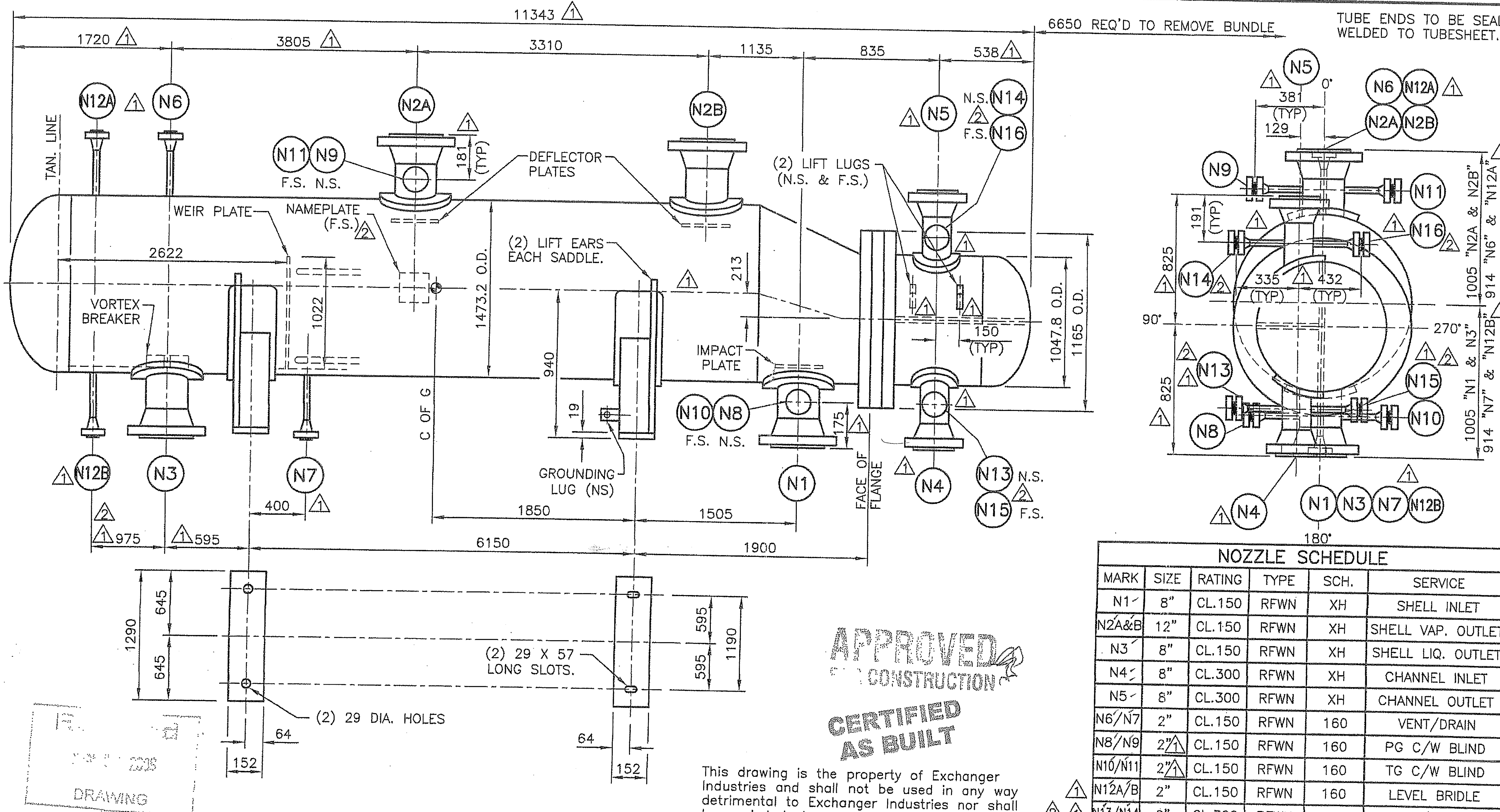


APPROVED FOR CONSTRUCTION

CERTIFIED AS BUILT

DRAWING

NOZZLE SCHEDULE

MARK	SIZE	RATING	TYPE	SCH.	SERVICE
N1	8"	CL.150	RFWN	XH	SHELL INLET
N2A&B	12"	CL.150	RFWN	XH	SHELL VAP. OUTLET
N3	8"	CL.150	RFWN	XH	SHELL LIQ. OUTLET
N4	8"	CL.300	RFWN	XH	CHANNEL INLET
N5	8"	CL.300	RFWN	XH	CHANNEL OUTLET
N6/N7	2"	CL.150	RFWN	160	VENT/DRAIN
N8/N9	2"	CL.150	RFWN	160	PG C/W BLIND
N10/N11	2"	CL.150	RFWN	160	TG C/W BLIND
N12A/B	2"	CL.150	RFWN	160	LEVEL BRIDLE
N13/N14	2"	CL.300	RFWN	160	PG C/W BLIND
N15/N16	2"	CL.300	RFWN	160	TG C/W BLIND

REVISION CONTROL BOX ⊙ Denotes DCR & Rev.# Added to This Sheet Only

1. PER CUST MARK-UP & E.I.. JAN 12/09 (FZ)
2. PER CUST MARK-UP & E.I.. APR 1/09 (FZ) NI-014815
3. PER E.I.. JUN 1/09 (FZ) A-014842

CUSTOMER: DPH FOCUS CORPORATION
FOR: ENCANA FCCL OIL SANDS LTD.
P.O. NO.: FCSR-DPH-4002B
TEMA TYPE: BKU
SIZE: 1022/1448-6934
SERVICE: AMINE REBOILER

SHELL & TUBE EXCHANGER OUTLINE DRAWING

NO. OF EXCHANGERS REQ'D: ONE

DWN FX | CKD GG | ITEM E-5868

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWG NO. 08-2953
SHEET 1 OF 16

MATERIAL LIST

LINE	PART	MATERIAL
	CHANNEL	
1	COVER/HEAD	SA-516-70N
2	TEMA FLANGE	SA-350-LF2 CL1 △1
3	CYLINDER	SA-516-70N
4	NOZZLE FLANGE	SA-350-LF2 CL1 △1
5	NOZZLE NECK	SA-333-6
6	NOZZLE REINFORCEMENT PAD	SA-516-70N
7	COUPLING/THREDOLET/PLUG	– △1
8	PASS PLATE	SA-516-70N
9	STUDBOLTS	SA-193-B7M
10	NUTS	SA-194-2HM
11		
12		
	SHELL	
13	TEMA FLANGE	SA-182-F316L
14	CYLINDER	SA-240-316L
15	HEAD	SA-240-316L
16	CONE	SA-240-316L
17	NOZZLE FLANGE	SA-182-F316L
18	NOZZLE NECK	SA-312-TP316L
19	NOZZLE REINFORCEMENT PAD	SA-240-316L
20	COUPLING/THREDOLET/PLUG	–
21	SUPPORT WRAPPER PLATE	SA-240-316L
22	SUPPORT	SA-516-70N
23	STUDBOLTS	SA-193-B7M
24	NUTS	SA-194-2HM
25		
26		
27		
	FLOATING HEAD	
28	FLANGE	–
29	SPLIT RING	–
30	DISH	–
31	PASS PLATE	–
32	STUDBOLTS	–
33	NUTS	–
34		
35		
36		

LINE	PART	MATERIAL
	TUBE BUNDLE	
37	TUBESHEET	SA-240-316L
38	TUBES	SA-789-S31803 (WELDED)
39	BAFFLE/SUPPORT PLATES	SA-240-316L
40	IMPACT PLATE	SA-240-316L
41	TIE-ROD/NUT/SPACER	316L S.S.
42		
43		
	GASKETS	
44	CHANNEL	316S.S. SPIRALWOUND
45	SHELL	316S.S. SPIRALWOUND
46	FLOATING HEAD	–
47	CHANNEL NOZZLE	316S.S. SPIRALWOUND △1
48	SHELL NOZZLE	316S.S. SPIRALWOUND △1
49		
50		

MATERIAL NOTES

(1) SHELLSIDE IN SOUR SERVICE MAT'L TO NACE MR 0175 △1
(2) CHANNEL SIDE NOT IN SOUR SERVICE.

CONSTRUCTION NOTES △1

(11) IN CATEGORY "D" WELDS, THE BACK SIDE OF ROOT PASS SHALL BE 100% MT (IF FEASIBLE) EXAMINED AFTER BACK GOUGING TO SOUND METAL.
(12) MPI OR LPI LIFTING LUG WELDS.

CERTIFIED AS BUILT

CONSTRUCTION NOTES

(1) CONSTRUCTION TO BE PER ASME CODE SECTION VIII DIVISION 1 2007 EDITION, TEMA CLASS "R" 9th EDITION, API 660 AND CUSTOMER SPECIFICATIONS.
(2) ALL BOLT HOLES TO STRADDLE CENTER LINES UNLESS NOTED OTHERWISE.
(3) CODE STAMP REQ'D: YES (PROVINCE OF ALBERTA).
(4) IMPACT TESTING: CHAN. CYLINDER & COVER EXEMPT PER UCS-66(a), PIPE & FLANGES EXEMPT PER UCS-66(g). WELD METAL EXEMPT PER UCS-67(a) (2). SHELL SIDE EXEMPT PER UHA-51(d)(1)(a). △3 TUBES EXEMPT PER UHA-51(g).
(5) STRESS RELIEVE: TUBE U-BENDS TO BE SOLUTION ANNEALED BY USING ELECTRIC RESISTANCE METHOD.
(6) RADIOGRAPHY: RT1 SHELL & CHANNEL.
(7) WELD PROCEDURES: C5, C2, M1-P8, A-34, SA-A17, M-78, M-117 (ONE PASS FILLET WELD).
(8) PAINT: CARBON STEEL ONLY FOR CHANNEL & SADDLES, NO PAINT FOR SHELL. △1 △2
  (a) SANDBLAST TO SSPC-SP10. △2
  (b) PRIME WITH ONE COAT SILICONE ZINC 2-3 MILS DFT (STANDARD STOCK COLOUR)
(9) INSULATION: 64mm THK. CALCIUM SILICATE INSULATION WITH 0.02" MIN. THK. SMOOTH ALUMINUM JACKETING C/W POLYSURLYN MOISTURE BARRIER. GIRTH FLANGES TO HAVE 25mm THK. REMOVABLE FLEXIBLE BLANKETS C/W 17 OZ TEFLON COATED FIBREGLASS CLOTH JACKET WITH HIGH TEMPETATURE GLASSFIBRE MATT INSULATION INSERT. (BY E.I.).
(10) ALL CATEGORY "D" JOINTS SHALL BE 100% UT, UT SHALL BE COMPLETED BEFORE NOZZLE REPADS ARE WELDED IN PLACE.

DESIGN CONDITIONS	SHELL SIDE	CHANNEL SIDE
DESIGN PRESSURE	345kPaG	2300kPaG
EXTERNAL PRESSURE	FV @ 149 °C	–
DESIGN TEMPERATURE	149 °C	204 °C
MDMT	-45°C	-45°C
C&H MAWP	345kPaG	2300kPaG
C&H MAWP LIMITED BY	TEMA FLANGE	TEMA FLANGE
HYDRO TEST PRESSURE	450kPaG	2990kPaG △1
CORROSION ALLOWANCE	0.0	3.18mm
N&C MAX. PRESS.	386kPaG	2316kPaG
N&C M.P. LIMITED BY	TEMA FLANGE	TEMA FLANGE
SHOP HYDRO TEST PRESS.	502kPaG	3012kPaG
NUMBER OF PASSES	KETTLE	FOUR
SURFACE AREA	350.4 SQ.M	
SHIPPING WEIGHT	13950 kgs	
WEIGHT FULL OF WATER	30510 kgs	
BUNDLE WEIGHT	6080 kgs	
CHANNEL WEIGHT	800 kgs	
CAPACITY	16.56 CU.M	

REVISIONS
△1 PER CUST MARK-UP & E.I.. JAN 12/09 (FZ)
△2 PER CUST MARK-UP. APR 1/09 (FZ)
△3 PER E.I.. JUN 1/09 (FZ)

MATERIALS & DESIGN CONDITIONS

NO. OF EXCHANGERS REQ'D: ONE

DWN FX | CKD GG | ITEM E-5868

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWG NO. 08-2953
SHEET 1A OF 16

1. NOTE: Any material welding to a pressure component must have a MTR and traceability or be qualified under Section VIII, Div. 1 ASME code for welding to a pressure part.

2. Connections abutting a component fabricated from plate (for example, a set on nozzle) are permitted, provided the edge of the hole in the plate to which the connections are attached shall be examined for lamination by means of a magnetic particle or dye-penetrant test. Indications found shall be cleared to sound metal and then back welded.

△1 3. The repads shall be of the same material and the same thickness as the shell. All repads to be air soap suds tested at 100 to 140 kPag.

4. All exposed flange gasket surfaces shall be coated with an easily removable rust preventative and shall be protected by a 12.7mm thk. plywood or 3mm steel cover complete with rubber gasket and (4) four bolts minimum.

5. All threaded connections shall be protected by metal plugs or caps of compatible material.
All tell tale and vent holes shall be plugged with grease to prevent water infiltration.

6. The item number, shipping weight, center of gravity and purchase order number shall be painted on the exchanger & insulation jacketing.

7. All boxes, crates, or packages shall be identified with the purchaser's order and equipment number.
All removable parts such as channel covers and channel cylinders shall be stamped with the equipment tag number on top of flange.

8. The interior of all exchangers shall be free of oil, water, grease, weld slag and splatter, rags, wood, and other foreign matter.

9. Weld Hardness Testing:
a) The weld metal and heat-affected zone of pressure retaining welds in components made from a material that has a P number of 1 shall be tested.
b) Examination shall be made after any postweld heat treatment.
c) Hardness shall not exceed 225 Brinell for materials with P numbers of 1.
d) Hardness shall be determined using Micro-Dur method.
e) One longitudinal weld, one circumferential weld, and each connection-to-component weld where the connection is NPS 2 or larger shall be tested.

10. All pressure retaining welds to be full penetration welds.

11. All hydrostatic testing shall be held for a minimum of one hour. Two gauges req'd.

△2 12. All PWHT vessels to have "NO WELDING ALLOWED" stenciled in white.

△2 13. Ship one copy of QC's wrap-up book with the Unit.

CERTIFIED AS BUILT

REVISIONS

△1	PER CUST MARK-UP & E.I..	JAN 12/09 (FZ)
△2	PER CUST MARK-UP & E.I..	APR 1/09 (FZ)

API 660 NOTES, CUSTOMER SPECIFICATION & MATERIAL NOTES

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWG NO. 08-2953

DWN FX | CKD GG | ITEM E-5868 | SHEET 1B OF 16

0.8 THK X 152 X 159
MAT'L: STAINLESS STEEL

CERTIFIED BY
EXCHANGER INDUSTRIES
A DIVISION OF PREMETALCO INC.
CALGARY,ALBERTA,CANADA

U				
W	MAWP: SHELL	345 kPag	AT	149 °C
RT1	MAEWP: SHELL	103 kPag	AT	149 °C
PHT–T	MAWP: TUBE	2300 kPag	AT	204 °C
–	MAEWP: TUBE	–	AT	–
–	MDMT: SHELL	–45 °C	AT	345 kPag
	MDMT: TUBE	–45 °C	AT	2300 kPag

