced or replaced in order to maintain effectiveness.

Take the following precautions even if the gas is treated in order to reduce the level of hydrogen sulfide. This will help to protect the engine against intervals when the devices for treating the fuel deteriorate. Even brief intervals of operation with high sulfur fuels can damage the engine, unless precautions are taken.

- Use an engine configuration that has a fuel system that is designed for sour gas.
- Maintain the temperature of the coolant outlet to a minimum of 110 °C (230 °F). Lower jacket water coolant temperatures permit water vapor and hydrogen sulfide to condense on the cylinder liners. Higher temperatures will reduce this condensation. Do not allow the rise in temperature across the engine to exceed 8.3 °C (15 °F). A rise in temperature of 5.6 °C (10 °F) is preferable.
- Establish an oil analysis program in order to ensure that the oil change intervals are not extended beyond the condemning limits of the oil. The oil analysis will also be able to detect other problems that may occur.

For additional information on gaseous fuels and on treatment of the fuel, refer to the following publications:

- Application and Installation, LEKQ7256, "Fuels/Fuel Systems"
- Application and Installation, LEKQ7260, "Low Energy Fuels"

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Fuel Filtration

SMCS Code: 1260: 1280

NOTICE

The customer is responsible for supplying clean, dry fuel to the engine.

Fuel filters are no less important than air filters to protect gas engines from dirt and debris. A proper fuel filter removes impurities that can damage the internal components of the engine.

The gas must be supplied to the engine at a pressure that is acceptable. For optimum operation, use a fuel filter that is properly sized for the gas pressure.

For many gas engines, fuel filters are a provision of the design for the application. These devices are included in the normal maintenance of the plant. Therefore, Caterpillar does not include a standard fuel filter as a part of each gas engine. However, fuel filters are available from your Caterpillar dealer.

Note: Use a fuel filter that is capable of filtering particles one micron in diameter.

Consult your Caterpillar dealer about the requirements for filtering your engine's fuel.

Cooling System Specifications

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General Coolant Information

SMCS Code: 1350: 1395

NOTICE

Refer to the engine's Operation and Maintenance Manual for any coolant information that may be specific to that application.

Functions of Cooling System

The cooling systems of modern gas engines are precisely balanced. The performance of the cooling system affects many of the engine's components. Optimum performance can only be obtained by proper installation and maintenance of the cooling system.

The engine's cooling system is designed to meet specific guidelines. The proper coolant/antifreeze will provide the following functions:

- Adequate heat transfer
- Compatibility with the cooling system's components such as hoses, seals, and piping
- Protection from water pump cavitation
- Protection from other cavitation erosion
- Protection from freezing and from boiling
- Protection from the buildup of corrosion, of sludge, and of scale

If a cooling system fails to perform any of the above functions, the following conditions can occur:

- Overheating
- Overcooling
- Leaks from hoses, from seals, and from piping.
- Cavitation erosion
- Damage from freezing or from boiling
- Plugging of passages for the coolant/antifreeze in components such as radiators, aftercoolers, oil coolers, and other heat exchangers

Many engine failures are related to the above conditions: cracking of the cylinder head and/or of the engine block, piston seizure, leakage of the water pump, failure of the water pump, and pitting of the cylinder liners.

These problems can be avoided through proper maintenance of the cooling system. Periodically evaluate the maintenance practices in order to make sure that the cooling system is properly maintained.

Properties of Coolant/Antifreeze

Coolant/antifreeze is normally composed of three elements: water, glycol, and additives. Each element must meet specific guidelines.

Water

Water is used in the cooling system in order to transfer heat.

NOTICE

Never use water alone without Supplemental Coolant Additives (SCA) or without inhibited coolant. Water alone is corrosive at engine operating temperatures. Water alone does not provide adequate protection against boiling or freezing.

Deionized water or distilled water is recommended for use in engine cooling systems.

If distilled water or deionized water is not available, use water with the properties that are listed in Table 6.

Table 6

Caterpillar Minir	num Acceptable Water R	lequirements	
Property	Maximum Limit	ASTM Test	
Chloride (CI)	40 mg/L (2.4 grains per US gal)	"D512", "D4327"	
Sulfate (SO ₄)	100 mg/L (5.9 grains per US gal)	"D516"	
Total Hardness	170 mg/L (10 grains per US gal)	"D1126"	
Total Solids	340 mg/L (20 grains per ⊍S gal)	"D1888"	
Acidity	pH of 5.5 to 9.0	"D1293"	

NOTICE

Use of water that does not meet the recommendations for the cooling system will damage the cooling system.

Do not use these types of water in the cooling system: sea water, softened water that has been conditioned with salt, hard water, and tap water.

Only use water that meets the recommendations for the cooling system.

If you are not sure about the properties of your water, consult one of the following sources for a water analysis:

- Caterpillar dealer
- · Local water utility company
- Agricultural agent
- Independent laboratory

Glycol

Glycol in the coolant helps to provide protection against boiling and freezing.

Most conventional heavy-duty coolant/antifreezes use ethylene glycol. In many applications, propylene glycol may also be used. In a 50/50 mixture with water, ethylene and propylene glycol provide similar protection against freezing and boiling.

Use a mixture that will provide protection against the lowest ambient temperature. For a comparison of the protection against freezing, refer to Table 7.

Table 7

Antifreeze Protection			
% Mixture	Lowest Protectiv	e Temperature	
Glycol and Water	Ethylene Glycol	Propylene Glycol	
50 / 50	-37 °C (-34 °F)	-32 °C (-26 °F)	
60 / 40	–51 °C (–60 °F)	-	

Note: 100 percent pure glycol will freeze at a temperature of -23 °C (-9 °F).

The minimum recommended mixture is 50 percent glycol and 50 percent water. For optimum performance, Caterpillar recommends a 50/50 mixture of a water/glycol solution.

Protection against freezing is reduced if the mixture is greater than 60 percent of ethylene glycol.

Protection against freezing is reduced if the mixture has more than 50 percent of propylene glycol.

NOTICE

Do not use propylene glycol in concentrations that exceed 50 percent glycol because of propylene glycol's reduced heat transfer capability. Use ethylene glycol in conditions that require additional protection against boiling or freezing.

To check the concentration of glycol, use the 1U-7298 Coolant/Battery Tester (Degree Celsius) or use the 1U-7297 Coolant/Battery Tester (Degree Fahrenheit). The testers give readings that are immediate and accurate. The testers can be used with ethylene or propylene glycol.

Additives

Additives help to protect the metal surfaces of the cooling system. A lack of coolant additives or insufficient amounts of additives enable the following conditions to occur:

- Corrosion
- Formation of mineral deposits
- Rust
- Scale
- Pitting and erosion from cavitation of the cylinder liner
- Foaming of the coolant

Many additives are depleted during engine operation. These additives must be replaced periodically. This can be done by adding Caterpillar Supplemental Coolant Additive (SCA).

Additives must be added at the proper concentration. Overconcentration of additives can cause the inhibitors to drop out-of-solution. The deposits can enable the following problems to occur:

- Formation of gel compounds
- · Reduction of heat transfer
- Leakage of the water pump seal
- Plugging of radiators, of coolers, and of small passages

For further information, see this Special Publication, "Supplemental Coolant Additive (SCA)" article.

Requirements for Venting of the Cooling System

To achieve optimum service life for the water cooled components in the gas engine, the cooling system must be able to purge air. Air can be introduced into the cooling system by different means:

- Air can be trapped in the cooling system when the system is filled or when the system is refilled.
- Air that is entrained in the mixture of coolant/antifreeze can be released by cavitation.
- Combustion gas can leak into the cooling system.