SERIAL NO. 08–2953 YEAR MFD. 2009

AMINE REBOILER

ITEM NO.: E-5868 TYPE: BKU TEMA CLASS "R" SIZE: 1022/1448–6934

HYDRO TEST PRESSURE: SHELL 450 KPag / CHANNEL 2990 KPag

WEIGHT: DRY: 13950 Kgs / WET: 30510 Kgs / BUNDLE: 6080 Kgs

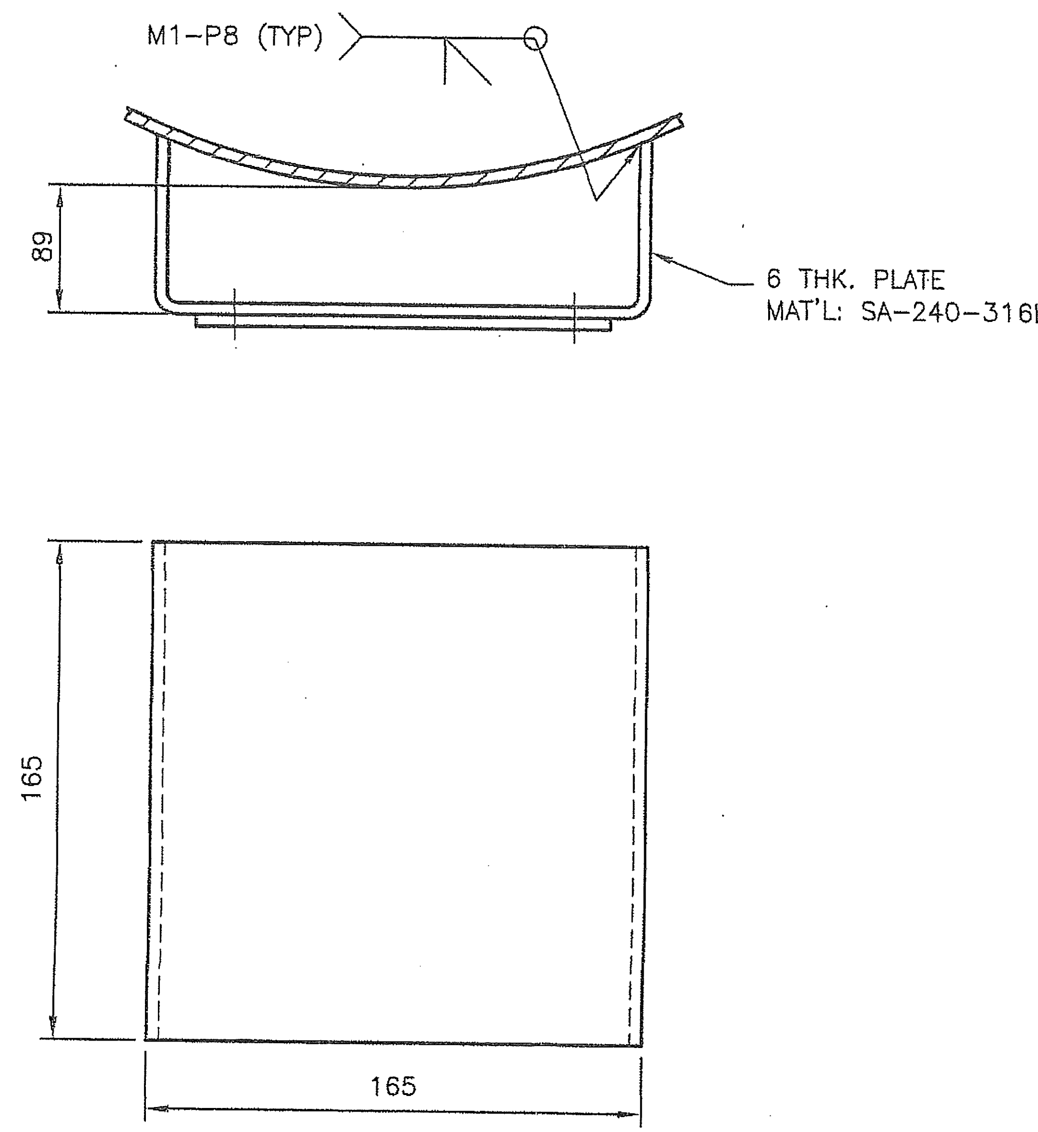
SHELL C.A.=0 CHANNEL C.A.=3.18mm 2

P.O.NO.: FCSR–DPH–4002B

HEAT EXCHANGED: 7755KW 2 SURFACE AREA: 350.4 SQ.M

PROV. REG. CRN

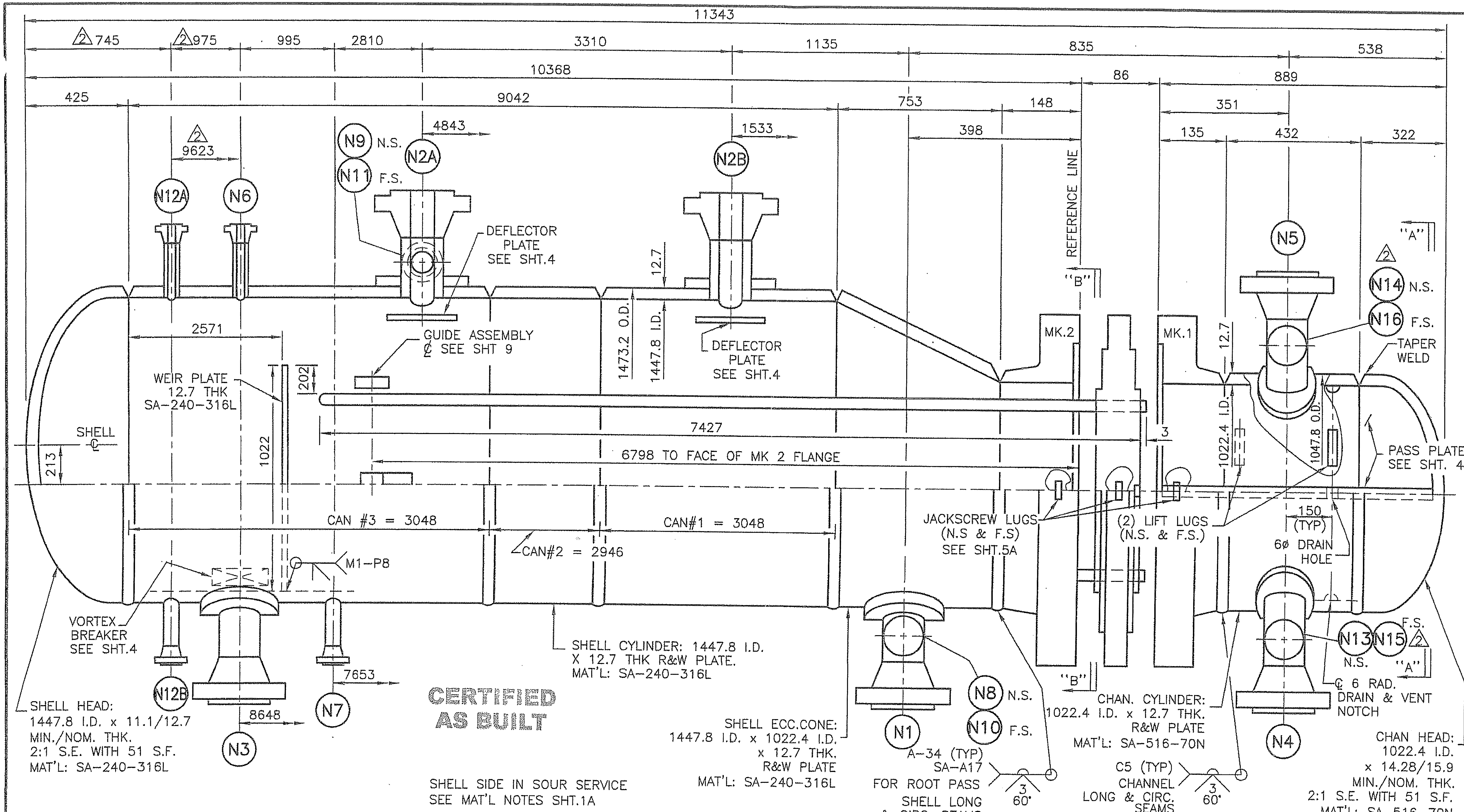
NO. REQ'D EACH EXCHANGER: ONE



NAMEPLATE BKT DETAIL
ONE REQ'D/EXCHANGER

CERTIFIED AS BUILT

REVISIONS	NAME PLATE DETAIL	EXCHANGER INDUSTRIES CALGARY, ALBERTA
2 PER CUST MARK–UP & E.I.. APR 1/09 (FZ)	NO. OF EXCHANGERS REQ'D: ONE	DWG NO. 08–2953
	DWN FZ CKD KW ITEM E–5868	SHEET 2 OF 16



NOTE: DOUBLE ARROWHEAD DIMENSIONS ARE TO REFERENCE LINE.

REVISIONS

2 PER CUST MARK-UP. APR 1/09 (FZ)

SHELL & CHANNEL DETAIL

NO. OF EXCHANGERS REQ'D: ONE

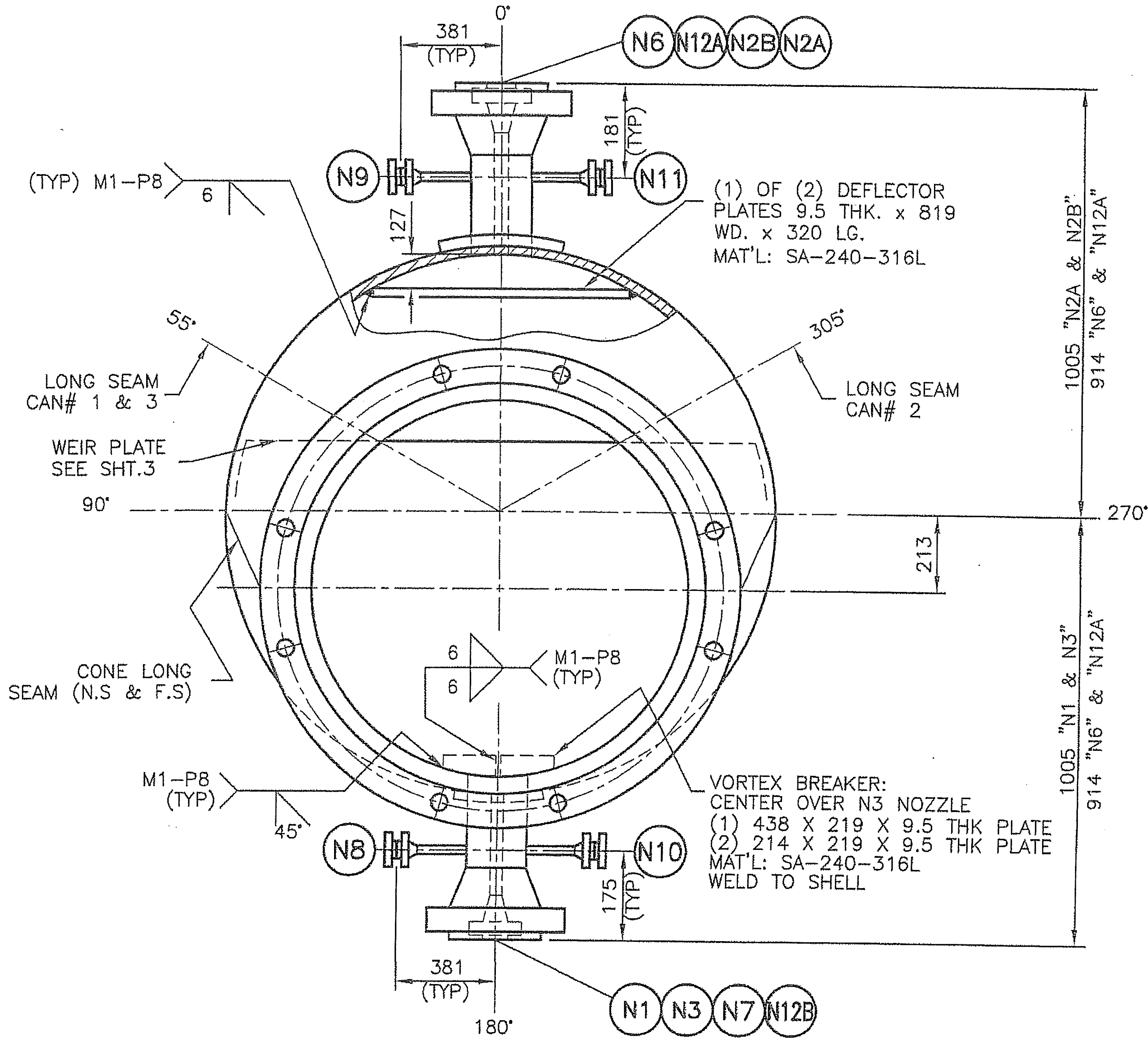
EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWN FZ	CKD KW	ITEM E-5868

DWG NO. 08-2953

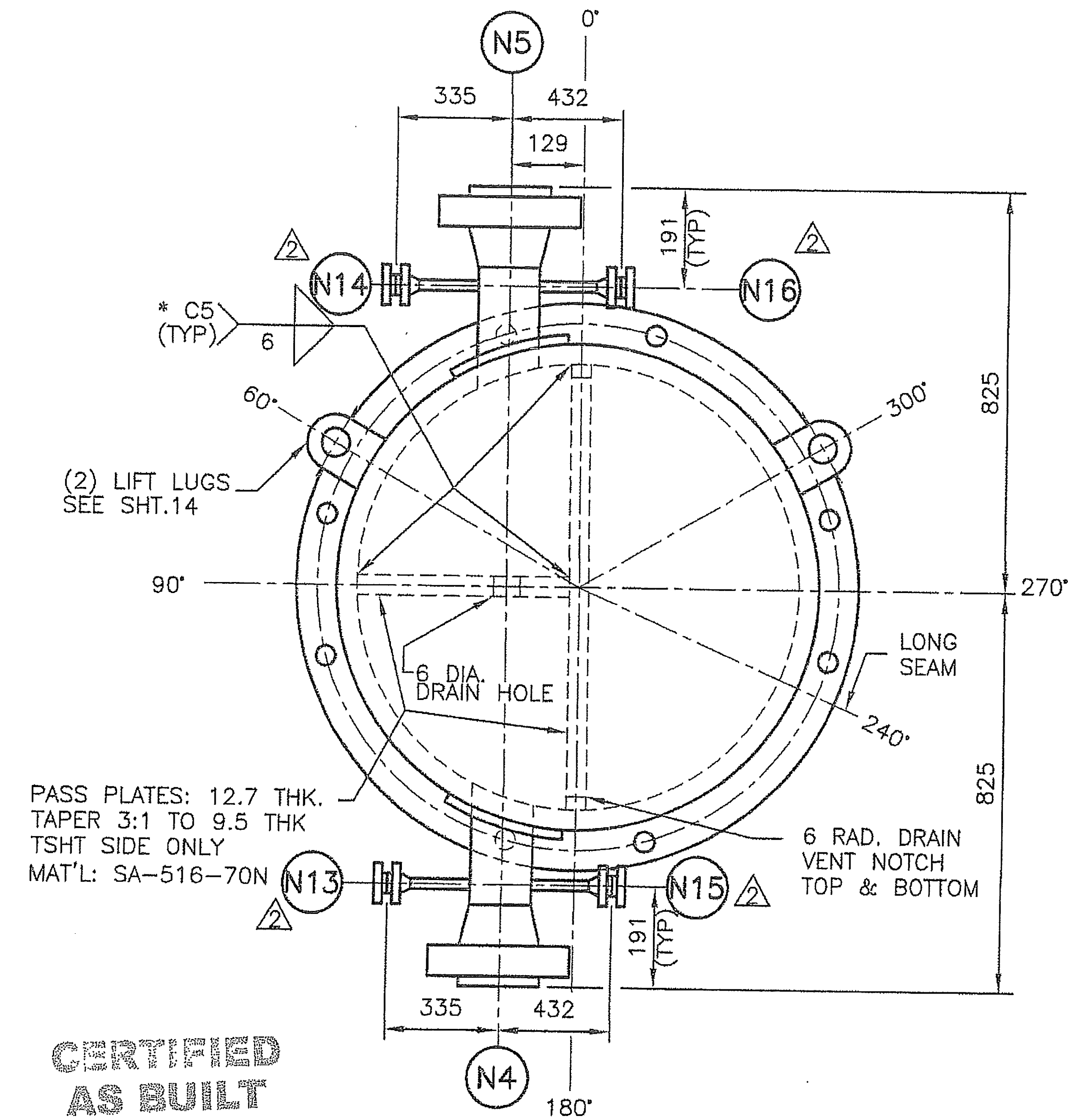
SHEET 3 OF 16

* PASS PLATE TO HAVE FULL PENETRATION WELDS 51mm IN FROM FLG END. WELD REMAINDER OF PASS PLATE WITH FILLET WELD



SECTION "B–B"

PREHEAT WELDS: 16 °C
RADIOGRAPHY: RT1
POST HEAT TREAT: NO



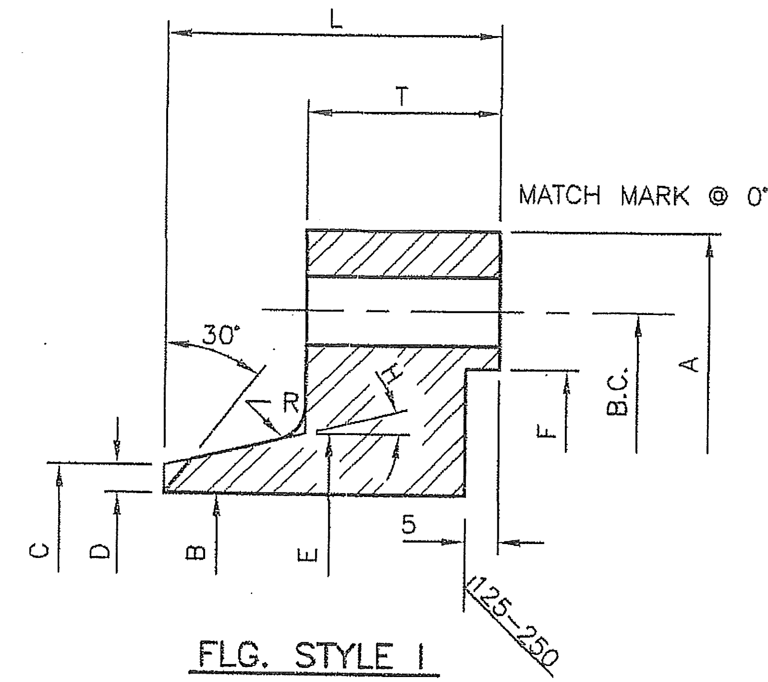
SECTION "A–A"

PREHEAT WELDS: 10 °C
RADIOGRAPHY: RT1
POST HEAT TREAT: NO

CERTIFIED AS BUILT

SHELL SIDE IN SOUR SERVICE
SEE MAT'L NOTES SHT.1A

REVISIONS	SHELL & CHANNEL SECTIONS	EXCHANGER INDUSTRIES CALGARY, ALBERTA
2 PER CUST MARK-UP. APR 1/09 (FZ)	NO. OF EXCHANGERS REQ'D: ONE	DWG NO. 08–2953
	DWN FZ / CKD KW / ITEM E–5868	SHEET 4 OF 16



FLG. STYLE I

CERTIFIED
AS BUILT

SHELL SIDE IN SOUR SERVICE
SEE MAT'L NOTES SHT.1A

MATERIAL: SA–350–LF2 CL1 MK1
SA–182–F316L MK2

250 OVERALL FINISH EXCEPT AS NOTED.

⚠2 NOTE:

STAMP EQUIPMENT TAG NUMBER
ON TOP OF EACH FLANGE.

LINE NO.	MK. NO.	NO. REQ'D	FLG. STYLE	A	B	C	D	E	F	H	R	T	L	B.C.	BOLT HOLES	
															NO.	DIA.
1	1	ONE	I	1165	1022.4	1047.7	12.7	1054	1070	7.12°	9.5	110	135	1118	64	25.4
2	2	ONE	I	↓	↓	↓	↓	↓	↓	↓	↓	122	148	↓	↓	↓

REVISIONS

⚠2 PER E.I. APR 1/09 (FZ)

FLANGE DETAIL

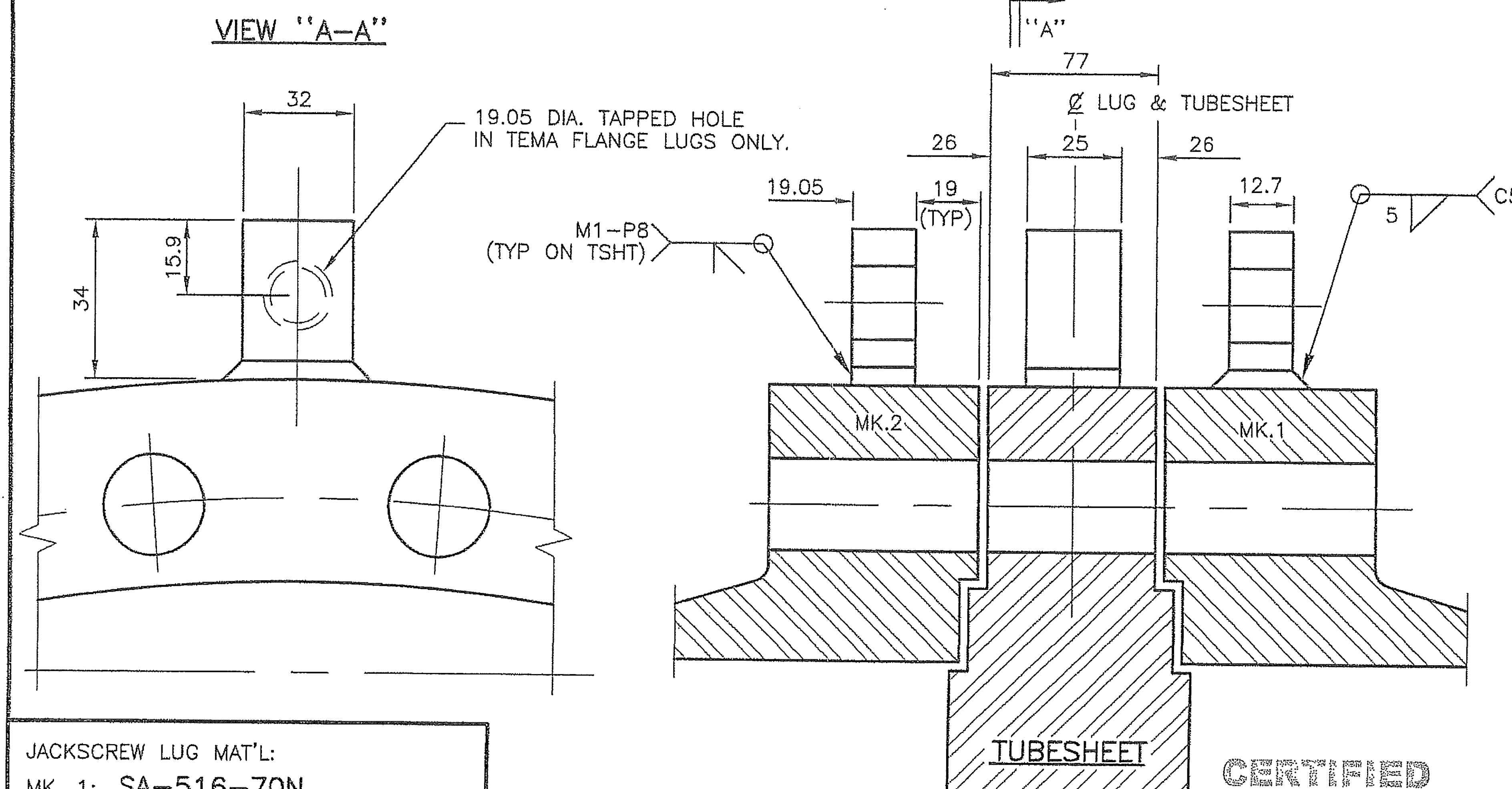
MK. 1 1022.4– 2300 kPaG
MK. 2 1022.4 – 345 kPaG
DESIGN TEMA "R"
NO. OF EXCHANGERS REQ'D: ONE

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWG NO. 08–2953

DWN FZ | CKD KW | ITEM E–5868

SHEET 5 OF 16



CERTIFIED AS BUILT

JACKSCREW LUG MAT'L:
MK. 1: SA-516-70N
MK. 2 & TSHT.: 316L S.S.
LUG LOCATION: 90° & 270°

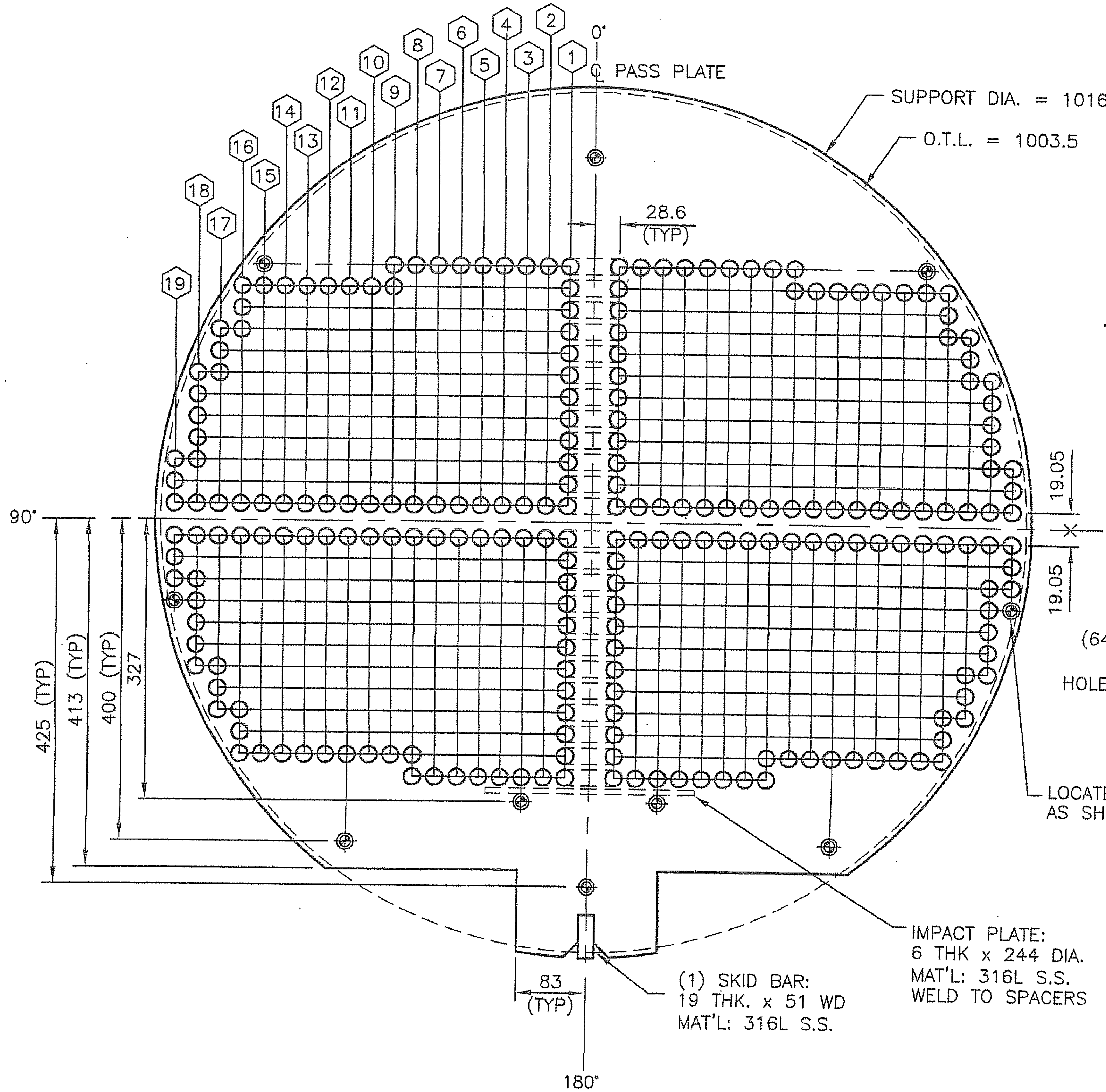
REVISIONS

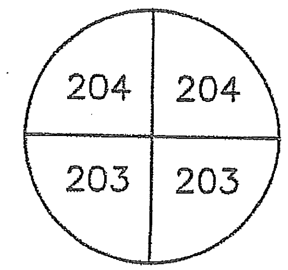
JACKSCREW LUG DETAIL

NO. REQ'D EACH EXCHANGER: TWO
NO. OF EXCHANGERS REQ'D: ONE

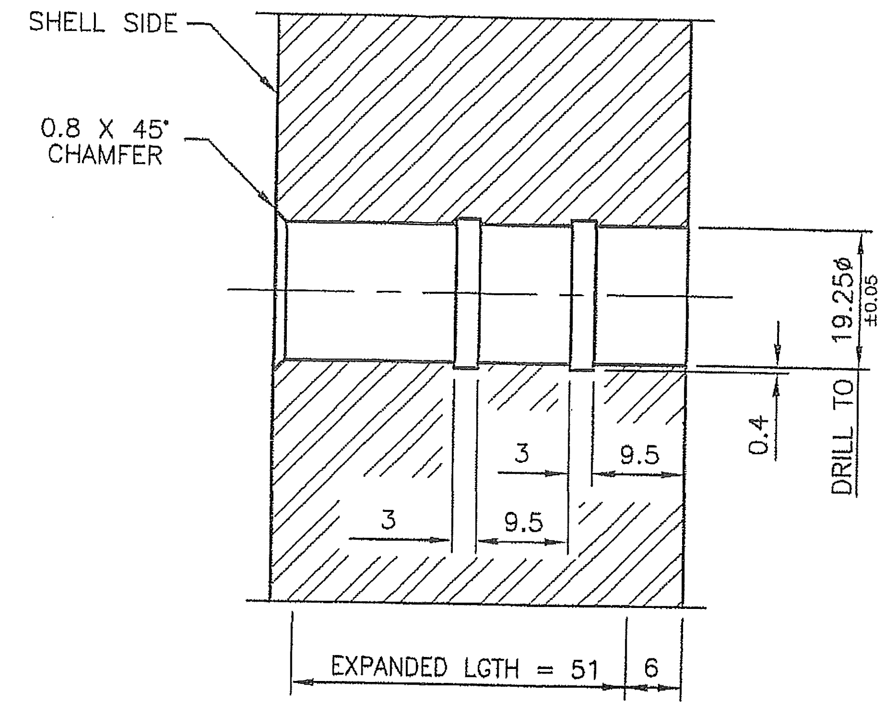
EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWN FZ	CKD KW	ITEM E-5868	DWG NO. 08-2953
			SHEET 5A OF 16

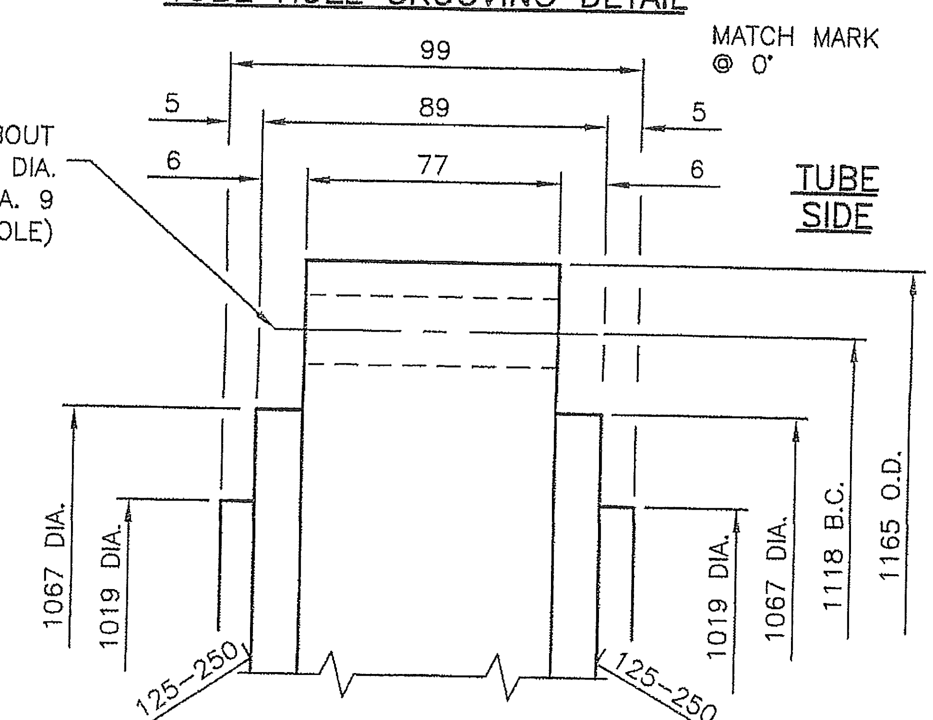




TUBES PER PASS



TUBE HOLE GROOVING DETAIL



TUBESHEET DETAIL

ONE REQ'D EACH EXCHANGER

MAT'L: SA-240-316L

CERTIFIED AS BUILT

TUBE O.D. = 19.05

TUBE PITCH = 25.4 90° SQ.

NO. OF TUBES = (407) "U"

NO. OF PASSES = FOUR

REVISIONS

TUBE HOLE LAYOUT

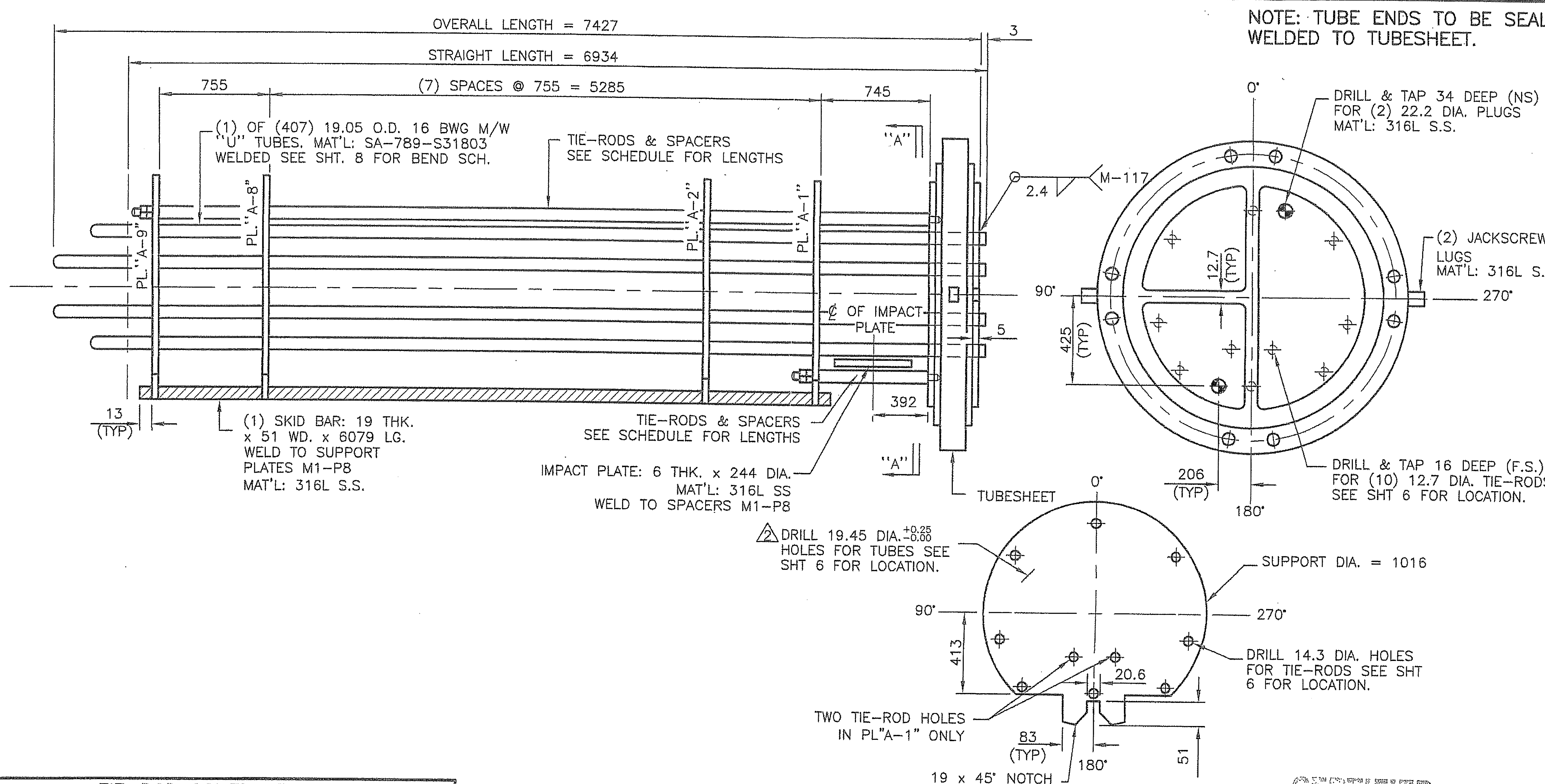
NO. OF EXCHANGERS REQ'D: ONE

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWN FZ	CKD KW	ITEM E–5868

DWG NO. 08–2953

SHEET 6 OF 16



CERTIFIED AS BUILT

VIEWED ON "A-A"

SUPPORT MAT'L: SA-240-316L

PLATE "A-1" TO "A-7"

(8) REQ'D 9.5 THK

PLATE "A-9"

(1) REQ'D 12.7 THK

TIE-ROD SCHEDULE

TIE-ROD DIA.: 12.7 TIE-ROD MAT'L: 316L S.S.

TOTAL NO. REQ'D EACH BUNDLE: (10) C/W (2) 316L S.S.

NO.:	(8)	(2)						
LGTH:	6852	810						

SPACER SCHEDULE

SPACER O.D.: 19.05 SPACER MAT'L: 316L S.S.

TOTAL NO. REQ'D EACH BUNDLE: (74)

NO.:	(64)	(10)						
LGTH:	745.5	745						

REVISIONS

2 PER E.I. APR 1/09 (FZ)

BUNDLE DETAIL

NO. REQ'D EACH EXCHANGER: ONE

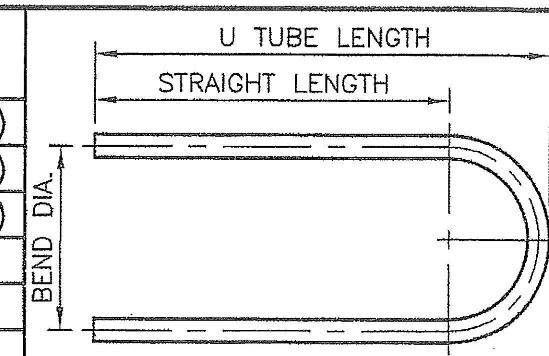
DWN FZ CKD KW ITEM E-5868

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWG NO. 08-2953

SHEET 7 OF 16

ROW NO.	NO. OF TUBES	BEND DIA.	STRAIGHT LENGTH	U TUBE LENGTH	OVERALL TUBE LENGTH
1	24	57 (2.25")	6934 (273")	6972 (274.5")	13958 (549.5625")
2	24	108 (4.25")		6998 (275.5")	14038 (552.6875")
3	24	159 (6.25")		7023 (276.5")	14118 (555.8125")
4	24	210 (8.25")		7049 (277.5")	14198 (559")
5	24	260 (10.25")		7074 (278.5")	14277 (562.125")
6	24	311 (12.25")		7099 (279.5")	14357 (565.25")
7	24	362 (14.25")		7125 (280.5")	14437 (568.375")
8	24	413 (16.25")		7150 (281.5")	14517 (571.5625")
9	23	464 (18.25")		7176 (282.5")	14597 (574.6875")
10	22	514 (20.25")		7201 (283.5")	14676 (577.8125")
11	22	565 (22.25")		7226 (284.5")	14755 (580.9375")
12	22	616 (24.25")		7252 (285.5")	14836 (584.125")
13	22	667 (26.25")		7277 (286.5")	14916 (587.25")
14	22	718 (28.25")		7303 (287.5")	14996 (590.375")
15	22	768 (30.25")		7328 (288.5")	15075 (593.5")
16	22	819 (32.25")		7353 (289.5")	15155 (596.6875")
17	18	870 (34.25")		7379 (290.5")	15235 (599.8125")
18	14	921 (36.25")		7404 (291.5")	15315 (602.9375")
19	6	972 (38.25")		7430 (292.5")	15394 (606.0625")
	(407) U TUBES TOTAL				



NOTES:

(1) STRESS RELIEVE: "U" BENDS & 152 mm OF STRAIGHT LENGTH TO BE SOLUTION ANNEALED BY USING ELECTRIC RESISTANCE METHOD (BY TUBE SUPPLIER).