For maximum service life of the water cooled components, all of the air must be purged from the water jacket of each component. The presence of air can allow some of the coolant/antifreeze to convert into steam. This changes the properties of the coolant/antifreeze. Removal of the air reduces the possibility of the conversion. Removal of the air improves the service life of the coolant/antifreeze.

The preferred method for venting of the engine's cooling system is the installation of vent lines. Follow these guidelines:

- The vent line must be routed from the highest point of the cooling system on the engine to a point that is higher than any of the engine's water cooled components.
- Each component that is in a position which can trap air must be vented. For example, the turbocharger and the exhaust bypass valve are usually located at the highest points of the cooling system. One line cannot remove the air from both components. If only one of the components is vented, the other component can still trap air. Both of the components must be vented.
- For each cooling circuit, route the vent line into the bottom of the expansion tank.
- The vent line must have a continuous upward slope. To avoid blockage in the vent line, make sure that the vent line is routed in a manner that will avoid trapped fluid. Do not allow any dips in the routing of the vent line.

In some applications, it may not be possible to install the recommended vent lines. In these cases, automatic vent lines must be installed. Install an automatic valve that is 0.6 to 0.9 m (2.00 to 3.00 ft) above the highest point of the cooling system on the engine.

Note: An automatic valve requires periodic service. Make sure that the valve is not plugged. If coolant/antifreeze leaks from a valve, correct the condition immediately. A valve that malfunctions can allow air to enter the cooling system after the engine is shut down.

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Coolant Recommendations

SMCS Code: 1350; 1352; 1395

General Recommendations

NOTICE

Never add coolant to an overheated engine. Engine damage could result. Allow the engine to cool first.

During shipping and storage, the engine must be protected from damage that can be caused by freezing of the cooling system. If the engine is shipped to a site with freezing temperatures and/or if the engine is stored in a location with freezing temperatures, the cooling system must contain antifreeze that will withstand the lowest ambient temperature. Frequently check the concentration of glycol in the coolant/antifreeze. Make sure that the concentration is adequate in order to prevent freezing. Otherwise, the cooling system must be completely drained.

For engines in any location, periodically check the concentration of the conditioner in the coolant/antifreeze. Make sure that the concentration is adequate in order to help prevent corrosion and other harmful conditions.

NOTICE

Never operate an engine without water temperature regulators in the cooling system. Water temperature regulators help to maintain the engine coolant at the proper operating temperature. Cooling system problems can develop without water temperature regulators.

NOTICE

Fill the cooling system no faster than 19 L (5 US gal) per minute to avoid air locks.

After a cooling system has been refilled, monitor the level of the coolant/antifreeze in the expansion tank. Maintain the level above the minimum mark until all of the air has been purged from the system. Then maintain the proper level for normal operation.

During normal operation, frequently check the level of the coolant/antifreeze in the expansion tank. If the level is low, add the proper mixture of coolant/antifreeze.

For engines in any location, check the concentration of the conditioner in the coolant/antifreeze according to the engine's Operation and Maintenance Manual, "Maintenance Interval Schedule". Obtain an S·O·S coolant analysis (Level 1) or use the appropriate test kit. Make sure that the concentration is adequate in order to help prevent corrosion and other harmful conditions.

To further monitor the cooling system, obtain regular S·O·S coolant analyses (Level 2) according to the engine's Operation and Maintenance Manual, "Maintenance Interval Schedule".

Recommended Coolant/Antifreeze

NOTICE

Do not use Extended Life Coolant (ELC) with Caterpillar Gas Engines.

ELC was not formulated for use in Caterpillar Gas Engines.

Use only the coolant/antifreeze that is recommended.

Preferred – Caterpillar Natural Gas Engine Coolant (NGEC)

Alternatively, use Caterpillar Diesel Engine Antifreeze/Coolant (DEAC) or a commercial heavy-duty coolant/antifreeze that meets "ASTM D6210" or "ASTM D4985" specifications.

The preferred coolant/antifreeze can contain either ethylene glycol or propylene glycol. The coolant/antifreeze must be low in silicates. The coolant/antifreeze must be mixed with water that meets the properties that are listed in the Table in the "General Coolant Information" topic. The coolant/antifreeze must also have the correct concentration of Supplemental Coolant Additive (SCA).

NOTICE

Do not use a commercial coolant/antifreeze that only meets the ASTM "D3306" specification. This type of coolant/antifreeze is made for light duty automotive applications.

Use only the coolant/antifreeze that is recommended.

Acceptable – In applications that do not require protection from boiling or from freezing, a mixture of Caterpillar SCA and water that meets the properties that are listed in the "Caterpillar Minimum Acceptable Water Requirements" Table in the "General Coolant Information" topic is acceptable.

Note: The preferred coolant/antifreeze and the acceptable mixture of SCA and water require different concentrations of SCA. Refer to the "Supplemental Coolant Additive (SCA)" topic.

Table 8 is a list of the coolant/antifreeze that is recommended for Caterpillar Gas Engines. The service life of the coolant/antifreeze that is used in Caterpillar Gas Engines is also listed. To achieve this service life, the coolants must be properly maintained. The maintenance program includes S·O·S coolant analysis.

Table 8

Recommended Coolant/Antifreeze and Service Life of the Coolant/Antifreeze		
Coolant/Antifreeze	Service Life (1)	
Caterpillar NGEC	Three Years	
Caterpillar DEAC	Tillee fears	
Commercial Heavy-Duty Coolant/Antifreeze that meets "ASTM D6210"	Two Years	
Commercial Heavy-Duty Coolant/Antifreeze that meets "ASTM D4985"	One Year	
Caterpillar SCA and Water	Two Years	
Commercial SCA and Water	One Year	

⁽¹⁾ The service life of coolant is also limited by use (service hours). Refer to the specific engine's Operation and Maintenance Manual, "Maintenance Interval Schedule".

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Supplemental Coolant Additive (SCA)

SMCS Code: 1350: 1352: 1395

Recommended Supplemental Coolant Additive (SCA)

The use of SCA helps to prevent the following conditions from occurring:

- Corrosion
- · Formation of mineral deposits

- · Cavitation erosion of the cylinder liners
- · Foaming of the coolant

Preferred – Caterpillar Supplemental Coolant Additive (SCA)

Acceptable – A commercial SCA that provides 1200 mg/L (70 grains per US gal) or 1200 ppm of nitrites in the final mixture of coolant/antifreeze

Note: A 50/50 concentration of Caterpillar NGEC or of Caterpillar DEAC does not require a treatment with an SCA at the initial fill. Commercial heavy-duty coolant/antifreeze that meets "ASTM D6210" or "ASTM D4985" specifications may require a treatment with an SCA at the initial fill. Read the label or the instructions that are provided by the OEM of the product.

To ensure that the correct amount of SCA is in the cooling system, the concentration of SCA must be tested on a scheduled basis. Obtain an S-O-S coolant analysis (Level 1) or use a test kit to check the concentration of the SCA according to the engine's Operation and Maintenance Manual, "Maintenance Interval Schedule".

WARNING

Cooling system coolant additive contains alkali. To help prevent personal injury, avoid contact with the skin and eyes. Do not drink cooling system coolant additive.

Coolant/Antifreeze and SCA

Note: Mixtures of glycol and water require a lower concentration of SCA than mixtures of only water and SCA. Mixtures of glycol and water require three to six percent of SCA.

NOTICE

Do not exceed the recommended six percent supplemental coolant additive concentration.

Test the concentration of the SCA with an S·O·S coolant analysis (Level 1) or with the 4C-9301 Coolant Conditioner Test Kit.