(2) MAX. OUT OF ROUNDNESS OF "U" BENDS TO BE 10% OF TUBE O.D.

(3) OVERALL TUBE LENGTH SHOWN IS EXACT LENGTH WITH NO ADDITION FOR TRIMMING.

TUBE DETAILS:

TUBE O.D. = 19.05 (0.75")

TUBE GAGE = 16 BWG M/W

TUBE MAT'L: SA-789-S31803 WELDED

REVISIONS

U BEND SCHEDULE

NO. OF BUNDLES REQ'D: ONE

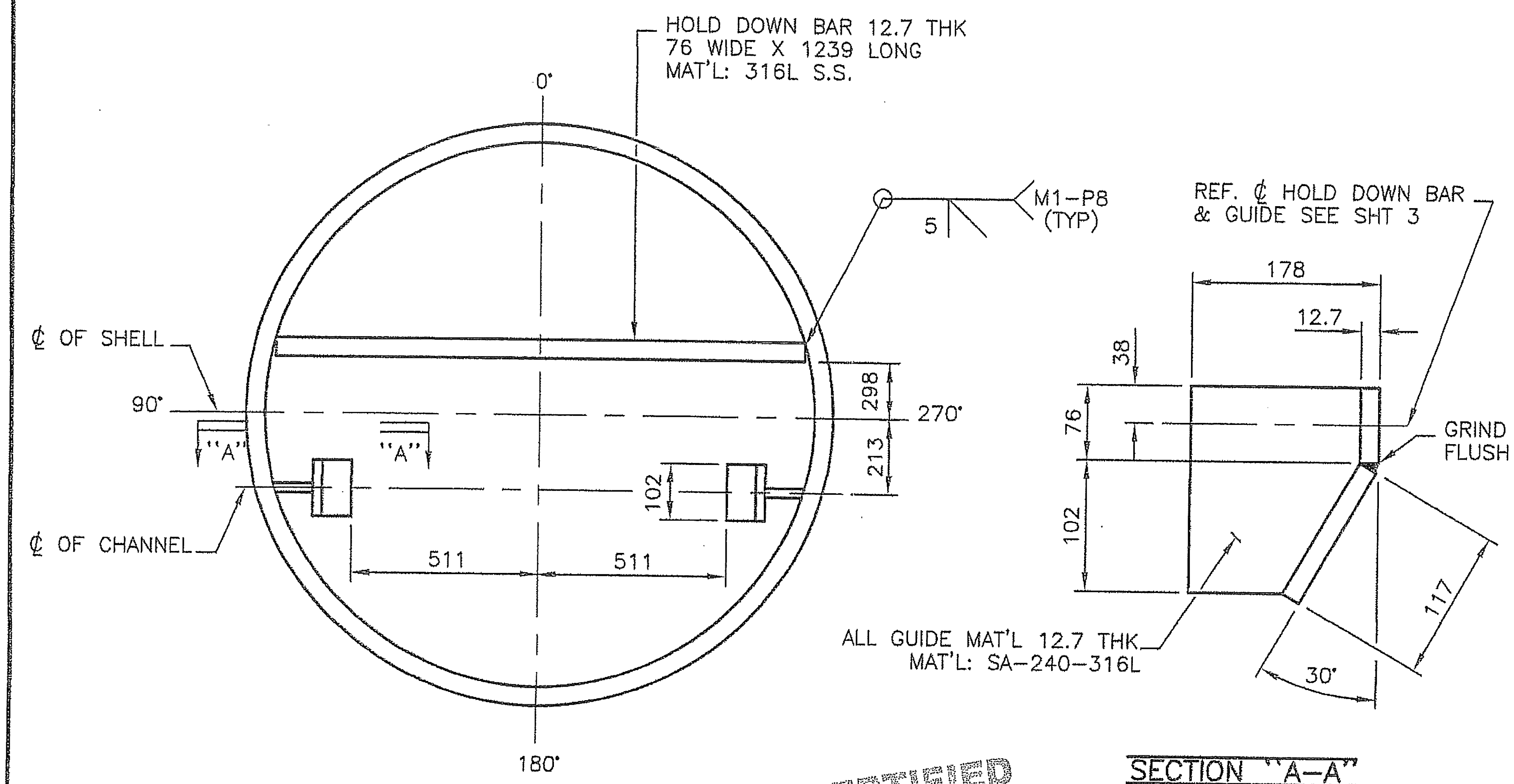
DWN FZ | CKD KW | ITEM E-5868

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWG NO. 08-2953

SHEET 8 OF 16

CERTIFIED AS BUILT



SHELL SIDE IN SOUR SERVICE
SEE MAT'L NOTES SHT.1A

REVISIONS

GUIDE ASSEMBLY DETAIL

NO. REQ'D EACH EXCHANGER: ONE
NO. OF EXCHANGERS REQ'D: ONE

EXCHANGER INDUSTRIES
CALGARY ALBERTA

DWN FZ	CKD KW	ITEM E-5868	DWG NO. 08-2953
			SHEET 9 OF 16

LOCATION	NO. REQ'D	SIZE	LENGTH	T.P.I.
CHANNEL TO SHELL	64	22.2 DIA.	375	9
JACKSCREWS **	4 *	19.5 DIA.	95	10
2"–CL.150 RFWN FLANGE TO BLIND	16 *	15.8 DIA.	83	11
2"–CL.300 RFWN FLANGE TO BLIND **	32 *	15.8 DIA.	89	11

* TOTAL

NOTES:
(1) NUMBER SHOWN IS NUMBER OF STUDBOLTS REQ'D FOR EACH EXCHANGER.
(2) TWO AMERICAN STANDARD HEAVY HEX. NUTS REQ'D FOR EACH STUDBOLT UNLESS NOTED OTHERWISE.
(3) COAT ENTIRE LENGTH OF STUDBOLTS WITH JET LUBE 550.

CERTIFIED AS BUILT

MATERIAL:
STUDBOLTS: SA–193–B7M
NUTS: SA–194–2HM
**STUDBOLTS: SA–193–B7
**NUTS: SA–194–2H

REVISIONS

BOLT SCHEDULE

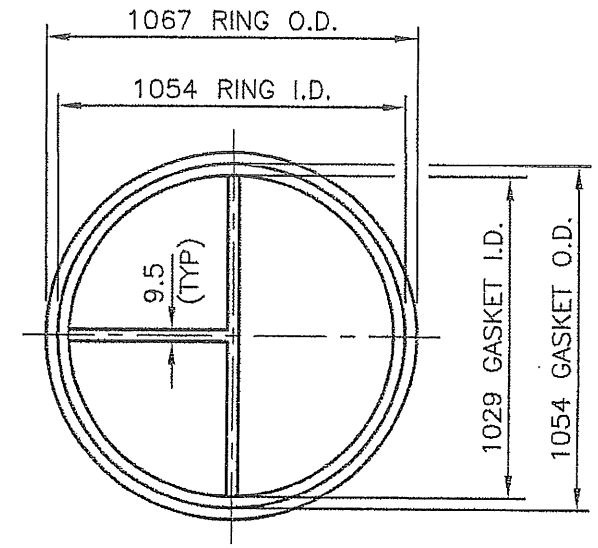
NO. OF EXCHANGERS REQ'D: ONE

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

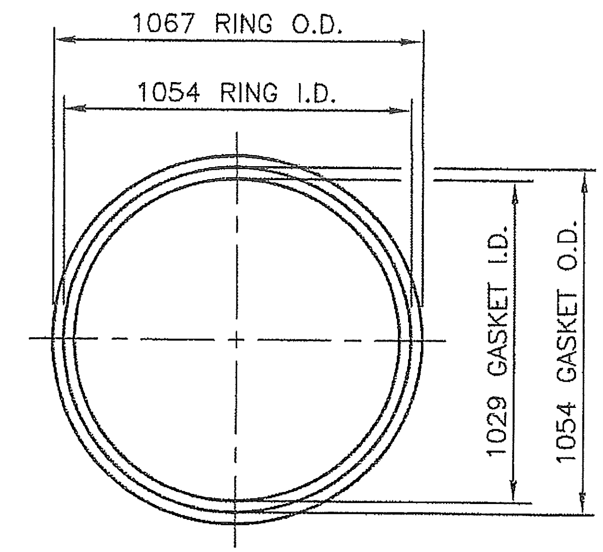
DWN FZ | CKD KW | ITEM E–5868

DWG NO. 08–2953

SHEET 10 OF 16



CHAN. FLANGE TO TUBESHEET
ONE REQ'D EACH SET
2300 kPaG @ 204°C



SHELL FLANGE TO TUBESHEET
ONE REQ'D EACH SET
345 kPaG @ 149°C

2"– CL.150 RFWN FLANGE ANSI B16.5 316 S.S.
SPIRALWOUND STYLE C.G. C/W CARBON STEEL
COMPRESSION RING.
(8) REQ'D TOTAL *

2"– CL.300 RFWN FLANGE ANSI B16.5 316 S.S.
SPIRALWOUND STYLE C.G. C/W CARBON STEEL
COMPRESSION RING.
(8) REQ'D TOTAL *

CERTIFIED
AS BUILT

NOTES:

(1) UNLESS OTHERWISE NOTED ALL GASKETS ARE TO BE: 5 THK 316SS SPIRAL WOUND C/W 3 THK. CARBON STEEL COMPRESSION RING & 3 THK. S.S.D.J. PASS PARTITION RIBS

(2) THICKNESS CALLED FOR IS THE TOTAL THICKNESS REQUIRED

(3) ALL GASKETS ARE TO BE ONE PIECE CONSTRUCTION

*INCLUDES ONE SPARE SET.

REVISIONS

GASKET DETAIL

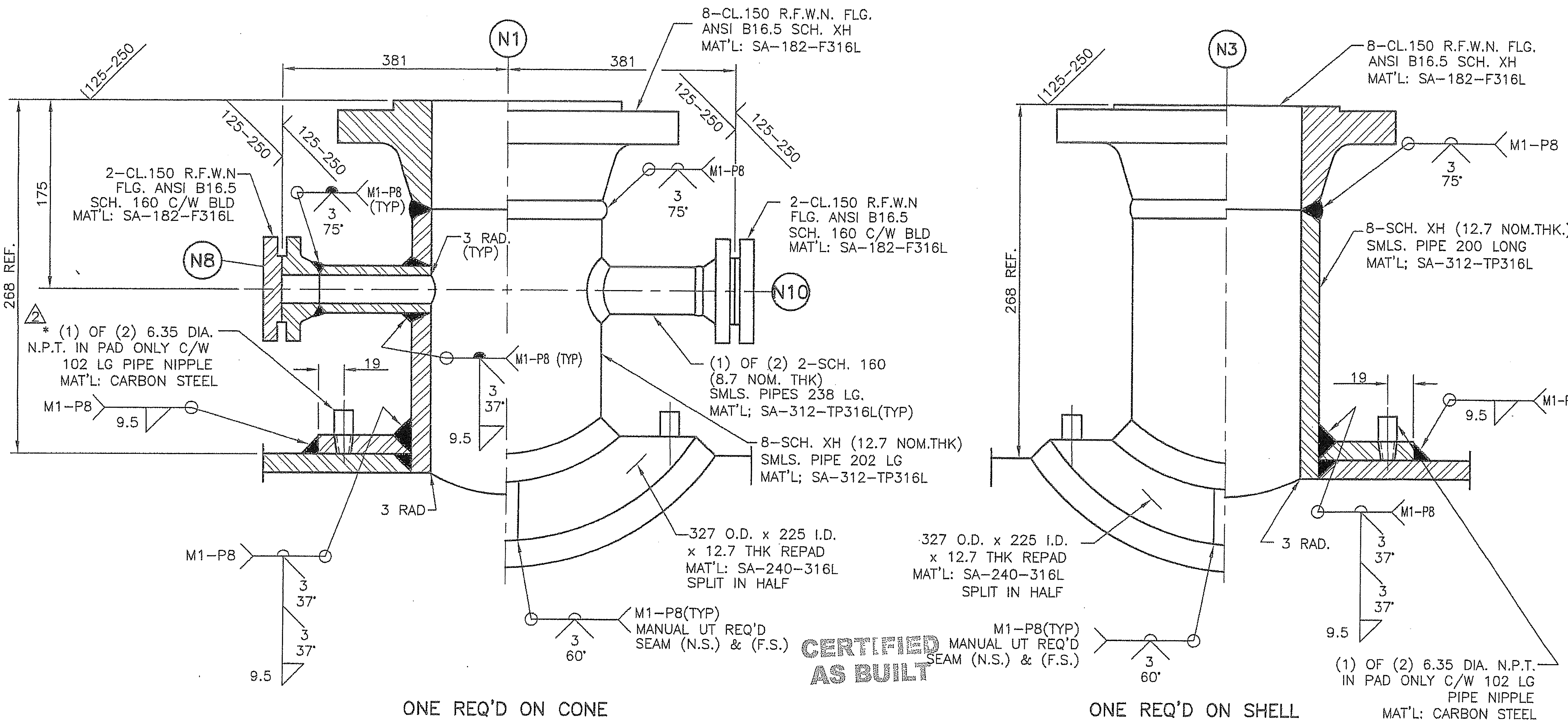
NO. OF SETS REQ'D EACH EXCHANGER: TWO*
NO. OF EXCHANGERS REQ'D: ONE

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWG NO. 08–2953

DWN FZ | CKD KW | ITEM E–5868

SHEET 11 OF 16



SHELL SIDE IN SOUR SERVICE SEE MAT'L NOTES SHT.1A

SEE SHT.1 FOR NOZZLE ORIENTATION

2

* LEAVE OPEN FOR USE AS A TELL-TALE HOLE DURING PRESSURE TESTING. HOLES TO BE FILLED WITH GREASE AFTER TEST (TYP).

REVISIONS
2 PER CUST MARK-UP. APR 1/09 (FZ)

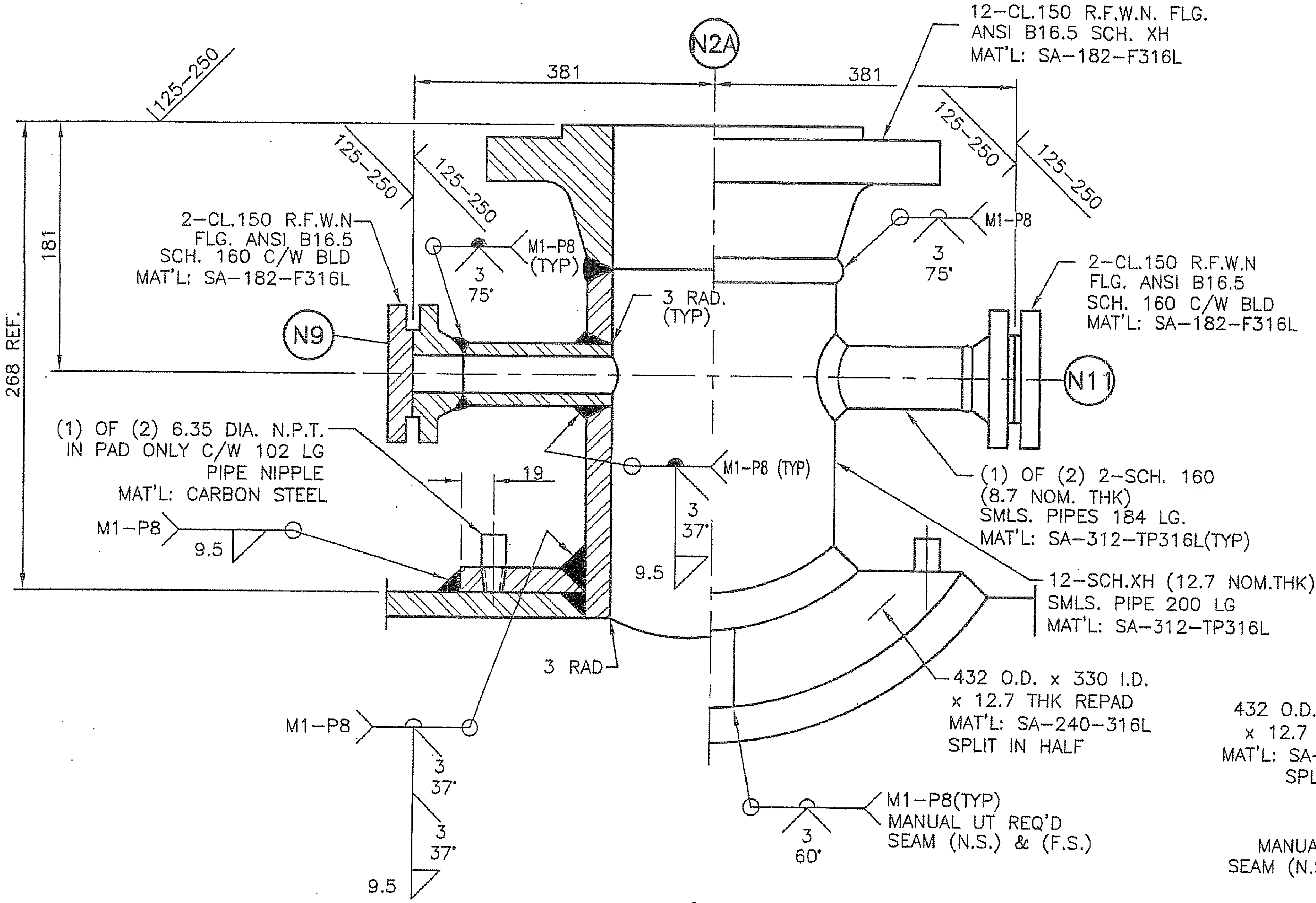
NOZZLE DETAIL

NO. OF EXCHANGERS REQ'D: ONE

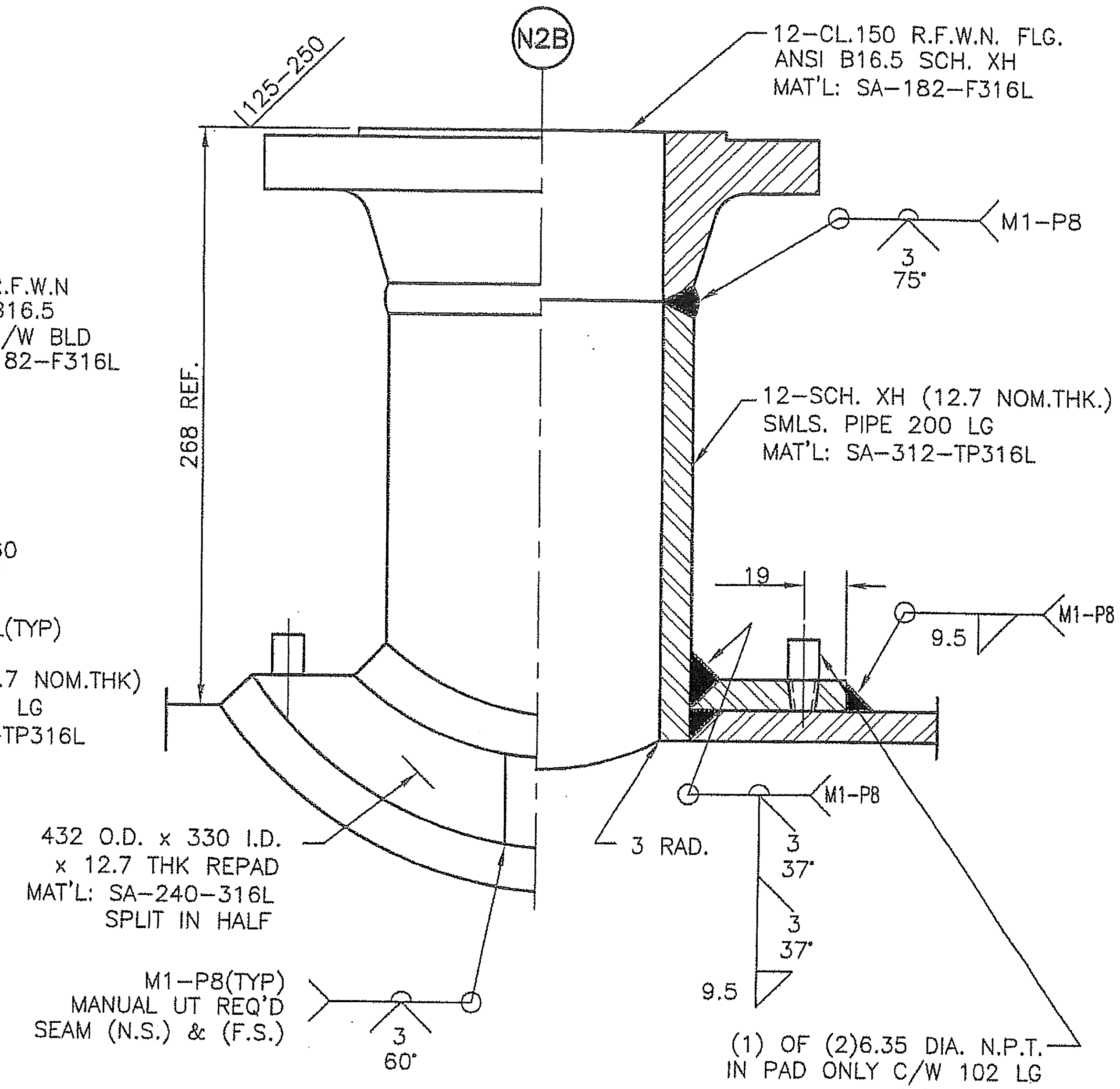
EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWN FZ	CKD KW	ITEM E-5868

DWG NO. 08-2953



ONE REQ'D ON SHELL



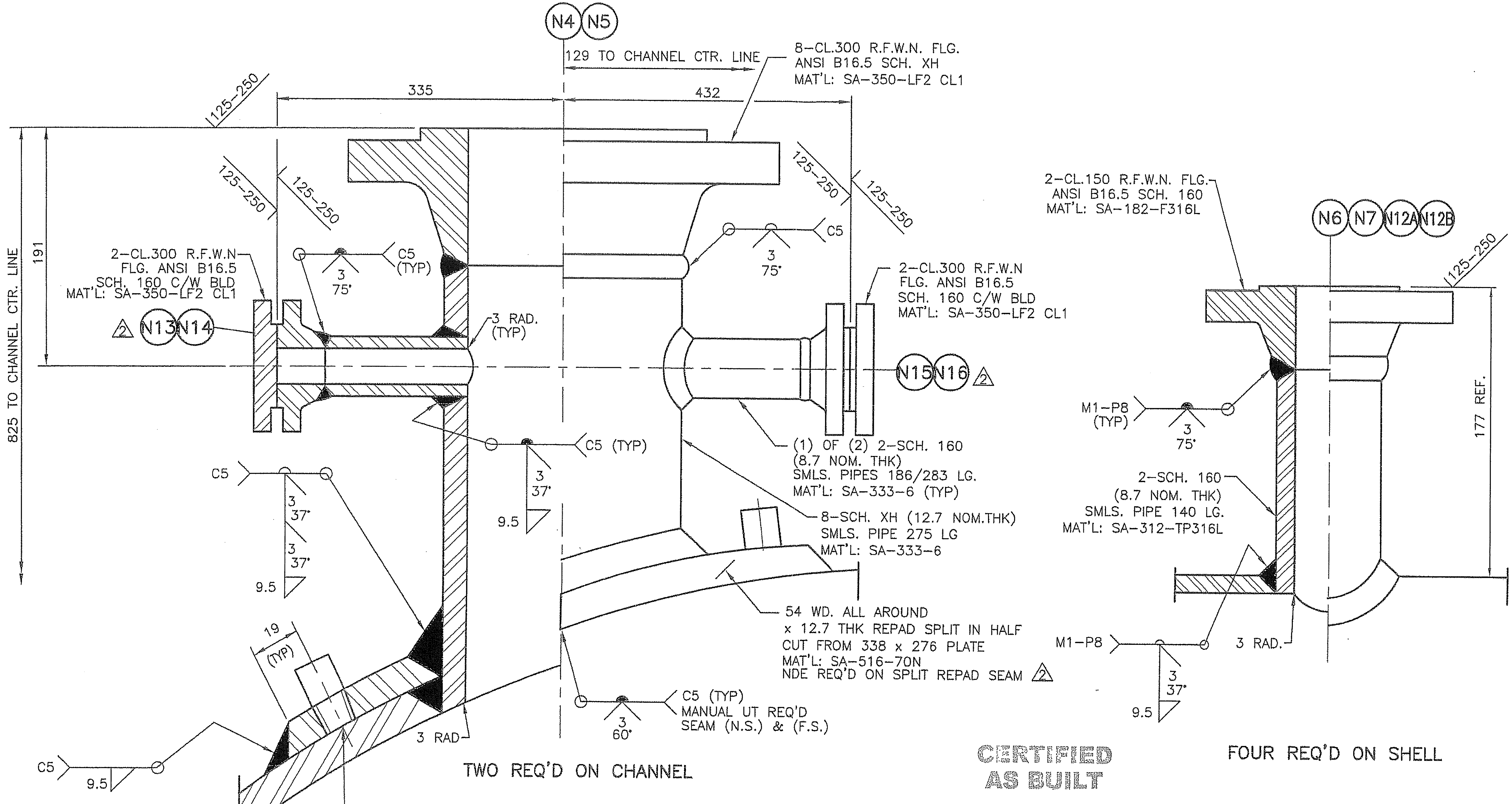
ONE REQ'D ON SHELL

CERTIFIED AS BUILT

SHELL SIDE IN SOUR SERVICE SEE MAT'L NOTES SHT.1A

SEE SHT.1 FOR NOZZLE ORIENTATION

REVISIONS	NOZZLE DETAIL NO. OF EXCHANGERS REQ'D: ONE	EXCHANGER INDUSTRIES CALGARY, ALBERTA
	DWN FZ / CKD KW / ITEM E-5868	DWG NO. 08-2953
		SHEET 13 OF 15

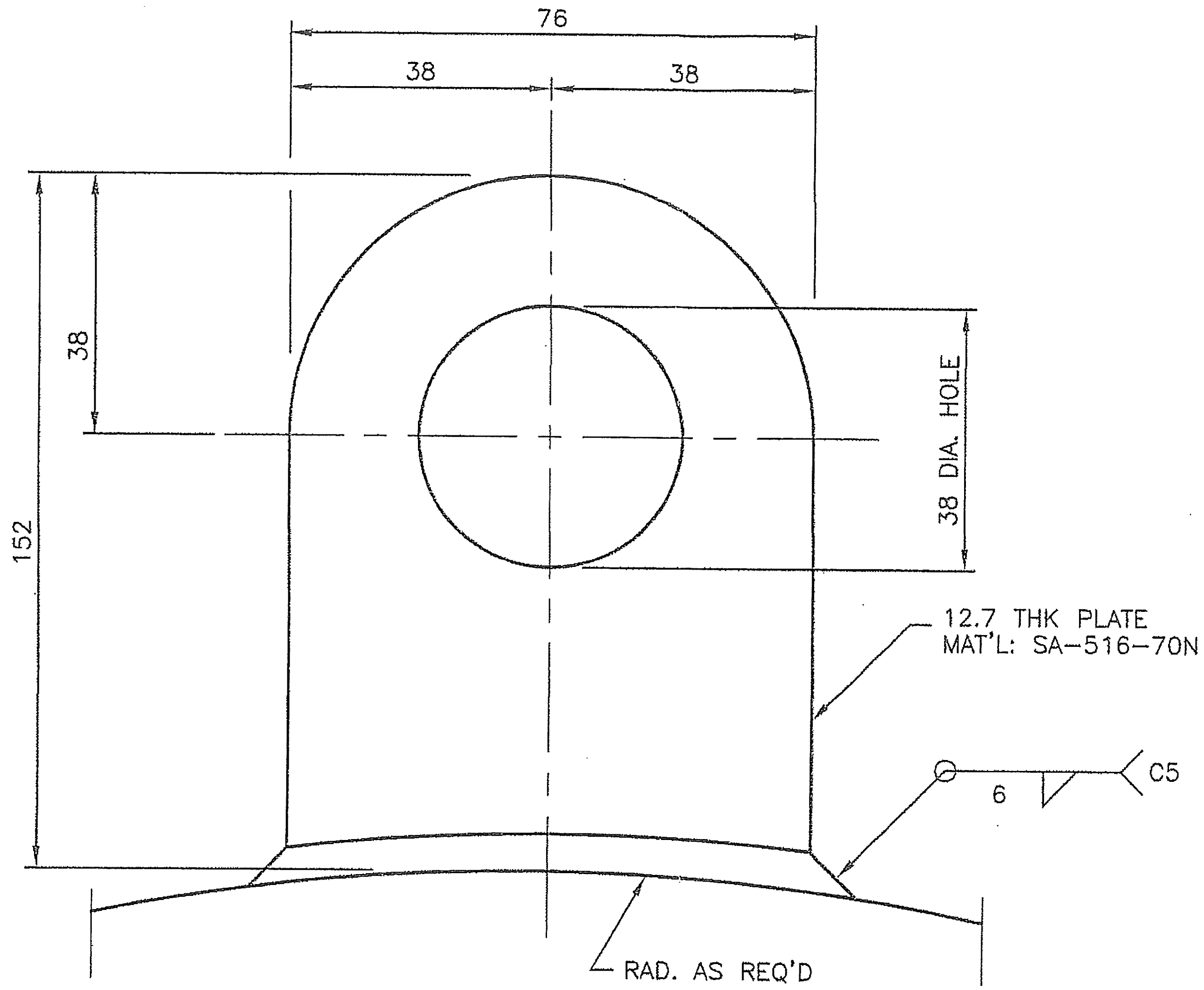


(1) OF (2) 6.35 DIA. N.P.T.
IN PAD ONLY C/W 102 LG
PIPE NIPPLE
MAT'L: CARBON STEEL

SHELL SIDE IN SOUR SERVICE SEE MAT'L NOTES SHT.1A

SEE SHT.1 FOR NOZZLE ORIENTATION

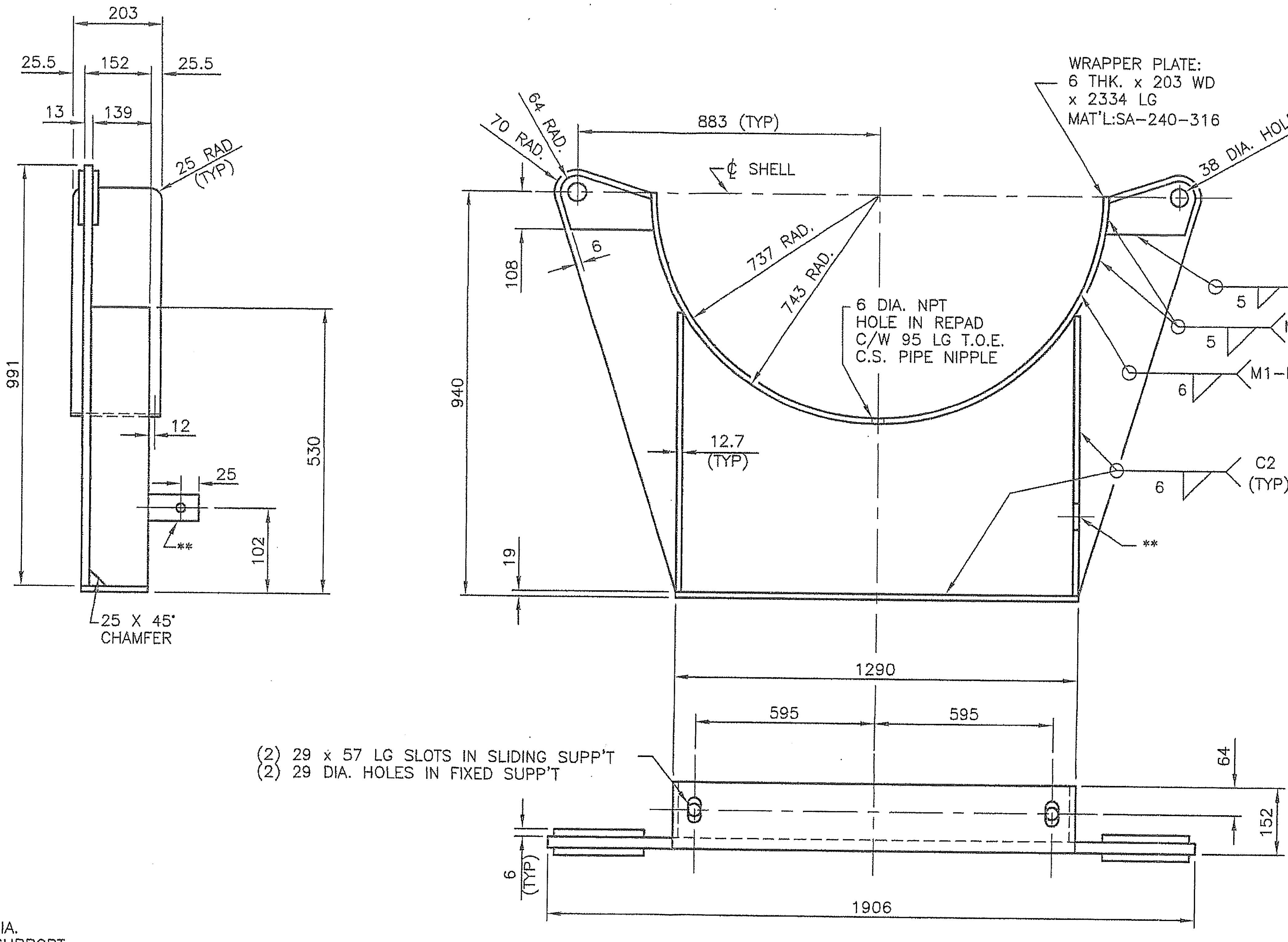
REVISIONS	SHELL NOZZLES	EXCHANGER INDUSTRIES CALGARY, ALBERTA
2 PER CUST MARK-UP. APR 1/09 (FZ)	NUMBER OF EXCHANGERS REQ'D: ONE	DWG NO. 08-2953
	DWN FZ · CKD KW · ITEM E-5868	SHEET 14 OF 15



TWO REQ'D ON CHANNEL CYLINDER

CERTIFIED
AS BUILT

REVISIONS	LIFT LUG DETAIL	EXCHANGER INDUSTRIES
	NO. OF EXCHANGERS REQ'D: ONE	CALGARY, ALBERTA
		DWG NO. 08-2953
	DWN FZ / CKD KW / ITEM E-5868	SHEET 15 OF 16



(2) REQ'D

**
GROUNDING LUG: 9.5 THK x
51 x 76 LONG C/W 11.1 DIA.
HOLE. LOCATE ON SLIDING SUPPORT

CERTIFIED
AS BUILT

NOTES:

ALL MATERIAL TO BE SA-516-70N EXCEPT AS NOTED.