Instructions are provided with the 4C-9301 Coolant Conditioner Test Kit.

Note: Caterpillar SCA has a nitrate base. Many commercial types of SCA have a base of phosphate that cannot be checked with a Caterpillar test kit. If a commercial SCA is used, follow the recommendations for testing that are provided by the OEM of the product.

If a commercial SCA is used, the final mixture of coolant/antifreeze must have 1200 mg/L (70 grains per US gal) or 1200 ppm of nitrites.

Water and SCA

A cooling system that uses a mixture of water only and SCA requires more SCA than a cooling system that uses a mixture of glycol and water. The mixture of only water and SCA requires six to eight percent of SCA.

NOTICE

Do not exceed the recommended eight percent supplemental coolant additive concentration.

Test the concentration of SCA with an S·O·S coolant analysis (Level 1) or with the 8T-5296 Coolant Conditioner Test Kit.

If you perform the test with the 8T-5296 Coolant Conditioner Test Kit, use the following instructions:

- Fill the syringe to the "1.0 ml" mark with the coolant.
- 2. Dispense the 1.0 mL coolant sample from the syringe into the empty mixing bottle.
- Add tap water to the mixing bottle in order to bring the level up to the "10 ml" mark. Place the cap on the bottle and shake the bottle.
- Add 2 to 3 drops of the "NITRITE INDICATOR SOLUTION B" to the mixing bottle. Move the bottle in a circular motion in order to mix the solution.
- Add 1 drop of "NITRITE TEST SOLUTION A" to the mixing bottle. Move the bottle in a circular motion in order to mix the solution.
- 6. Repeat 5 until the solution changes color from red to light gray, green, or blue. Record the number of drops of "NITRITE TEST SOLUTION A" that were required to cause the color change.
- 7. Use Table 9 to interpret the results.

Table 9

Number of Drops	Concentration of SCA	Maintenance Required
Less than 25	Less than the recommended concentration of SCA	Add SCA. Retest the coolant.
25 to 30	The recommended concentration of SCA	None
More than 30	More than the recommended concentration of SCA	Remove the coolant. Replace with water only Retest the coolant.

Excessive Concentrations of SCA

An excessive concentration of SCA can result in the formation of deposits.

If the concentration of SCA is greater than the recommended level, drain some of the coolant/antifreeze. Refill the cooling system and operate the engine in order to fully dilute the mixture. Then, test the concentration again. Repeat this process until the concentration is acceptable.

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Cooling System Maintenance

SMCS Code: 1350; 1352; 1395

Cooling system maintenance has a direct effect on engine operation and on the service life of the engine. Maintain the coolant to the standards that are recommended in the engine's Operation and Maintenance Manual. Refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule". Follow these guidelines:

- Use the recommended coolant/antifreeze.
- Maintain the proper concentration of Supplemental Coolant Additive. Use the correct method of testing.
- Maintain the protection against freezing.
- Clean the cooling system and refill the system according to the engine's Operation and Maintenance Manual.
- Consult your Caterpillar dealer about S·O·S Coolant Analysis.

Fluid Products for the Cooling System

Table 10

Quantities and Part Numbers of Caterpillar Natural Gas Engine Coolant (NGEC)			
Туре	3.8 L (1 US gal)	19 L (5 US gal)	208 L (55 US gal)
50% Glycol 50% Water	233-9797	233-9798	233-9799

Table 11

Quantities and Part Numbers of Caterpillar Diesel Engine Antifreeze/Coolant (DEAC)			
Туре	3.8 L (1 US gai)	208 L (55 US gal)	Bulk
Undiluted Concentrate	8C-3684	8C-3686	2P-9868
50% Glycol 50% Water	•	-	3E-9439
40% Glycol 60% Water	-	-	119-5147

Table 12

Quantities and Part Numbers of Caterpillar Supplemental Coolant Additive (SCA)			
0.47 L (1 pint)	0.95 L (1 qt)	18.9 L (5 US gal)	208 L (55 US gal)
8T - 1589	3P - 2044	8C-3680	5P-2907

Table 13

Quantities and Part Numbers of Caterpillar Cooling System Cleaner			
0.95 L (1 qt) 3.8 L 18.9 L (1 US gal) (5 US gal)		208 L (55 US gal)	
4C-4610	4C-4611	4C-4612	4C-4613

Test Tools for the Cooling System

Table 14

Test Tools for the Cooling System and Function of the Tools			
Part	Function		
1U-7297 Coolant/Battery Tester (Degree Fahrenheit)	Check the freezing point of the coolant/antifreeze.		
1U-7298 Coolant/Battery Tester (Degree Celsius)			
4C-9301 Coolant Conditioner Test Kit	Check the concentration of the SCA in mixtures of glycol and water.		
4C-9297 Test Strip (Coolant Conditioner)	Test strips for checking the concentration of the SCA in mixtures of glycol and water		
8T - 5296 Coolant Conditioner Test Kit	Check the concentration of the SCA in mixtures of only water and SCA. The instructions that are provided with the test kit must be modified for this test. Refer to the "Water and SCA" topic.		
164-3310 Infrared Thermometer	Measure surface temperatures without contacting the surface.		
164 - 3320 Infrared Thermometer Gp (110 Volt AC Adapter)			
166-9030 Infrared Thermometer Gp (220 Volt AC Adapter)			

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S-O-S Coolant Analysis

SMCS Code: 1350; 1352; 1395; 7542-008; 7542

Testing the engine coolant is important to ensure that the engine is protected from internal cavitation and from corrosion. The analysis also tests the ability of the coolant to protect the engine from boiling and from freezing.

Coolant analysis can be performed at your Caterpillar dealership. Caterpillar's S·O·S coolant analysis is an excellent way to monitor the condition of your coolant and your cooling system.

The most critical aspect of coolant analysis is the interpretation of the results. The analyst must be properly trained in order to provide a correct diagnosis. The analyst must understand several variables.

Different coolants have different formulations and different condemning limits. Different commercial labs may use different methods to test for the same variable. These other considerations are also important for interpreting the results of a coolant analysis:

- The number of hours on the sample
- The equipment that uses the coolant
- The application of the equipment

Analysts at Caterpillar's S·O·S fluid labs are trained to determine the acceptability of coolants. These analysts have knowledge of the equipment and applications. These qualifications enable the analysts to detect problems before damage occurs.

NOTICE

Always use a designated pump for oil sampling, and use a separate designated pump for coolant sampling. Using the same pump for both types of samples may contaminate the samples that are being drawn. This contaminate may cause a false analysis and an incorrect interpretation that could lead to concerns by both dealers and customers.

Caterpillar's S·O·S coolant analysis is a program with two levels. The program is based on periodic samples. The samples are analyzed. The results are reported, and appropriate recommendations are made according to the results.

S.O.S Coolant Analysis (Level 1)

A coolant analysis (Level 1) is a test of the properties of the coolant that includes the following items:

- Glycol concentration for protection from boiling and freezing
- Ability to protect from erosion and corrosion
- pH
- Conductivity

- Water hardness
- Visual analysis
- · Analysis of the odor

The results are reported, and appropriate recommendations are made.

S-O-S Coolant Analysis (Level 2)

A coolant analysis (Level 2) is a comprehensive chemical evaluation of the coolant. This analysis is also a check of the overall condition of the inside of the cooling system. The following services are provided:

- Full Level 1 analysis
- Identification of the source of metal corrosion and of contaminants
- Identification of buildup of the impurities that cause corrosion
- Identification of buildup of the impurities that cause scaling
- Determination of possible electrolysis within the engines' cooling system

The results are reported, and appropriate recommendations are made.

For more information on S·O·S coolant analysis, consult your Caterpillar dealer.