REVISIONS

SUPPORT DETAIL

NO. OF EXCHANGERS REQ'D: ONE

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWN FZ	CKD KW	ITEM E-5868

DWG NO. 08-2953

SHEET 16 OF 16

EXCHANGER INDUSTRIES

MECHANICAL DESIGN CALCULATION COVER SHEET

205-V2.05

Design Code: ASME Section VIII Div 1
2007 Edition and Addenda

Date October 28, 2008

Customer	DPH Focus Corporation
Owner	Encana FCCL Oil Sands Ltd.
Location	Foster Creek, AB
Customer Reference	PO#: FCSR-DPH-4002A Rev. 0
E.I. Job No.	08-2953
Item	E-5868
Prepared by	WZ
Description	Amine Reboiler

File 2953

Checked by KW

Design Conditions	Shellside	Tube	
Pressure	50	334	psi
Temperature	300	399	°F
Vacuum	FV@300		°F
MDMT	-49	-49	°F
Corrosion	0	0.125	inch
Radiography	Full (RT1)	Full (RT1)	
PWHT	No	U-Bends ANNEALED	

Calculation Set Revision Number	Description and Page Number	UG-22 Checked?	DWG Changed?	Date	Approved
0	Initial Issue -- All Pages	Yes	N/A	27-Oct-08	KW

VENDOR CONTROL
RECEIVED
MAR 17 2009
DPH FOCUS CORP.

VENDOR DRAWING REVIEW
- [x] A. Reviewed without comment. Proceed. Provide As-Built drawing.
- [ ] B. Reviewed with comments. Reissue For Construction. Proceed with fabrication.
- [ ] C. Reviewed with comments. Reissue For Review. Proceed with material order only.
- [ ] D. Reviewed with comments. Reissue For Review. DO NOT proceed with matl. or fabr.
- [ ] E. ______

RETURN REPRODUCIBLE DWG. BY ______

DATE MAR 23/09 SIGNED ______

DPH FOCUS JOB # 9971

EXCHANGER INDUSTRIES

61-V2.03

Customer DPH Focus Corporation
Job 08-2953
Item E-5868

Date January 23, 2009
Dsgn WZ
Chkd KW
File 2953

Table of Contents

EXCHANGER INDUSTRIES

206-V1.08

ASME Section VIII Div 1 2007 Edition and Addenda Calculation Checklist

Date October 27, 2008
Customer DPH Focus Corporation
Dsgn WZ
E.I. Job No. 08-2953
Chkd
Item E-5868
File (.CAL) 2953
Rev 0

		Shellside	Tubeside
UG-22	Are the Primary Membrane Stress Calculations Included ?	Yes	Yes
	Are the Support Calculations Included ?	Yes	Yes
	Are the Nozzle Loadings Included ?	Yes	Yes
	Are the Attachment / Lifting Loadings Included ?	Yes	Yes
	Are the Thermal Loadings Included ?	No	No
	Are the Dynamic, Cyclic, or Shock Loadings Included ?	No	No
	Are the Weather and Seismic Loadings Included ?	No	

Supplemental	Is the Unit In Lethal Service ?	No	No
	Is the Unit In Sour or Hydrogen Service ?	Yes	Yes
	Is the Unit Generating Steam Over 50 psi ?	No	No

	Shellside	Tubeside	Tubesheet	
Impact Testing	Exempt UHA-51(d)(1)	Required Per UCS-66	Exempt UHA-51(d)(1)	

		Shellside	Tubeside
UG-20 f 1	Is the Material P-No 1, Gr-1 or 2 ?	No	Yes
	Listed on UCS-66 Curve A and below ½ inch thick ?	No	No
	Listed on UCS-66 Curve B, C or D and below 1 inch thick or less ?	No	Yes
	Vessel is exempt per this Paragraph	No	Yes

		Shellside	Tubeside
UG-20 f 2	Will the Vessel be hydro tested per UG-99b, UG-99c or 27-3 ?	Yes	Yes
	Vessel is exempt per this Paragraph	Yes	Yes

		Shellside	Tubeside
UG-20 f 3	Is the Design Temperature above 650°F (343°C) or Below -20°F (-29°C)	No	No
	Vessel is exempt per this Paragraph	Yes	Yes

		Shellside	Tubeside
UG-20 f 4	Are Thermal or Mechanical Shock Loads Controlling ?	No	No
	Vessel is exempt per this Paragraph	Yes	Yes

		Shellside	Tubeside
UG-20 f 5	Are Cyclic Loads Controling ?	No	No
	Vessel is exempt per this Paragraph	Yes	Yes

	Flat Cover	Tubesheet
Tubesheet / Flat Cover Listed on UCS-66 Curve A and below 2 inch thick ?		No
Tubesheet / Flat Cover Listed on UCS-66 Curve B, C or D and 4 inch thick or less ?		

For	DPH for Encana FCCL Oil Sands Ltd.	Date	Jan 23, 2009
Job	08-2953	Dsgn	WZ
Item	E-5868	Chkd	WJ
		Rev	0

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953.BJT Date: 27/08/2008 Time: 4:05:11 PM

```
Component:  Kettle Cylinder
ASME Section VIII-1 2007 UG-27 Thickness of Shells under Int. Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-240 S31603 Grd 316L Plate(G5)
Design pressure        P = 50 psi        Design temperature    T = 300 F
Radiography              = Full          Joint eff.circ str.   E = 1
Design stress          S = 16700 psi     Joint eff.long str.   E = 1
Design stress, long    S = 16700 psi     Min thk. UG-16(b) tmin = 0.0625 in
Inside corr.allow.   CAI = 0.0 in        Outside corr. all. CAO = 0.0 in
Material tolerance   Tol = 0.0 in        TEMA min. thickness tm = 0.3125 in
Outside diameter      OD = 58.0 in       Corroded radius      IR = 28.5 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
              t = (P*IR / (S*E-0.6*P))+cai+cao+tol = 0.0855 in   UG-27(c)(1)
  Longitudinal stress
            t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.0426 in   UG-27(c)(2)
Actual wall thickness of cylinder:            tnom = 0.5 in
  (Required wall tks. for nozzle attachments, E=1     ,  tri = 0.0855 in )
ASME Section VIII-1 2007 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-240 S31603 Grd 316L Plate(G5)
Design pressure      PE = 15 psi          Design temperature   T = 300 F
Inside corr. allow. CAI = 0 in            Corrosion allow.   CAO = 0 in
Radiography             = Full            Material tol.      Tol = 0 in
Cyl. outside dia.    Do = 58 in           Cylinder length EP  L = 392.625 in
Nominal thickness  tnom = 0.5 in          (tnom-CAI-CAO-Tol)  t = 0.5 in
L/Do ratio          Ldo = 6.7694          Do/t              Dot = 116.0
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.000141        B factor HA-4       B = 1845

Max allowed external pressure: Pa = 4*B / (3*Dot)             = 21.2 psi
Actual external design pressure:                           PE = 15 psi

   (Required cyl. tks. for nozzle attachments at PE, tre = 0.436 in  )
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Oct 24, 2008**
Job	**08-2953**	**Dsgn**	**WZ**
Item	**E-5868**	**Chkd**	KW
		Rev	**0**


```
Component:  Front Head Cover
ASME Section VIII-1 2007 UG-32 Formed Heads, and Sections,
                               Pressure on Concave Side
 -- Calculations --- Ellipsoidal Cover Internal Pressure with t/L >= 0.002
Material:  SA-516 K02700 Grd 70 Plate
Design pressure         P = 334 psi         Design temperature  T = 399 F
Radiography               = Full            Joint efficiency    E = 1
Design stress           S = 20000 psi       TEMA min. thk      tm = 0.5 in
                                            Min thk UG-16(b) tmin = 0.25 in
Inside corr.all.    CAI = 0.125 in          Outside corr.all. CAO = 0.0 in
Major/minor rat.   D/2h = 2.0               Forming tolerance Tol = 0.0625 in
Corroded min. thk     t = 0.3388 in         Equiv.dish radius   L = 36.45 in
Minimum thickness    ts = 0.4375 in         Ratio ts/L       ts/L = 0.012
K =0.1667*(2+(D/2h)**2) = 1.0002            Material tol.     Tol = 0.0 in
Outside diameter     OD = 41.5 in           Corroded diameter  ID = 40.5 in

Required wall thickness of the cover:
            t = (P*ID*K / (2*S*E-0.2*P))+cai+cao+tol = 0.5263 in  App. 1-4(c)
Actual wall thickness of cover:                 . tnom = 0.625 in

   (Required wall tks. for nozzle attachments, E=1     ,  tri = 0.3388 in )
   (If opening & reinf. are within 80% of head diameter, tri = 0.3049 in )
```

```
Component:   Front Head Cylinder
 ASME Section VIII-1 2007 A08 UG-27 Thickness of Shells under Int. Pressure

--- Calculations --- Cylinder Internal Pressure
Material:  SA-516 K02700 Grd 70 Plate
Design pressure        P = 334 psi       Design temperature    T = 399 F
Radiography              = Full          Joint eff.circ str.   E = 1
Design stress          S = 20000 psi     Joint eff.long str.   E = 1
Design stress, long    S = 20000 psi     Min thk. UG-16(b) tmin = 0.1875 in
Inside corr.allow.   CAI = 0.125 in      Outside corr. all. CAO = 0.0 in
Material tolerance   Tol = 0.0 in        TEMA min. thickness tm = 0.5 in
Outside diameter      OD = 41.25 in      Corroded radius      IR = 20.25 in

Required wall thickness of the cylinder , greater of:
  Circumferential stress
              t = (P*IR / (S*E-0.6*P))+cai+cao+tol = 0.4666 in   UG-27(c)(1)
  Longitudinal stress
            t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.2935 in   UG-27(c)(2)

Actual wall thickness of cylinder:            tnom = 0.5 in


  (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.3416 in )
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Oct 24, 2008**
Job	**08-2953**	**Dsgn**	**WZ**
Item	**E-5868**	**Chkd**	KW
		Rev	**0**

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953.BJT Date: 27/08/2008 Time: 4:05:11 PM

```
Component:  Shell Cover
ASME Section VIII-1 2007 UG-32 Formed Heads, and Sections,
                                Pressure on Concave Side
--- Calculations --- Ellipsoidal Cover Internal Pressure with t/L >= 0.002
Material:  SA-240 S31603 Grd 316L Plate(G5)
Design pressure        P = 50 psi         Design temperature  T = 300 F
Radiography              = Full           Joint efficiency    E = 1
Design stress          S = 16700 psi      TEMA min. thk      tm = 0.3125 in
                                          Min thk UG-16(b) tmin = 0.125 in
Inside corr.all.     CAI = 0.0 in         Outside corr.all. CAO = 0.0 in
Major/minor rat.    D/2h = 2.0            Forming tolerance Tol = 0.0625 in
Corroded min. thk      t = 0.0854 in      Equiv.dish radius   L = 51.3 in
Minimum thickness     ts = 0.4375 in      Ratio ts/L       ts/L = 0.00853
K =0.1667*(2+(D/2h)**2) = 1.0002          Material tol.     Tol = 0.0 in
Outside diameter      OD = 58.0 in        Corroded diameter  ID = 57.0 in
Required wall thickness of the cover:
           t = (P*ID*K / (2*S*E-0.2*P))+cai+cao+tol = 0.1479 in  App. 1-4(c)
Actual wall thickness of cover:                   tnom = 0.5 in
   (Required wall tks. for nozzle attachments, E=1     ,  tri = 0.0854 in )
   (If opening & reinf. are within 80% of head diameter, tri = 0.0768 in )
ASME Section VIII-1 2007 UG-33 Formed Heads, Pressure on Convex Side
--- Calculations --- Ellipsoidal Cover External Pressure
Material:  SA-240 S31603 Grd 316L Plate(G5)
Design pressure       PE = 15 psi        Design temperature   T = 300 F
Inside corr. allow. CAI = 0 in           Outside corr. all. CAO = 0 in
Radiography              = Full          Forming tolerance  Tol = 0.0625 in
                                         Material tolerance Tol = 0 in
Cover outside dia.    Do = 58 in         Outside sph.radius  Ro = 52.2 in
Nominal thickness   tnom = 0.5 in        tnom-CAI-CAO-Tol     t = 0.4375 in
Ko factor (UG-33.1)   Ko = 0.9           Ro/t ratio         Rot = 119.3143
UG-33(a)     255.41/1.67 = 152.94 psi    Mod. of elasticity  ME = 27000000 psi
A factor = 0.125/Rot     = 0.001048      B factor HA-4        B = 7307
Maximum allowed external pressure:       Pa = B / Rot           = 61.24 psi
Actual external design pressure:                             PE = 15 psi
   (Required cov. tks. for nozzle attachments at PE, tre = 0.1585 in )
```

Cone to Cylinder Reinforcement (internal pressure)
Per ASME Code Sec VIII, Div 1 2007 A07 App 1.5

For	DPH Focus Corporation	Date	October 28, 2008
Job	08-2953	Dsgn	wz
Item	E-5868	Chkd	KW
		File (.A15)	2953
		Rev	0

Design Pressure P	50	psi	Eccentric Cone		
Design Temperature	300	°F	Cone Length Lc	29.625	inch
Corrosion Ca	0	inch	Cone thickness Tc	0.5	inch
			Weld Efficiency E	1	
Cone Material	SA-240-316L (G5)				
Stress Hot Sc	16,700	psi	Half Apex Angle Alpha	29.48	deg
Stress Cold	16,700	psi	Cos (Alpha)	0.8705	
Large Cylinder Material	SA-240-316L (G5)		Small Cylinder Material	SA-182-F316L	
Stress Hot SsL	16,700	psi	Stress Hot SsS	16,700	psi
Stress Cold	16,700	psi	Stress Cold	12,700	psi
Large Cyl TsL	0.5	inch	Small Cyl TsS	0.5	inch
Large Cylinder ID (R&W)	57	inch	Small Cyl. ID (Fig/TSHT)	40.25	inch
Axial load f1	0	lb/in	Axial load f2	0	lb/in
Cyl Length LL	320	inch			
Large Cylinder tr	0.0855	inch	Small Cylinder tr	N/A	inch

P/SsL E = 0.0030

From Table 1-5.1 Delta = 17.98

Reinforcement per 1-5 (d) (1)

1-5 (e) (3) Not Applicable

ArL = 0.2682 sqin

<u>Area available per 1-5 (d) (2)</u>

<u>1-5 (e) (4) Not Applicable</u>

$$A_{eL} = (t_s - t)\sqrt{(R_L t_s)} + (t_c - t_r)\sqrt{\frac{R_L t_c}{\cos a}}$$

AeL = 3.1904 sqin

<u>tr for cone at large end</u>

tr = 0.0982 inch

Reinforcement Adequate

<u>MAWP</u>
Corroded & Hot (psi) = 252
New & Cold (psi) = 252

```
Component:  Tubes
ASME Section VIII-1 2007 UG-27 Thickness of Shells under Int. Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-789 S31803 Wld. tube
Design pressure        P = 349 psi        Design temperature    T = 399 F
Radiography              =  -             Joint eff.circ str.   E = 1
Design stress          S = 20308 psi      Joint eff.long str.   E = -
Design stress, long    S = -              Min thk. UG-16(b) tmin = 0.0625 in
Inside corr.allow.   CAI = 0.0 in         Outside corr. all. CAO = 0.0 in
Material tolerance   Tol = 0.0 in         TEMA min. thickness tm = 0.0 in
Outside diameter      OD = 0.75 in        Corroded radius     OR = 0.375 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
            t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.0064 in   APP.1-1(A)
  Longitudinal stress
          t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = -           UG-27(c)(2)
Actual wall thickness of cylinder:             tnom = 0.065 in
  (Required wall tks. for nozzle attachments, E=-     ,  tri = -         )
TEMA RCB-2.31 U-Bend Requirements - Minimum tube wall thk in the bent portion
   to = t1 * (1 + do / (4*R)) + c        to = 0.0128 in
Min. Code wall thk    t1 = 0.011 in      Outside diameter    do = 0.75 in
Min. Code wall thickness:                Corrosion allowance  c = 0 in
     Internal press t1i = 0.0064 in      External pressure   t1e= 0.011 in
Min. mean bend radius R = 1.125 in
ASME Section VIII-1 2007 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-789 S31803 Wld. tube
Design pressure      PE = 50 psi          Design temperature  T = 399 F
Inside corr. allow. CAI = 0 in            Corrosion allow.  CAO = 0 in
Radiography             = Full            Material tol.     Tol = 0 in
Cyl. outside dia.    Do = 0.75 in         Cylinder length EP  L = 273 in
Nominal thickness  tnom = 0.065 in        (tnom-CAI-CAO-Tol)  t = 0.065 in
L/Do ratio          Ldo = 364.0           Do/t              Dot = 11.5385
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 26406000 psi
A factor SII-D-FigG   A = 0.009192        B factor HA-5       B = 22269
Max allowed external pressure: Pa = 4*B / (3*Dot)             = 2573.35 psi
Actual external design pressure:                           PE = 50 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.011 in  )
```

For	DPH for Encana FCCL Oil Sands Ltd.	Date	Jan 23, 2009
Job	08-2953	Dsgn	WZ
Item	E-5868	Chkd	KW
		Rev	0

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953.BJT Date: 27/08/2008 Time: 4:05:11 PM

Component: Front Pass Partition

```
Pass Partition Plate Max. Allowed Pressure Differential (TEMA 1999 RCB-9.132)
Pass plate material: SA-516 K02700 Grd 70 Plate
  Thickness              t = 0.5 in
  TEMA min thk        tmin = 0.5 in
  Corrosion allowance    c = 0.25 in      Minimum thickness, tm
  Design stress          S = 20000 psi    tm = b*SQRT((qa*B)/(1.5*S)) + c

Max. allowable pressure drop:  q = (1.5*S*((t-c)/b)**2)/B = see table below
```

Sides fixed	Dim a in	Dim b in	a/b	B factor	q psi	tm in	Selected
a & b	34.875	20.125	1.733	0.594	7.8	0.25	*
a	34.875	20.125	1.733	0.497	9.3	0.25	
b	34.875	20.125	1.733	0.679	6.8	0.25	

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Feb 18, 2009**
Job	**08-2953**	**Dsgn**	**WZ**
Item	**E-5868**	**Chkd**	KD
		Rev	**0**

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 10:38:21 AM

```
Component: Front Tubesheet
Tubesheet Details - ASME VIII-1 2007 A08 - UHX - U-tube Construction
Materials of construction      Fig UHX-12.1 U-Tube Tubesheet configuration (d)
Tubesheet:    SA-240 S31603 Grd 316L Plate(G5)
Tubes:        SA-789 S31803 Wld. tube
Shell:        SA-240 S31603 Grd 316L Plate(G5)
Channel:      SA-516 K02700 Grd 70 Plate
Design conditions              Shell side  Tube side  Tubes  Tubesheet
  Design pressure       psi        50        * 334       (* = controlling)
        Vacuum          psi      * -15         -
  Design temperature     F        300         399      399       399
All.stress tubesheet  S = 15710 psi     All.stress tubes      St = 23892 psi
All.stress shell     Ss = 16700 psi     All.stress channel    Sc = 20000 psi
Yield stress shell  Sys = 19000 psi     Yield stress chann. Syc = 32511 psi
Mod.of elas.tubesheet E = 26406000 psi  Mod.of elas. tubes    Et = 26406000 psi
All.str.tubes at T  Stt = 23892 psi     Mod.of E.tubes at T Ett = 26406000 psi
Mod.of elas.shell    Es = 27000000 psi  Mod.of elas. channel Ec = 27704000 psi
Poisson Ratio shell  vs = 0.3           Poisson ratio chan.   vc = 0.3
Shell diameter       Ds = 40.25 in      Channel diameter      Dc = 40.5 in
Shell thickness      ts = 0.5 in        Channel thickness     tc = 0.375 in
Tube OD             dt = 0.75 in        Tube thickness         tt = 0.065 in
Number of tube holes Nt = 814           Tube pitch             p = 1.0 in
Outer tube limit     Do = 39.507 in     Outer tube radius     ro = 19.3785 in
Tube expan. ratio   rho = 0.533         Tube expanded len.   ltx = 2.0 in
Gasket Gs diameter   Gs = 41.0 in       Gasket Gc diameter    Gc = 41.0 in
Center distance      UL = 1.5 in        Gasket G diameter      G = 41.0 in
Tubesheet cor.all.   ct = 0.125 in      Pass groove depth    hgt = 0.1875 in
Tubesheet cor.all.   cs = 0.0 in        Pass groove depth    hgs = 0.0 in
Tubes     cor.all.    c = -             Effective groove depth:
h'g = MAX[(hgt-ct),(0)]                                      h'g = 0.0625 in
Bolt circle diameter  C = 44.0 in       Bolt load           Wmax = 532322 lbf
Shell bolt load      Ws = 532322 lbf    Channel bolt load     Wc = 532322 lbf
Tubesheet diameter    A = 45.875 in     Shear diameter        Do = 39.507 in
Tubesheet thickness   h = 3.75 in       Actual tubesheet thk  ha = 3.875 in
UHX-12.5.1 Step 1. Determnie Do, Mu, Mu* and h'g from UHX-11.5.1
Basic ligamente efficiency, mu = (p - dt) / p                 mu = 0.25
Effective tube hole diameter  d* = dt-2*tt*(Et/E)*(St/S)*rho     = 0.6446 in
                (maximum of)  d* = dt-2*tt                       = 0.62 in
                                                              d* = 0.6446 in
Pass lane area limit                                      4*Do*p = 158.03 in2
Actual pass lane area, AL                                     AL = 144.78 in2
Effective tube pitch = p/SQRT(1-(4*MIN[AL,4*Do*p]/Pi*Do**2)) p* = 1.0649 in
Effective ligament efficiency, mu* = (p*-d*)/p*              mu* = 0.3947
UHX-12.5.2 Step 2. Calculate diameter ratios rhos and rhoc.  For each loading
   case, calculate moment Mts due to pressures Ps and Pt acting on the
   unperforated tubesheet rim.
   Rhos = Gs / Do     Rhos = 1.0378      Rhoc = Gc / Do    Rhoc = 1.0378
   MTS = (Do**2/16)*((rhos-1)*(rhos**2+1)*Ps - (rhoc-1)*(rhoc**2+1)*Pt)
   Load case                               1           2             3
   Shell Pressure, psi                     0          -15           -15
   Tubes Pressure, psi                   334           0            334
   Moment MTS,lbf*in/in               -2557.4      -114.85      -2672.25
UHX-12.5.3 Step 3. Calculate h/p.  If rho changes, recalculate d* and mu* from
   figure UHX-11.5.1.  Determin E*/E and v* relative to h/p from UHX-11.5.2.
   Determine E*/E and v* from Fig UHX-11.4                   h/p = 3.75
           Ratio E*/E = 0.4524                        Factor v* = 0.3169
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Feb 18, 2009**
Job	**08-2953**	**Dsgn**	**WZ**
Item	**E-5868**	**Chkd**	KWT
		Rev	**0**


```
Tubesheet Details - ASME VIII-1 2007 A08 - UHX - U-tube Construction
UHX-12.5.5 Step 5. Calculate diameter ratio K and coefficient F
       K = A/Do                                  K = 1.1612
       F = ((1-v*)/E*)*E*Ln(K))                  F = 0.2256
UHX-12.5.6 Step 6. For each loading case, calculate moment M* acting on the
                   unperforated tubesheet rim.
      M* = Mts + ((Gc-Gs)/ (2*Pi*Do)) * Wmax
   Load case                              1            2            3
   Moment M*,lbf*in/in               -2557.4      -114.85     -2672.25
Component: Front Tubesheet
Tubesheet Details - ASME VIII-1 2007 A08 - UHX - U-tube Construction
UHX-12.5.7 Step 7. For each loading case, calculate the maximum bending
   moments acting on the tubesheet at the periphery Mp and at the center Mo
   At the periphery:
   Mp = (M* - (Do**2/32) * F * (Ps - Pt)) / (1 + F)
   At the center:
   Mo = Mp + (Do**2/64) * (3+v*) * (Ps-pt)
   M = MAX[|Mp|,|Mo|]
   Load case                              1            2            3
   Mp,lbf*in/in                      912.59        40.98       953.57
   Mo,lbf*in/in                   -26104.68     -1172.37    -27277.04
   M ,lbf*in/in                    26104.68      1172.37     27277.04

UHX-12.5.8 Step 8. For each loading case, calculate the tubesheet bending
   stress sigma.
                       sigma = 6 * M / (mu* * (h - h'g)**2)
   Load case                              1            2            3
   sigma, psi                         29184         1311        30494
   Allowable stress, psi              31420        31420        31420
   Min tubesheet thickness, in       3.6163       0.8156       3.6953
UHX-12.5.9 Step 9. For each loading case, calculate the average shear stress
   in the tubesheet at the outer edge of the perforated region.
                       Tau = (1/(4*mu)*(Do/h)*|Ps-Pt|
   Load case                              1            2            3
   Tau, psi                            3519          158         3677
   Allowable stress, psi              12568        12568        12568
   Min tubesheet thickness, in       1.0499       0.0472       1.0971
```

For	DPH for Encana FCCL Oil Sands Ltd.	Date	Feb 18, 2009
Job	08-2953	Dsgn	WZ
Item	E-5868	Chkd	KW
		Rev	0

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 10:38:21 AM

Pressure case	Ps psi	Pt psi	MTS	M*	Mp	Mo	M	F
			lbf*in/in					
- 1 -	0	334	-2557	-2557	913	-26105	26105	0.2256
- 2 -	50	0	383	383	-137	3908	3908	0.2256
- 3 -	50	334	-2175	-2175	776	-22197	22197	0.2256
- 4 -	0	0	0	0	0	0	0	0
- 5 -	0	0	0	0	0	0	0	0
- 6 -	0	0	0	0	0	0	0	0
- 7 -	0	334	-2557	-2557	913	-26105	26105	0.2256
- 8 -	-15	0	-115	-115	41	-1172	1172	0.2256
- 9 -	-15	334	-2672	-2672	954	-27277	27277	0.2256
- 10-	0	0	0	0	0	0	0	0
- 11-	0	0	0	0	0	0	0	0
- 12-	0	0	0	0	0	0	0	0

Pressure case	**sigma** psi	**Smax** psi	**hmin** in	**tau** psi	**Smax** psi	**hmin** in
- 1 -	29184	31420	3.6163	3519	12568	1.0499
- 2 -	4369	31420	1.4375	527	12568	0.1572
- 3 -	24815	31420	3.3396	2992	12568	0.8927
- 4 -	0	31420	0.0	0	12568	0.0
- 5 -	0	31420	0.0	0	12568	0.0
- 6 -	0	31420	0.0	0	12568	0.0
- 7 -	29184	31420	3.6163	3519	12568	1.0499
- 8 -	1311	31420	0.8156	158	12568	0.0472
- 9 -	30494	31420	3.6953	3677	12568	1.0971
- 10-	0	31420	0.0	0	12568	0.0
- 11-	0	31420	0.0	0	12568	0.0
- 12-	0	31420	0.0	0	12568	0.0

UHX-9 Tubesheet Flanged Extension (Use Non G5 Stress)

```
G   = diameter of gasket load reaction                     G = 41.0 in
hG  = gasket moment arm                                   hG = 1.5 in
Sa  = allowable stress for tubesheet extension
        at ambient temperature                            Sa = 16700 psi
Sd  = allowable stress for tubesheet extension
        at design temperature                             Sd = 11700 psi ( Non G5 Stress )
Ta  = ambient temperature                                 Ta = 70 F
Td  = design temperature                                  Td = 399 F
Wo  = flange design bolt load, opeating conditions        Wo = 528324 lbf
Wg  = flange design bolt load, gasket seating             Wg = 532322 lbf
Minimum required thickness of the tubesheet flanged extension
hro = SQRT(1.9 * Wo * hG) / (Sd * G)                     hro = 1.7717 in
hrg = SQRT(1.9 * Wg * hG) / (Sa * G)                     hro = 1.4885 in
hr  = MAX[hro, hrg]                                       hr = 1.7717 in
```

EXCHANGER INDUSTRIES

Tapped Stud Holes/Collar Bolts Maintain Gasket Seating @ Zero Pressure Calculation

		Rev	0
For	DPH for Encana FCCL Oil Sands Ltd.	Date	23-Jan-09
Job	08-2953	Dsgn	WZ
Item	E-5868	Chkd	KLS

Bolt Diameter	0.875	in
Bolt Circle	44	in
Actual Bolt Area	26.82	in^2
Total # of Bolts	64	
Joint-Contact Loads Hp	9660	lbs
Tube Sheet Effective Thickness	3	in
Tapped Stud Holes (Collar Bolts)	16	
Gasket m	3	
Bolt Stress Cold	20000	psi

Max. Bolt Spacing Bmax	6.8928571
Bolt Spacing B	8.6393798
Correction Factor Cf	1.3486352
Tapped Stud Holes/Collar Bolts Required	3.38

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Oct 27, 2008**
Job	**08-2953**	**Dsgn**	**WZ**
Item	**E-5868**	**Chkd**	KJ
		Rev	**0**

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 9:44:16 AM

```
Component:  Front Head Flng At TS
ASME Section VIII-1 2007 App. 2 Bolted Flange With Ring Type Gaskets
Flange type: Integral tapered hub - code fig.2-4(6)
Flange material: SA-350 K03011 Grd LF2 Cls 1 Forgings
Int. design pressure  PI = 334 psi      Design temperature     T = 399 F
Ext. design pressure  PE = 0 psi        B1 = B+g1 or B+go     B1 = -
Inside corr. allow   CAI = 0.125 in     Outside corr. all.   CAO = 0.0 in
Stress (operating)   SFO = 20000 psi    Stress (atmos.)      SFA = 20000 psi
Outside diameter       A = 45.875 in    Inside spherical rad.  L = -
Inside diameter        B = 40.5 in      Hub thickness         g1 = 0.5 in
Bolt circle diameter   C = 44.0 in      Hub tks. at attach.   go = 0.375 in
Mean gasket diameter   G = 41.0 in      Weld leg/hub length    h = 1.0 in
Hub to bolt circle     R = 1.25 in      Bolt circle to OD      E = 0.9375 in
Flange thickness       t = 4.125 in
Overlay thickness     OL = -
Gasket material: Sprl-Wnd SS with Outer Ring
Gasket outside dia.  ODG = 41.5 in      Gasket width         Wth = 0.5 in
Outer metal ring OD      = 42.0 in      Inner metal ring OD      = -
Outer metal ring width   = 0.25 in      Inner metal ring width   = -
Outer metal ring ID      = 41.5 in      Inner metal ring ID      = -
Gasket thickness     tks = 0.125 in     Gasket factor          m = 3.0
Gasket seating stress  y = 10000 psi    Gasket eff. width      b = 0.25 in
Gasket unit stress    Sg = 9532 psi                   factor f = 0.125 in
Gasket rib length    Rib = 60.75 in     Seating width         bo = 0.25 in
Gasket rib eff width  Br = 0.1875 in     (Table 2-5.2  facing 1a/1b  Col. II )
Bolt material: SA-193 G41400 Grd B7M Bolt(<= 2 1/2)
Bolt diameter        Dia = 0.875 in     No. of bolts         No. = 64
Bolt root area      Area = 0.419 in2    Sg = Ab*Sa/((Pi/4)*(do-f)**2-di**2)
Stress (operating)    SB = 20000 psi    Stress (atmos.)       SA = 20000 psi
Joint-contact compr. load    HP = 6.2832*b*G*PI*m+2*Br*m*PI*RIB =    87358 lbf
Hydrostatic end force         H = 0.7854*G*G*PI                 =   440966 lbf
Hydrostatic end force        He= 0.7854*G*G*PE                  =        0 lbf
Operating conditions:
Min. calc. bolt load        WM1 = HP+H                          =   528324 lbf
Min. used bolt load         WM1 = max of 2 mating flanges       =   528324 lbf
Bolting up conditions:
Minimum bolt load           WM2 = b*3.1416*G*Y+Br*Y*RIB         =   435920 lbf
Min. used bolt load         WM2 = max of 2 mating flanges       =   435920 lbf
Required bolt area           AM = WM2/SA or WM1/SB              =    26.42 in2
Available bolt area          AB = No.Bolt*Area                  =    26.82 in2
Design bolt load              W = 0.5*(AM+AB)*SA                =   532322 lbf
Minimum gasket width       NMIN = AB*SA/(6.283*y*G)             =   0.2082 in
Gasket compression stress  Gcst = AB*SA/(Pi*G*Wth)              =     8328 psi
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Oct 27, 2008**
Job	**08-2953**	**Dsgn**	**WZ**
Item	**E-5868**	**Chkd**	KW
		Rev	**0**

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 9:44:16 AM

```
Loads:                     Integral Flange Calculations
Operating conditions:
Hydrostatic end load        HD = 0.785*B*B*PI       = 430276 lbf
Hydrostatic end load        HDe= 0.785*B*B*PE       =      0 lbf
Gasket load                 HG = WM1-H              =  87358 lbf
Result. hydrostatic force   HT = H-HD               =  10690 lbf
Result. hydrostatic force   HTe= He-HDe             =      0 lbf
Bolting up conditions:
Gasket load                 HG = W                  = 532322 lbf
Operating conditions:
Hydrostatic lever arm       hd = R+0.5*g1           = 1.5 in
Gasket load lever arm       hg = (C-G)/2            = 1.5 in
Result. hydro. lever arm    ht = (R+g1+hg)/2.0      = 1.625 in
Bolting up conditions:
Gasket load lever arm       hg = (C-G)/2            = 1.5 in
Operating conditions:
Hydrostatic moment          MD = HD*hd              = 645414 lbf*in
Gasket moment               MG = HG*hg              = 131038 lbf*in
Result. hydro. moment       MT = HT*ht              =  17371 lbf*in
Total operating moment     MOP = MD+MG+MT           = 793823 lbf*in
Total operating mom. MOPe= HDe(hd-hg)+HTe(ht-hg)    =      0 lbf*in
Bolting up conditions:
Bolt up moment            MATM = W*hg               = 798483 lbf*in
Effective bolt moment       MB = MATM*SFO/SFA       = 798483 lbf*in
Total moment                MO = MOP  or MB         = 798483 lbf*in
Bolt spacing correction      M = MO*Cf              = 798483 lbf*in
 (TEMA 1999 RCB-11.23) Cf= 1
Flange shape constants:
       K = A/B          = 1.1327       ho = SQ(B*G0)    = 3.8971
      TF = Fig.2-7.1    = 1.8652     h/ho = h/ho        = 0.2566
       Z = Fig.2-7.1    = 8.066         F = Fig.2-7.2   = 0.8905
       Y = Fig.2-7.1    = 15.6046       V = Fig.2-7.3   = 0.4234
       U = Fig.2-7.1    = 17.1479       f = Fig.2-7.6   = 1.0122
   G1/G0 = G1/Go        = 1.3333        e = F/ho        = 0.2285
       t =              = 4.125 in
       D = U*ho*g0*g0/V = 22.1969   Alpha = t*e+1.0     = 1.9425
    Beta = 1.333*t*e+1.0 = 2.2564   Gamma = Alpha/TF    = 1.0414
   Delta = t*t*t/D      = 3.1621   Lambda = Gamma+Delta = 4.2036
Stress calculations:                            Allowable stress:
Long. hub     SH = (f*M)/(Lambda*g1**2*B)  =   18991 psi 1.5*SFO =   30000 psi
Radial        SR = Beta*M/(Lambda*t**2*B)  =     622 psi     SFO =   20000 psi
Tangential   ST1 = M*Y/(t**2*B)-(Z*SR)     =   13064 psi     SFO =   20000 psi
  (greater)  ST2 = (SH+SR)/2 or (SH+ST1)/2 =   16027 psi     SFO =   20000 psi
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Oct 27, 2008**
Job	**08-2953**	**Dsgn**	**WZ**
Item	**E-5868**	**Chkd**	KW
		Rev	**0**

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 9:44:16 AM

```
Component:   Front Head Flng At TS
ASME Section VIII Div.1 2007, Appendix 2, 2-14 Flange Rigidity
--- Calculations ---
Operating moment,     Mo = 793823 lbf*in Gasket seat. moment Ma = 798483 lbf*in
Factor V               V = 0.423          Factor L              L = 4.2036
Mod. elast.design T   Ed = 27704000 psi   Mod.elast.atm. temp Ea = 29200000 psi
Thickness g0          g0 = 0.375 in       Factor h0            h0 = 3.8971 in
Factor KI             KI = 0.3            Factor KL            KL = 0.2
Corrosion allowance   ca = 0.125 in       Factor K              K = 1.1327
Thickness, T           T = 4.125 in
Rigidity index, J, loose flange type
Gasket seating  J = 109.4 * Ma / (E * T ** 3 * Ln(K) * KL) = -
Operating       J = 109.4 * Mo / (E * T ** 3 * Ln(K) * KL) = -
Rigidity index, J, integral flange type
Gasket seating  J = 52.14 * Ma * V / (L * E * G0 ** 2 * ho * KI) = 0.8734
Operating       J = 52.14 * Mo * V / (L * E * G0 ** 2 * ho * KI) = 0.9152
  ASME appendix 2 calculation of hub thikcness 'go' as a cylinder
Design pressure        P = 334 psi        Allowable stress      S = 20000 psi
Outside radius        OR = 0.0 in         Inside radius        IR = 20.25 in
Joint efficiency       E = 1              Corrosion allowance   c = 0.125 in
  Min 'go' = P * IR / (S * E - 0.6 * P) + c                     UG-27(c)(1)
  Minimum calculated thickness for hub thickness 'go' = 0.4666 in
New hub thickness  'go' = 0.5 in       New hub thickness  'g1' = 0.625 in
Corroded thickness 'go' = 0.375 in     Corroded thickness 'g1' = 0.5 in
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Oct 27, 2008**
Job	**08-2953**	**Dsgn**	**WZ**
Item	**E-5868**	**Chkd**	KS
		Rev	**0**