Reference Information Section

Reference Materials

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Reference Material

SMCS Code: 1000

The following literature can be obtained through any Caterpillar dealer.

Lubricants

- Data Sheet, PEHP0002, "Multipurpose Lithium Complex Grease with Molybdenum (MPGM)"
- Data Sheet, PEHP0003, "Multipurpose Lithium Complex Grease (MPG)"
- Data Sheet, PEHP0017, "Special Purpose Grease (SPG) Bearing Lubricant"
- Special Publication, PEDP7036, "S-O-S Fluid Analysis"
- Special Publication, PEHP6001, "How To Take A Good Oil Sample"

Fuels

- Application and Installation Guide, LEKQ7256, "Fuels, Fuel Systems"
- Application and Installation Guide, LEKQ7260, "Low Energy Fuels"

Coolants

- Data Sheet, PEHP7057, "Coolant Analysis"
- Special Publication, PEDP7036, "S:O·S Fluid Analysis"
- Special Publication, SEBD0518, "Know Your Cooling System"
- Special Publication, SEBD0970, "Coolant and Your Engine"

Miscellaneous

 Software Program; LEKQ6378, "Methane Number" Program"

- Special Instruction, SEHS9298, "Installation and Maintenance of Gaseous Fuel Filters"
- Special Publication, NENG2500, "Caterpillar Tools and Shop Products Guide"
- Special Publication, PECP9067, "One Safe Source"
- Special Publication, SEBF8029, "Index to Guidelines for Reusable Parts and Salvage Operations"

Additional Reference Material

The "Engine Fluids Data Book" can be obtained from the following locations: local technological society, local library, and local college. If necessary, consult EMA at the following address:

Engine Manufacturers Association Two North LaSalle Street, Suite 2200 Chicago, Illinois, USA 60602 E-mail: ema@enginemanufacturers.org (312) 827-8700 Facsimile: (312) 827-8737

The "Society of Automotive Engineers (SAE) Specifications" can be found in your SAE handbook. This publication can also be obtained from the following locations: local technological society, local library, and local college. If necessary, consult SAE at the following address:

SAE International 400 Commonwealth Drive Warrendale, PA, USA 15096-0001 Telephone: (724) 776-4841

The "American Petroleum Institute Publication No. 1509" can be obtained from the following locations: local technological society, local library, and local college. If necessary, consult API at the following address:

American Petroleum Institute 1220 L St. N.W. Washington, DC, USA 20005 Telephone: (202) 682-8000

The International Organization for Standardization (ISO) offers information and customer service regarding international standards and standardizing activities. ISO can also supply information on the following subjects that are not controlled by ISO: national standards, regional standards, regulations, certification, and related activities. Consult the member of ISO in your country.

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European classifications are established by the Counseil International Des Machines a Combustion (CIMAC) (International Council on Combustion Engines).

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Product and Dealer Information

Note: For product identification plate locations, see the section "Product Identification Information" in the Operation and Maintenance Manual.

Delivery Date:			
Product	Information		
Model:			
Product Identif	ication Number:		
Engine Serial N	Number:		
Transmission S	erial Number:		
Generator Seria	al Number:		
Attachment Se	rial Numbers:		
Attachment Info	ormation:		
Customer Equi	pment Number:		
Dealer Equipm	ent Number:		
Dealer In	formation		
		Decemb	
Name:		Branch:	
Address:	<u> </u>		
	Dealer Contact	Phone Number	<u>Hours</u>
Sales:			
Parts:			
Service:			





CATERPILAREIM TED WARRANTY

Industrial Engine Products and Electric Power Generation Products Worldwide

('excluding the Commonwealth of Independent States)

Caterpillar Inc. or any of its subsidiaries ("Caterpillar") warrants new and Remanufactured engines and electric power generation products sold by it (Including any products of other manufacturers packaged and sold by Caterpillar) and operating outside the Commonwealth of independent States (formerly USSR), to be free from defects in material and workmanship.

A different warranty statement applies to product operating in the Commonwealth of independent States. Copies of this warranty may be obtained by writing Caterpillar Inc.; 100 N.E. Adams St., Reoria, IL. USA 61629-9260.

This warranty does not apply to CM product engines sold for use in on-highway vehicle or marine applications, engines in machines manufactured by or for Caterpillar, 3500 and 3600 Family engines used in tocomotive applications, 3000 Family engines or Caterpillar brand battaries. These products are covered by other Caterpillar warranties.

This warranty is subject to the following:

Warranty Period

The warranty period for new engines, Uninterruptible Power Systems (UPS systems), and electric power generation products is 12 months (24 months for mobile agricultural and standby electric power generation applications) after date of delivery to the first user.

The warranty period for all Remanufactured engines is 6 months (12 months for mobile agricultural and standby electric power generation applications) after date of delivery to the first user.

Caterpillar Responsibilities

If a defect in material or workmanship is found during the warranty period. Caterpillar will, during normal working hours and through a place of business of a Caterpillar dealer or other source approved by Caterpillar.

- Provide (at Catarpillar's choice) new. Remanufactured or Caterpillar-approved repaired parts or assembled components needed to correct the defect.
- Note: Items replaced under this warranty become the property of Caterpillar.
- Replace: lubricating oil, filters, coolant and other service Items made unusable by the defect?
- Provide reasonable of customary labor needed to correct the defect, including labor to disconnect the product from and reconnect the product from and reconnect the product to its attached, equipment, mounting, and support systems if required:
- For new 3114, 3116 and 3126 engines and electric power generation products (including any new products of other manufacturers packaged and sold by Caterpillar):
- Provide travel labor, up to four hours round trip if, in the opinion of Caterpillar, the product cannot reasonably be transported to a place of business of a Caterpillar dealer or other source approved by Caterpillar (travel labor in excess of four frours round trip, and any meals, mileage, lodging, atc. is the user's responsibility).

For all other products:

Provide reasonable travel expenses for authorized mechanics, including meals; mileage.

and lodging, when Caterpillar chooses to make the repair on site:

User Responsibilities

The user is responsible for:

- Providing proof of the delivery date to the first user.
- Labor costs, except as stated under "Caterplilar Responsibilities", including costs beyond those required to disconnect the product from and reconnect the product to its attached equipment, mounting and support systems.
- Travel expenses not covered under "Caterpillar Responsibilities"
- All costs associated with transporting the product to and from the place of business of a Caterpillar dealer of other source approved by Caterpillar.
- Premium or overtime labor costs.
- Parts shipping charges in excess of those which there usual and customary.
- Local taxes, if applicable.
- Costs to investigate complaints, unless the problem is caused by a defect in Caterpillar material or workmanship.
- Giving timely notice of a warrantable failure and promptly making the product available for repair.
- Parformance of the required maintenance (including use of proper fuel, oil, lubricants and coolant) and items replaced due to normal wear and tear.
- Allowing Ceterpillar, access to all electronically stored date.

(continued on reverse side...



Limitations

Caterpillar is not responsible for:

- Failures resulting from any use or installation which Caterpillar judges improper.
- Failures resulting from attachments, accessory items and parts not sold or approved by Caterpillar.
- Failures resulting from abuse, neglect and/or improper repair.
- Failures resulting from user's delay in making the product available after being notified of a potential product problem.
- Failures resulting from unauthorized repair or adjustments, and unauthorized fuel setting changes.
- Damage to parts, fixtures, housings, attachments, and accessory items which are not part of the engine or electric power generation product

(including any products of other manufacturers packaged and sold by Caterpillar).

 Repair of components sold by Caterpillar that are warranted directly to the user by their respective manufacturer. Depending on type of application, certain exclusions may apply. Consult your Caterpillar dealer for more information.

For products operating outside of Australia, Fiji, Nauru, New Caledonia, New Zealand, Papua New Guinea, the Solomon Islands and Tahiti, the following is applicable:

NEITHER THE FOREGOING EXPRESS WARRANTY NOR ANY OTHER WARRANTY BY CATERPILLAR, EXPRESS OR IMPLIED, IS APPLICABLE TO ANY ITEM CATERPILLAR SELLS WHICH IS WARRANTED DIRECTLY TO THE USER BY ITS MANUFACTURER.

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CATERPILLAR EXCLUDES ALL LIABILITY FOR OR ARISING FROM ANY NEGLIGENCE ON ITS PART OR ON THE PART OF ANY OF ITS EMPLOYEES, AGENTS OR REPRESENTATIVES IN RESPECT OF THE MANUFACTURE OR SUPPLY OF GOODS OR THE PROVISION OF SERVICES RELATING TO THE GOODS.

IF OTHERWISE APPLICABLE, THE VIENNA CONVENTION (CONTRACTS FOR THE INTERNATIONAL SALE OF GOODS) IS EXCLUDED IN ITS ENTIRETY.

For electric power generation products sold for personal or family use, operating in the USA, its territories and possessions, some states do not allow limitations on how long an implied warranty may last nor allow the exclusion or limitation of incidental or consequential damages. Therefore, the previously expressed exclusion may not apply to you. This warranty gives you specific legal rights and you may also have other rights which vary by jurisdiction. To find the location of the nearest Caterpillar dealer or other authorized repair facility, call (800) 447-4986. If you have questions concerning this warranty or its applications, call or write:

In USA and Canada: Caterpillar Inc., Engine Division, P. O. Box 610, Mossville, IL 61552-0610, Attention: Customer Service Manager, Telephone (800) 447-4986. Outside the USA and Canada: Contact your Caterpillar dealer.

For products operating in Australia, Fiji, Nauru, New Caledonia, New Zealand, Papua New Guinea, the Solomon Islands and Tahiti, the following is applicable:

THIS WARRANTY IS IN ADDITION TO WARRANTIES AND CONDITIONS IMPLIED BY STATUTE AND OTHER STATUTORY RIGHTS AND OBLIGATIONS THAT BY ANY APPLICABLE LAW CANNOT BE EXCLUDED, RESTRICTED OR MODIFIED ("MANDATORY RIGHTS"). ALL OTHER WARRANTIES OR CONDITIONS, EXPRESS OR IMPLIED (BY STATUTE OR OTHERWISE), ARE EXCLUDED.

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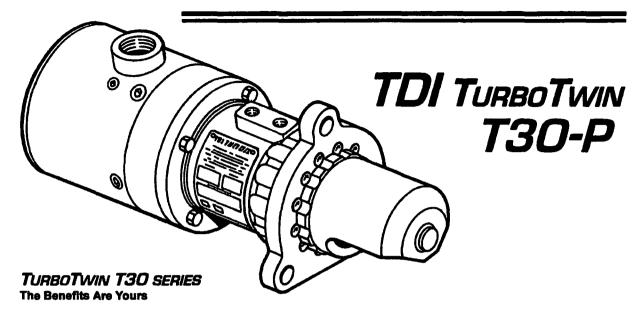
TO THE EXTENT PERMITTED UNDER THE MANDATORY RIGHTS, IF CATERPILLAR IS THE SUPPLIER TO THE USER, CATERPILLAR'S LIABILITY SHALL BE LIMITED AT ITS OPTION TO (a) IN THE CASE OF SERVICES, THE SUPPLY OF THE SERVICES AGAIN OR THE PAYMENT OF THE COST OF HAVING THE SERVICES SUPPLIED AGAIN, AND (b) IN THE CASE OF GOODS, THE REPAIR OR REPLACEMENT OF THE GOODS, THE SUPPLY OF EQUIVALENT GOODS, THE PAYMENT OF THE COST OF SUCH REPAIR OR REPLACEMENT OR THE ACQUISITION OF EQUIVALENT GOODS.

CATERPILLAR EXCLUDES ALL LIABILITY FOR OR ARISING FROM ANY NEGLIGENCE ON ITS PART OR ON THE PART OF ANY OF ITS EMPLOYEES, AGENTS OR REPRESENTATIVES IN RESPECT OF THE MANUFACTURE OR SUPPLY OF GOODS OR THE PROVISION OF SERVICES RELATING TO THE GOODS.

CATERPILLAR IS NOT LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES UNLESS IMPOSED UNDER MANDATORY RIGHTS.

IF OTHERWISE APPLICABLE, THE VIENNA CONVENTION (CONTRACTS FOR THE INTERNATIONAL SALE OF GOODS) IS EXCLUDED IN ITS ENTIRETY.

This warranty covers every major component of the products. Claims under this warranty should be submitted to a place of business of a Caterpillar dealer or other source approved by Caterpillar. For further information concerning either the location to submit claims or Caterpillar as the issuer of this warranty, write Caterpillar Inc., 100 N. E. Adams St., Peoria, IL USA 61629-9260, or its subsidiary, Caterpillar of Australia Ltd., 1 Caterpillar Drive, Private Mail Bag 4, Tullamarine, Victoria 3043, Australia.



 The gear train and bearings are factory grease-packed for the life of the starter, so it requires no maintenance. There are no rubbing parts, so there is no external lubrication required. Lubricator problems, installation expense, system maintenance, and the messy and hazardous oil film around the starter exhaust . . . all are eliminated ENVIRONMENTALLY SAFE

• The TURBOTWIN T30-P starter fits a wide range of engine applications, up to 20 liters. One basic design can be used for a broad range of engine types.

APPLICATION VERSATILITY

 The TURBOTWIN T30-P is ideal for remote or "black" start applications. The unit requires only simple control lines for its operation. SIMPLICITY

 Piping consists of only a single supply line with a ball valve or TDI relay valve in the line. See the typical manual or electric installation diagrams. EASE of INSTALLATION

 The efficient twin-turbine motor design increases the torque applied to the ring gear, using less air per start than competitive designs. Refer to the performance curves for 6 nozzle models. The T30 Series includes models with 3. 6. and 12 nozzles. LOWER AIR CONSUMPTION

The T30-P starter can be used over a wide range of drive pressures from 30 psig (2 BAR) to 150 psig (10 BAR). It is suitable for operation on either compressed air or natural gas. The lightweight, 29 Lb, unit is capable of delivering over 21 HP (15.65 kW) of cranking power at only 120 psig (8 BAR).

BROAD RANGEOF OPERATION

 TURBOTWIN T30 Series starters are constructed from durable, high quality materials. Major components are made from high strength aluminum or steel alloy.

HEAVY DUTY CONSTRUCTION

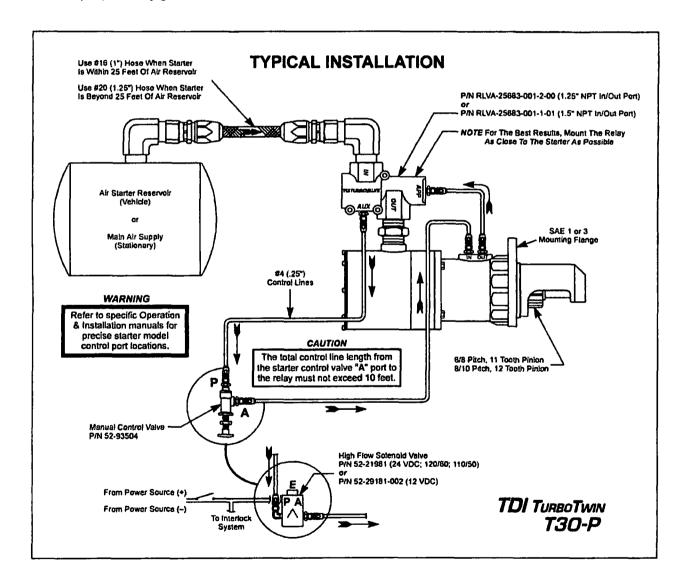
The durable turbine motor design in the TURBOTWIN T30 Series has no rubbing parts. It's tolerant of solid and liquid contamination in the supply gas with nearly no adverse affects. The motor is well adapted to running on "sour" natural gas.

CONTAMINATED SUPPLY GAS

6800 Poe Ave. • Dayton, OH 45413-0557 Tel: 937 / 898 - 9600 Fax: 937 / 898 - 8431 TECH DEVELOPMENT INC. introduced the first turbine technology for starting industrial engines in 1979. The TURBOTWIN T30 Series features an innovative and more reliable turbine motor than anything on the market today. DEVELOPMENT HISTORY

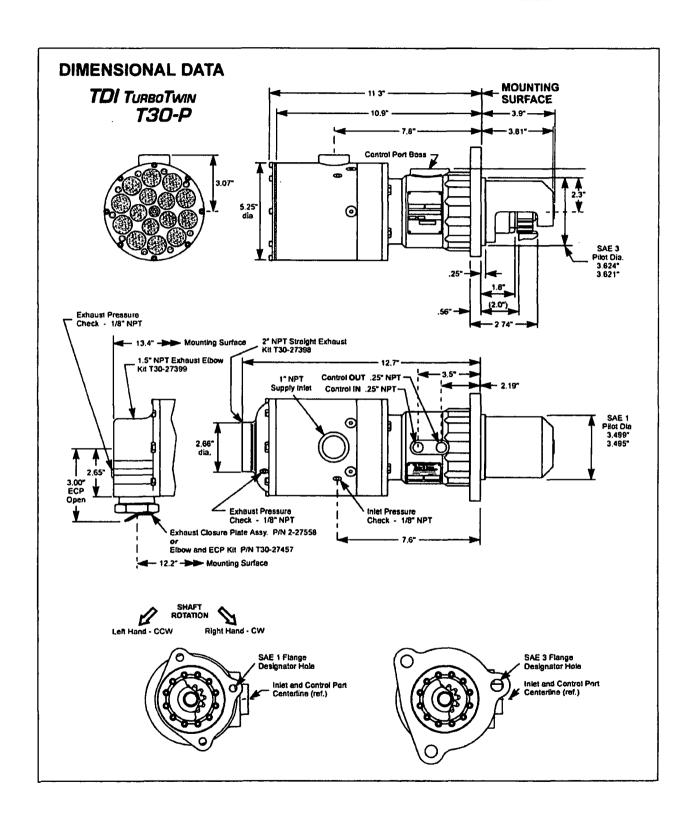
The TURBOTWIN T30 Series is the result of TDI's continuing turbine starter design innovations. Based on our successful TURBOTWIN T100 Series starters, the TURBOTWIN T30 Series starters should exceed customer requirements in every installation.

 The high horsepower of a turbine air motor combined with the planetary gear speed reducer results in a very efficient and compact unit. The TURBOTWIN T30 Series models are powered by a pair of axial flow turbines coupled to a simple planetary gear reduction set. DESCRIPTION of OPERATION



from TECH DEVELOPMENT INC.

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from TECH DEVELOPMENT INC.

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Torque (lb.ft.) TDI TURBOTWIN 150 psig T30-P 125 30 **PERFORMANCE** 120 psig **CURVES** 24 100 90 psig Model T306-P 75 **6 NOZZLES** 60 psig 70° F. Compressed Air 9.0:1 Ratio 50 4 INLET Pressure FLOW (Scfm) **150 PSIG** 600 25 478 **120 PSIG 90 PSIG** 365 60 PSIG 255 5 10 15 20 25 30 35 40 45 50 55 60 Pinion Speed (rpm/100) Torque (lb.ft.) 35 125 30 120 psig 25 1004 20 Model T306-P 90 psig 6 NOZZLES 75 70° F, Methane Gas 15 9.0:1 Ratio 60 psig

T30 Series: Flexibility To Meet Any Requirement

T30-I Inertia Engagement

INLET Pressure

120 PSIG

90 PSIG

60 PSIG

FLOW (Scfm)

600

465

330

T30-P Pre-Engaged

T30-Y Pre-Engaged/Overhung

50

T30-M Industrial Air/Gas Drive Motor

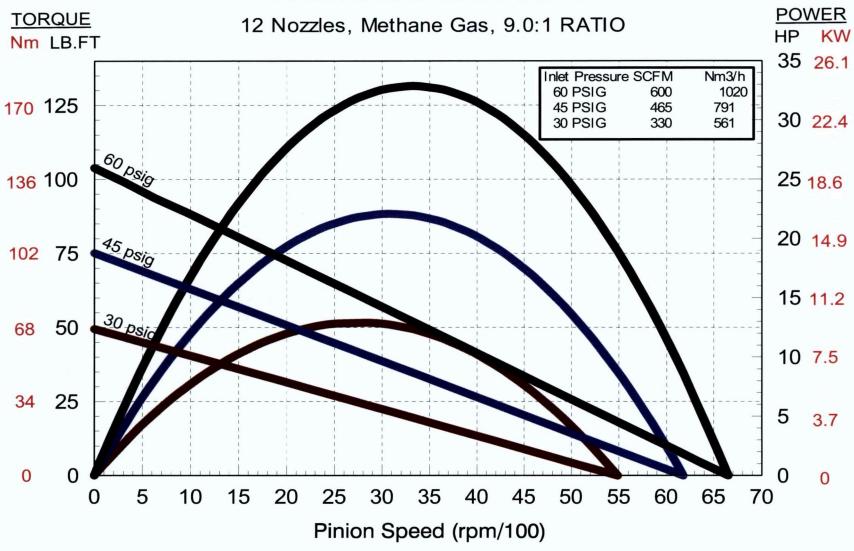
5 10 15 20 25 30 35 40 45 50 55 60 65 70 Pinion Speed (rpm/100)

10

from TECH DEVELOPMENT INC. 6800 Poe Ave. • Dayton, OH 45413-0557 Tel: 937 / 898 - 9600 Fax: 937 / 898 - 8431

Pub T30-713 6/97 Man AN96-613

T312 Performance Curve

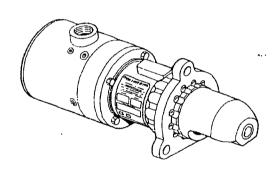




Publication T30-706, Rev. 1 Dated: May 9, 2001

400 108

INSTALLATION AND OPERATING MANUAL



MODEL: T30-I
TURBOTWIN Engine Air Starter

TDI TURBOTVINIM FROM TECH DEVELOPMENT, Inc

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1.0 GENERAL INFORMATION

This manual provides instructions for the installation and operation of the TDI TurboTwin™ Model T30-T air starters. If there are questions not answered by this manual, please contact your TDI TurboTwin™ distributor or dealer for assistance.

The T30-I model is a turbine driven air starter with inertia engaged drive. They are best suited for diesel engines up to 20 Liters (1220 CID) or gasoline engines up to 28 Liters (1709 CID). The T30-I is designed for installation on engines which use an SAE 3 mounting pad.

The T30 Series starters are suited to operate within a wide range of inlet air pressures and ambient temperatures. The engine size and parasitic loading will determine the exact minimum pressure that will ensure reliable starting.

The T30 Series starters are designed for operation with compressed air or natural gas. Moderate amounts of foreign matter or liquid in the air stream will normally not adversely affect T30 Series starters. As with all other TDI TurboTwin™ models, no lubrication is required in the supply air.

You need to review the rest of this manual before installing your TDI TurboTwin™ T30 Series starter.

1.1 WARNINGS, CAUTIONS, & NOTES

Throughout this manual, certain types of information will be highlighted for your attention:

WARNING - used where injury to personnel or damage to the equipment is possible.

CAUTION - used where there is the possibility of damage to the equipment.

MOTE used to point and special interest atomicities

1.2 INSTALLATION and SERVICE

The TDI TurboTwin™ T30 Series starters provide distinct advantages of size and efficiency compared to electric motor, vanetype, or other turbine-type air starters. It is important to properly install the starter to receive full benefit of these advantages. Repair technicians or service organizations without turbine starter experience should not attempt to repair this machine until they receive factory approved training from TDI, or its representatives. Proper operation of your TDI TurboTwin™ T30 Series starter will assure continued reliable and superior performance for many years.

WARNING

The TDI TurboTwin™ T30 Series starter must be installed and operated in accordance with the instructions given in this manual. Failure to properly install the starter, or failure to operate it according to these instructions may result in damage to the starter or the engine, or cause personal injury.

NOTE

THIS STARTER IS TO BE SERVICED ONLY BY AUTHORIZED TDI TURBOTWIN™ DISTRIBUTORS, DEALERS, AND REPAIR STATIONS. DO NOT OPERATE THIS STARTER UNLESS IT IS PROPERLY ATTACHED TO AN ENGINE.

2.0 ORIENTATION OF THE STARTER

If the factory orientation of the starter's mounting flange (drive housing) assembly, or optional exhaust port does not fit your engine installation, these components can be re-oriented.

2.1 MODEL T30-I ORIENTATION

A. Determine the required orientation of the mounting flange assembly and any optional exhaust port.

A Mois that the mounting flarge assambly can be rotated to twelve different positions relative to the gearbox and the gearbox Lenging assent by an isolated to four

TDI TURBOTWINIM

FROM TECH DEVELOPMENT, Inc

positions relative to the inlet port. Additionally, the optional exhaust housing can be rotated to eight positions relative to the inlet port.

CAUTION

All screw threads are treated at the factory with a fastener retention compound. Every screw and tapped hole must be clean and have a drop of Loctite 290 applied to the threads before being reinstalled.

2.1.1 Drive Housing / Mounting Flange Re-Orientation

Remove the twelve mounting flange attachment socket head cap screws.

Rotate the mounting flange to the desired position and reinstall the twelve socket head cap screws. Torque the twelve screws to 9.4 Lb-Ft. (12.7 Nm).

CAUTION

Ensure that the O-ring on the drive housing remains in position and is not cut.

WARNING

Do not remove the five radial screws that connect the inlet and turbine housing. The inlet and turbine housing assembly must remain in the same position relative to each other.

3.0 INSTALLING THE STARTER

The T30 Series installation is shown in Figures 2 & 3 The components illustrated may vary in shape, but there must at least be a start initiation switch, air supply, and a starter relay valve to correctly install and operate a T30 Series starter.

NOTE

Mounting the air piloted relay valve on the starter is preferred in installations where the space is available.

TDI recommends mounting the air piloted relay valve no more than 3 meters (10 feet) from the starter's inlet port, and as close to the starter as possible. If the starter is being installed on a vehicle where the air tank is within 3 meters (10 feet) of the starter, then the relay valve may be mounted on the tank.

A turbine driven starter does not require lubrication in the supply air. Therefore, if a vane-type starter motor is being replaced, TDI recommends that all lubrication devices and lines be removed to minimize flow restrictions

WARNING

If a fuel (pulse) lubricator has previously been installed in the system, disconnect and plug the line to eliminate spraying diesel fuel on the engine.

Liberally grease the starter's pinion teeth with chassis lube and then mount the T30 Series starter on the engine. Tighten all mounting hardware as appropriate.

After mounting the starter to the engine, attach the supply air line from the tank, any control air lines, and solenoid to the ignition system and/or palm valve to the air piloted relay valve.

TDI recommends installation of a "Glad Hand" / quick disconnect for auxiliary pressurization of the air tank.

Because turbine starters are sensitive to flow restrictions, care must be taken to use uniform sized hose or tubing and fittings for connection of the supply air line. Tees, elbows, and line length must be kept to a minimum. TDI recommends that hose or flex couplings be installed to eliminate possible leakage caused by strain on the supply air line.

Normally an air strainer is not required. In dirty environments, use of a #40 mesh. Yestrainer is recommended.

Only type approved metallic hose assemblies are approved in permanently presourized compressed air lines of starters

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Non-metallic hose assemblies are allowed only in case the piping system will be emptied after the starting procedure

Pipe unions must be type approved by GL. Downstream of the pressure regulator a pressure relief valve is to be provided.

WARMING

Recheck all connections for tight fit.

Fill the air system tank. The T30 Series starter is now ready to operate.

4.0 STARTER OPERATION

The maximum operating pressure limit is that pressure measured at the starter inlet pressure check port during the crank cycle. In order to check the starter inlet pressure, an 1/8" NPT pipe tap connection is provided just below the main inlet for attaching a pressure gauge. Refer to Figure 1. IN NO CASE SHOULD INLET OPERATING PRESSURE EXCEED 10.3 BAR (150 PSIG).

WARNING

Do not operate the TDI TurboTwin T30 Series air starter with air pressure greater than the pressure rating on the nameplate. This pressure is to be measured at the starter inlet while the starter is running.

The static supply pressure will always be higher than the operating pressure. As a guideline, the maximum pressure limit (proof pressure) that the T30 Series starter may be subjected to is 300 PSIG (20.7 Bar).

System pressure that exceeds the maximum operating limit must use a pressure reducer device to ensure operating pressure limit to the T30 Series starter is maintained.

System pressure that exceeds the 300 PSIG (20.7 Bar) limit must, in addition to a pressure reducer device, incorporate a pressure relief valve, set below 300 PSIG Bar (20.7), in the supply air line.

All appropriate local pressure codes and pressure limitations on other system components must be adhered to and supersede guidelines given in this manual.

Follow the engine manufacturer's instructions for starting the engine.

WARNING

Do not engage the starter while the engine is running.

If the starter fails to function properly when first operated, or its performance deteriorates with use, refer to the Operator's Trouble Shooting Guide, Section 6.0. If you cannot solve the problem, or repair is necessary, contact your local TDI TurboTwin™ distributor or dealer.

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5.0 WARRANTY

TDI TURBOTWIN ENGINE STARTER WARRANTY

Tech Development Inc. (TDI) warrants to the original user of the TDI TurboTwin™ Model T30 Series air starters to be free from defects in material and workmanship for a period of one year from date of purchase by such user. The warranty period shall begin on the actual delivery date to the original user or twelve (12) months from the date of shipment from TDI, whichever comes first. The conditions of this warranty are: a) TDI is notified within this period by return of such product to TDI or its authorized distributor or dealer, transportation prepaid by user; b) such product has been installed according to TDI's specifications; c) such product has not been misused, abused or improperly maintained by user; d) the defect is not the result of normal wear and tear; and e) such starter product has not been repaired with parts not manufactured or authorized by TDI, and TDI installation and repair procedures as outlined in the appropriate manual were properly followed.

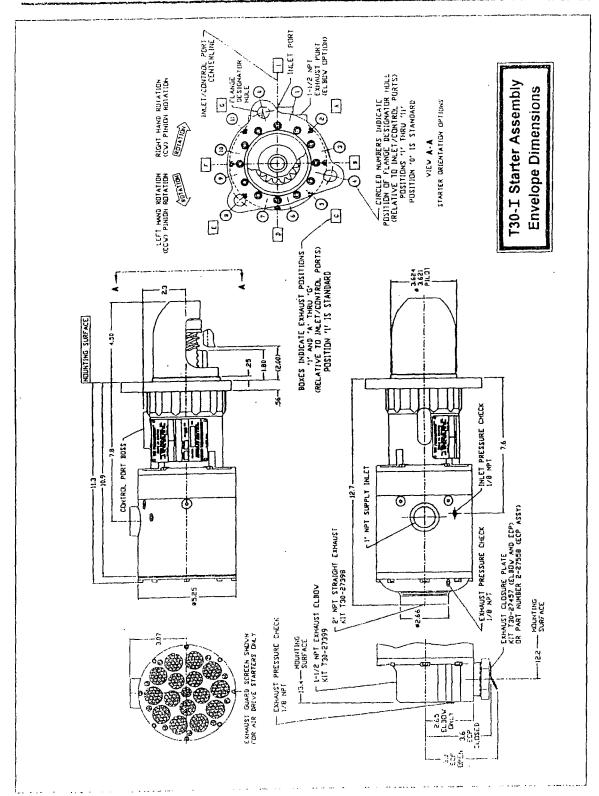
Tech Development Inc. shall, at its option, either repair or replace, without charge, any such starter product found by TDI's examination to be defective, or by mutual agreement, refund the user's purchase price in exchange for such starter product. Repairs or replacements are warranted for the remainder of the original warranty period.

Tech Development Inc. makes no other warranty, and IMPLIED WARRANTIES INCLUDING ANY WARRANTY OR MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE ARE HEREBY DISCLAIMED.

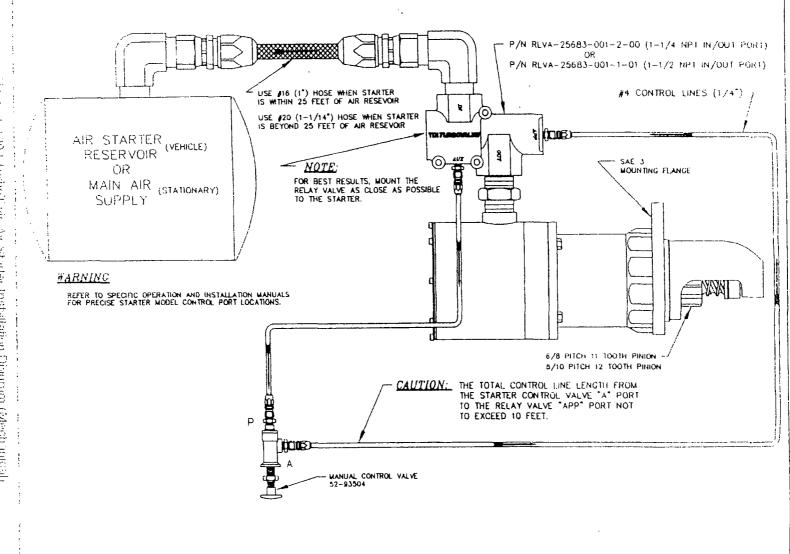
This warranty constitutes the entire obligation of Tech Development Inc. relating to the sale and use of such product, and TDI's maximum liability is limited to the purchase price of such product at the date of purchase. In no event shall TDI be liable for incidental, indirect, consequential or special damages of any nature arising from the sale or use of such engine starter product.

6.0 OPERATOR'S TROUBLESHOOTING GUIDE

TROUBLE	PROBABLE CAUSE	SOLUTION
1 Air always flow through	A. Relay valve improperly	A. Check typical installation
exhaust	installed.	diagram and correct
	B. Relay valve not sealing	B. Check for damaged sealing
	properly.	ring, replace relay valve or
		damaged parts.
	C. Control valve not sealing.	C. Check control valve and replace
	pressure remains in APP port of	if necessary.
	relay valve.	
Starter engages but does not	A. Bad relay valve	A. Replace relay valve.
run.		
3. Starter does not run, small air	A. Nozzle blockage.	A. Remove blockage or obstruction
flow from turbine exhaust.		from nozzles.
Starter does not run. Normal	A. Excessive bends in the	A. Shorten length or straighten
air flow from exhaust.	supply line.	supply air line
5. Pinion does not engage	A. Air pressure is too low	A. Increase air pressure to 40 -150
-		psig.
	B. Damaged pinion teeth.	B. Replace pinion or starter drive
	A Aires And Investment	as necessary.
6. Starter runs but engine cranks slowly or not at all.	A. Air pressure too low	A. Increase air pressure to 40 -150 psig.
	B. Excessive back pressure.	B. Increase inlet pressure or
	·	reduce back pressure.
	C. Worn or broken starter drive.	C. Replace starter drive.
	D. Worn Starter Drive	D. Replace Starter Drive
	E. Nozzle blocked or damaged.	D. Remove blockage or replace
		damaged parts.
· · · · · · · · · · · · · · · · · · ·	A. Control valve is not sealing correctly.	A. See 1C. above
	B. Relay valve is not sealing	B. See 1B. above
	correctly.	5. 000 15. 0.000
	A. Air connections are too tight.	A. Tighten loose fittings. Repair or
extended shut down.	3	replace damaged fittings.
	B. Damaged air lines: crushed,	B. Replace damaged lines.
	frayed, kinked.	
	C. Relay valve is not sealing	C. See 1B. above
	correctly.	
	D. Control valve is stuck open.	D. See 1C. above

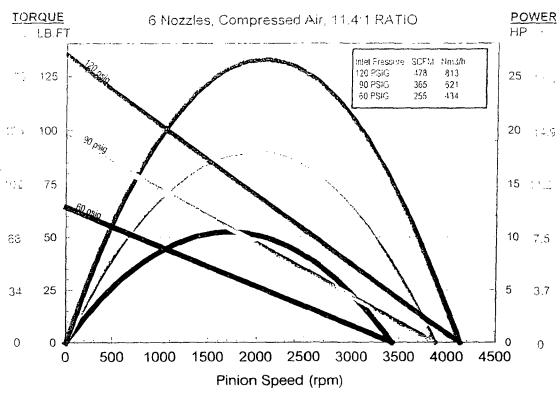


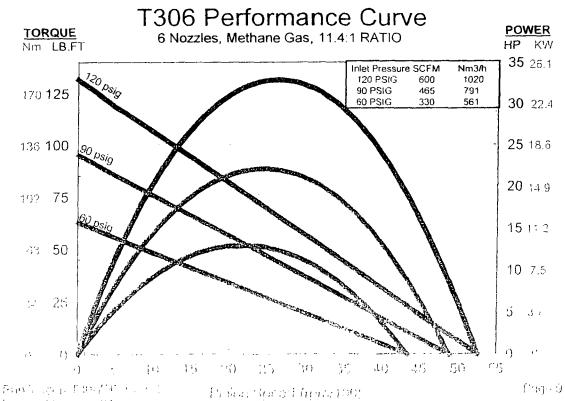
Physics Elected Burboll win Alic Souther Elevatorie Orlewing



35) Judad Mic Air Stater Installation Disgress (Meditional)

T306 Performance Curve





Land May France

TECH DEVELOPMENT INC.

6800 POE AVENUE . BOX 13557 . DAYTON OHIO . 45413-0557

PHONE: 937-898-9600 • FAX: 937-898-8431

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