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 9:44:16 AM

```
Component:  Front Shell Flng
ASME Section VIII-1 2007 App. 2 Bolted Flange With Ring Type Gaskets
Flange type: Integral tapered hub - code fig.2-4(6)
Flange material: SA-182 S31603 Grd F316L Forgings
Int. design pressure  PI = 50 psi        Design temperature      T = 300 F
Ext. design pressure  PE = 15 psi        B1 = B+g1 or B+go      B1 = -
Inside corr. allow   CAI = 0.0 in        Outside corr. all.    CAO = 0.0 in
Stress (operating)   SFO = 12700 psi     Stress (atmos.)       SFA = 16700 psi
Outside diameter       A = 45.875 in     Inside spherical rad.  L = -
Inside diameter        B = 40.25 in      Hub thickness         g1 = 0.625 in
Bolt circle diameter   C = 44.0 in       Hub tks. at attach.   go = 0.5 in
Mean gasket diameter   G = 41.0 in       Weld leg/hub length    h = 1.0 in
Hub to bolt circle     R = 1.25 in       Bolt circle to OD      E = 0.9375 in
Flange thickness       t = 4.625 in
Overlay thickness     OL = -
Gasket material: Sprl-Wnd SS with Outer Ring
Gasket outside dia.  ODG = 41.5 in       Gasket width         Wth = 0.5 in
Outer metal ring OD      = 42.0 in       Inner metal ring OD      = -
Outer metal ring width   = 0.25 in       Inner metal ring width   = -
Outer metal ring ID      = 41.5 in       Inner metal ring ID      = -
Gasket thickness     tks = 0.125 in      Gasket factor          m = 3.0
Gasket seating stress  y = 10000 psi     Gasket eff. width      b = 0.25 in
Gasket unit stress    Sg = 9532 psi                      factor f = 0.125 in
Gasket rib length    Rib = 0.0 in        Seating width         bo = 0.25 in
Gasket rib eff width  Br = 0.0 in         (Table 2-5.2  facing 1a/1b  Col. II )
Bolt material: SA-193 G41400 Grd B7M Bolt(<= 2 1/2)
Bolt diameter        Dia = 0.875 in      No. of bolts         No. = 64
Bolt root area      Area = 0.419 in2     Sg = Ab*Sa/((Pi/4)*(do-f)**2-di**2)
Stress (operating)    SB = 20000 psi     Stress (atmos.)       SA = 20000 psi
Joint-contact compr. load    HP = 6.2832*b*G*PI*m+2*Br*m*PI*RIB =     9660 lbf
Hydrostatic end force         H = 0.7854*G*G*PI                 =    66013 lbf
Hydrostatic end force        He= 0.7854*G*G*PE                  =    19804 lbf
Operating conditions:
Min. calc. bolt load        WM1 = HP+H                          =    75673 lbf
Min. used bolt load         WM1 = max of 2 mating flanges       =   528324 lbf
Bolting up conditions:
Minimum bolt load           WM2 = b*3.1416*G*Y+Br*Y*RIB         =   322013 lbf
Min. used bolt load         WM2 = max of 2 mating flanges       =   435920 lbf
Required bolt area           AM = WM2/SA or WM1/SB              =    26.42 in2
Available bolt area          AB = No.Bolt*Area                  =    26.82 in2
Design bolt load              W = 0.5*(AM+AB)*SA                =   532322 lbf
Minimum gasket width       NMIN = AB*SA/(6.283*y*G)             =    0.2082 in
Gasket compression stress  Gcst = AB*SA/(Pi*G*Wth)              =     8328 psi
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Oct 27, 2008**
Job	**08-2953**	**Dsgn**	**WZ**
Item	**E-5868**	**Chkd**	KW
		Rev	**0**

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 9:44:16 AM

```
Loads:                       Integral Flange Calculations
Operating conditions:
Hydrostatic end load          HD = 0.785*B*B*PI      =  63620 lbf
Hydrostatic end load          HDe= 0.785*B*B*PE      =  19086 lbf
Gasket load                   HG = WM1-H             = 462312 lbf
Result. hydrostatic force     HT = H-HD              =   2393 lbf
Result. hydrostatic force     HTe= He-HDe            =    718 lbf
Bolting up conditions:
Gasket load                   HG = W                 = 532322 lbf
Operating conditions:
Hydrostatic lever arm         hd = R+0.5*g1          = 1.5625 in
Gasket load lever arm         hg = (C-G)/2           = 1.5 in
Result. hydro. lever arm      ht = (R+g1+hg)/2.0     = 1.6875 in
Bolting up conditions:
Gasket load lever arm         hg = (C-G)/2           = 1.5 in
Operating conditions:
Hydrostatic moment            MD = HD*hd             =  99406 lbf*in
Gasket moment                 MG = HG*hg             = 693467 lbf*in
Result. hydro. moment         MT = HT*ht             =   4038 lbf*in
Total operating moment       MOP = MD+MG+MT          = 796912 lbf*in
Total operating mom. MOPe= HDe(hd-hg)+HTe(ht-hg)     =   1327 lbf*in
Bolting up conditions:
Bolt up moment              MATM = W*hg              = 798483 lbf*in
Effective bolt moment         MB = MATM*SFO/SFA      = 607230 lbf*in
Total moment                  MO = MOP  or MB        = 796912 lbf*in
Bolt spacing correction        M = MO*Cf             = 796912 lbf*in
 (TEMA 1999 RCB-11.23) Cf= 1
Flange shape constants:
       K = A/B              = 1.1398        ho = SQ(B*G0)      = 4.4861
      TF = Fig.2-7.1        = 1.8626      h/ho = h/ho          = 0.2229
       Z = Fig.2-7.1        = 7.6882         F = Fig.2-7.2     = 0.8968
       Y = Fig.2-7.1        = 14.8787        V = Fig.2-7.3     = 0.4562
       U = Fig.2-7.1        = 16.3502        f = Fig.2-7.6     = 1.0
   G1/G0 = G1/Go            = 1.25           e = F/ho          = 0.1999
       t =                  = 4.625 in
       D = U*ho*g0*g0/V     = 40.1993    Alpha = t*e+1.0       = 1.9246
    Beta = 1.333*t*e+1.0    = 2.2325     Gamma = Alpha/TF      = 1.0333
   Delta = t*t*t/D          = 2.461     Lambda = Gamma+Delta   = 3.4943
Stress calculations:                               Allowable stress:
Long. hub      SH = (f*M)/(Lambda*g1**2*B)  =    14505 psi 1.5*SFO =   19050 psi
Radial         SR = Beta*M/(Lambda*t**2*B)  =      591 psi     SFO =   12700 psi
Tangential    ST1 = M*Y/(t**2*B)-(Z*SR)     =     9225 psi     SFO =   12700 psi
  (greater)   ST2 = (SH+SR)/2 or (SH+ST1)/2 =    11865 psi     SFO =   12700 psi
```

For	DPH for Encana FCCL Oil Sands Ltd.	Date	Oct 27, 2008
Job	08-2953	Dsgn	WZ
Item	E-5868	Chkd	KW
		Rev	0

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 9:44:16 AM

```
Component:  Front Shell Flng
ASME Section VIII Div.1 2007, Appendix 2, 2-14 Flange Rigidity
--- Calculations ---
Operating moment,     Mo = 796912 lbf*in Gasket seat. moment Ma = 798483 lbf*in
Factor V              V = 0.456         Factor L                L = 3.4943
Mod. elast.design T  Ed = 27000000 psi  Mod.elast.atm. temp Ea = 28300000 psi
Thickness g0         g0 = 0.5 in        Factor h0              h0 = 4.4861 in
Factor KI            KI = 0.3           Factor KL              KL = 0.2
Corrosion allowance  ca = 0.0 in        Factor K                K = 1.1398
Thickness, T          T = 4.625 in
Rigidity index, J, loose flange type
Gasket seating  J = 109.4 * Ma / (E * T ** 3 * Ln(K) * KL) = -
Operating       J = 109.4 * Mo / (E * T ** 3 * Ln(K) * KL) = -
Rigidity index, J, integral flange type
Gasket seating  J = 52.14 * Ma * V / (L * E * G0 ** 2 * ho * KI) = 0.5708
Operating       J = 52.14 * Mo * V / (L * E * G0 ** 2 * ho * KI) = 0.5971
  ASME appendix 2 calculation of hub thikcness 'go' as a cylinder
Design pressure       P = 50 psi        Allowable stress        S = 12700 psi
Outside radius       OR = 0.0 in        Inside radius          IR = 20.25 in
Joint efficiency      E = 1             Corrosion allowance  c = 0.125 in
  Min 'go' = P * IR / (S * E - 0.6 * P) + c                     UG-27(c)(1)
  Minimum calculated thickness for hub thickness 'go' = 0.0794 in
New hub thickness  'go' = 0.5 in       New hub thickness  'g1' = 0.625 in
Corroded thickness 'go' = 0.5 in
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Feb 18, 2009**
Job	**08-2953**	**Dsgn**	**WZ**
Item	**E-5868**	**Chkd**	KW
		Rev	**0**

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 11:16:15 AM

```
Component:  Nozzle N1 (Shellside 8")
 ASME VIII-1 2007 A08 UG-27 Thickness of Cylinders under Internal Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-312 S31603 Grd TP316L Smls. pipe
Design pressure       P = 50 psi         Design temperature    T = 300 F
Radiography            = Full            Joint efficiency      E = 1
Design stress         S = 12700 psi
Inside corr.allow. cai = 0.0 in          Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0625 in       Minimum thickness tmin = 0.3442 in
Outside diameter     OD = 8.625 in       Corroded radius      OR = 4.3125 in
- Min. thk. not less than UG-45(a), UG-16(b), UG-45(b):
  - UG-45(a) Internal pressure:
              t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.0795 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.096 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.125 in
    UG-45(b) Smaller of:                         t = 0.3442 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.3442 in
      - UG-45(b) Greater of:              t = 0.4985 in
        - UG-45(b)(1)+cai+cao+tol = 0.1607 in
        - UG-45(b)(2)+cai+cao+tol = 0.4985 in
                        Minimum thickness:             tmin = 0.3442 in
                        Nominal thickness:             tnom = 0.5 in
ASME Section VIII-1 2007 A08 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-312 S31603 Grd TP316L Smls. pipe
Design pressure       PE = 15 psi         Design temperature  T = 300 F
Inside corr. allow. CAI = 0 in           Corrosion allow.  CAO = 0 in
Radiography             = Full           Material tol.     Tol = 0.0625 in
Cyl. outside dia.    Do = 8.625 in       Cylinder length EP  L = 12 in (Max.)
Nominal thickness  tnom = 0.5 in         (tnom-CAI-CAO-Tol)  t = 0.4375 in
L/Do ratio          Ldo = 1.3913         Do/t              Dot = 19.7143
(2*S) or (0.9*yield) SE = -              Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.011079       B factor HA-4       B = 11101
Max allowed external pressure: Pa = 4*B / (3*Dot)              = 750.8 psi
Actual external design pressure:                            PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0335 in )
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Feb 18, 2009**
Job	**08-2953**	**Dsgn**	**WZ**
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		Rev	**0**

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 11:16:15 AM

Component: Reinforcement Nozzle N1(Shellside 8")

```
 ASME Section VIII-1 2007 A08 UG-37  Reinforcement Required for Openings in
                                  Shells and Formed Heads
--- Design Conditions:
Int. design pressure PI = 50 psi         Ext. design press.  PE = 15 psi
Design temperature     T = 300 F         Fig.UW-16.1 Sketch (h)
Vessel material: SA-240 S31603 Grd 316L Plate(G5)
Inside corr. allow. CAI = 0.0 in         Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 16700 psi      Joint efficiency      E = 1
Vessel outside dia    Do = 58.0 in       Corroded radius      IR = 28.5 in
Nominal thickness   tnom = 0.5 in        Reinforcement limit lp = 7.625 in
Req. tks. int.pres.   tr = 0.0982 in     Req. tks.ext.pres. tre = 0.436 in
Corroded thickness     t = 0.5 in        Reinf. efficiency    E1 = 1.0
Attachment Material: SA-312 S31603 Grd TP316L Smls. pipe
Inside corr. allow. CAI = 0.0 in         Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 12700 psi      Joint efficiency      E = 1
Nozzle outside dia. Don = 8.625 in       Corroded radius      OR = 4.3125 in
Nominal thickness   tnom = 0.5 in        Reinforcement limit ln = 1.25 in
Req.tks. int.pres.   trn = 0.017 in      Req.tks.ext.pres. trne = 0.0335 in
Corroded thickness    tn = 0.5 in        Nozzle Projection    ha = 0.0 in
                                         Nozzle Proj. used     h = 0.0 in
Reinforcement element material: SA-240 S31603 Grd 316L Plate(G5)
Limit of reinf.       Dp = 12.875 in     Nominal thickness    te = 0.5 in
Outside diameter         = 12.875 in     Design stress        Se = 16700 psi
Minimum weld size tmin   = 0.5 in        Leg size(1/2*tmin)(Act)= 0.375 in
1/2 * tmin (minimum)     = 0.25 in       1/2 * tmin  (actual)    = 0.2625 in
Weld  tw    (minimum)    = 0.35 in       Weld tw     (actual)    = 0.2625 in
Weld  tc    (minimum)    = 0.25 in       Weld tc     (actual)    = 0.2625 in
    smaller |0.25 in    |                Leg size tw (actual)    = 0.375 in
 tc    of   |0.7 * tmin|                 Leg size tc (actual)    = 0.375 in
Outward nozzle weld    L1 = 0.375 in     fr1 = Sn/Sv               = 0.7605
Outer element weld     L2 = 0.375 in     fr2 = Sn/Sv               = 0.7605
Inward nozzle weld     L3 = 0.0 in       fr3 = Sn/Sv or Se/Sv      = 0.7605
Inward nozzel weld new    = 0.0 in       fr4 = Se/Sv               = 1.0
Corroded int.proj.thk ti = 0.0 in
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Feb 18, 2009**
Job	**08-2953**	**Dsgn**	**WZ**
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		Rev	**0**

Heat Exchanger Mechanical Design **Teams 21.0**

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```
 Corroded inside diameter                                    d = 7.625 in
Vessel wall length available for reinforcement    2*Lp-d = 7.625 in
Plane correction factor (Fig.UG-37)                    F = 1.0
Offset distance from centerline                     doff = 0.0 in
Reinforcement areas (internal pressure condition) ASME 2007 A08 UG-37
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 2.9674 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.7073 in2
                                                          A1 = 2.9674 in2
A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t      | = 0.9184 in2
     Smaller of:  | 2*(tn-trn)*(2.5*tn+te)*fr2 | = 1.2857 in2
                                                          A2 = 0.9184 in2
A3 = Nozzle wall inward      | 5*t*ti*fr2   | = 0.0 in2
     Smallest of:            | 5*ti*ti*fr2  | = 0.0 in2
                             | 2*h*ti*fr2   | = 0.0 in2
                                                          A3 = 0.0 in2
A41 = Outward nozzle weld = (L1**2)*fr3 = 0.1069 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.1406 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                          A4 = 0.2476 in2
JE = pad joint efficiency = 0.9
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4*JE       A5 = 1.9125 in2
Aa = Area Available = A1+A2+A3+A4+A5                      Aa = 6.0458 in2
A = Area required    = (d*tr*F)+2*tn*tr*F*(1-fr1)          A = 0.7724 in2
ASME VIII-1 2007 A08 Reinforcement areas (external pressure) UG-37(d)
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.4727 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.1127 in2
                                                          A1 = 0.4727 in2
A2 = Nozzle wall outward  | 5*(tn-trne)*fr2*t   | = 0.8869 in2
     Smaller of:  | 2*(tn-trne)*(2.5*tn+te)*fr2| = 1.2417 in2
                                                          A2 = 0.8869 in2
A3 = Nozzle wall inward      | 5*t*ti*fr2   | = 0.0 in2
     Smallest of:            | 5*ti*ti*fr2  | = 0.0 in2
                             | 2*h*ti*fr2   | = 0.0 in2
                                                          A3 = 0.0 in2
A41 = Outward nozzle weld =   (L1**2)*fr3 = 0.1069 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.1406 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                          A4 = 0.2476 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4          A5 = 1.9125 in2
Aa = Area Available = A1+A2+A3+A4+A5                      Aa = 3.5197 in2
A = Area required    = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))    A = 1.7145 in2
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Feb 18, 2009**
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Heat Exchanger Mechanical Design **Teams 21.0**

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Nozzle attachment weld loads - UG-41 - Strength of reinforcement

```
Total weld load (UG-41(b)(2))
  W = (A-A1+2*tn*fr1(E1*t-F*tr))*Sv                          W = -
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                        W(1-1) = 35441 lbf
Weld load for strength path 2-2 (UG-41(b)(1)
  W(2-2) = (A2+A3+A41+A43+2*tn*t*fr1)*Sv             W(2-2) = 23473 lbf
Weld load for strength path 3-3 (UG-41(b)(1)
  W(3-3) = (A2+A3+A5+A41+A42+A43+2*tn*t*fr1)*Sv      W(3-3) = 41791 lbf
Reinforcing element strength = A5 * Se                      = 15969 lbf
Nozzle attachment weld loads - ASME 2007 UG-41 - Strength of reinforcement
 Unit stresses - UW15(c)and UG-45(c)
    Inner fillet weld shear          =    6223 psi
    Outer fillet weld shear          =    8183 psi
    Groove weld tension              =    9398 psi
    Groove weld shear                =    7620 psi
    Nozzle wall shear                =    8890 psi
 Strength of connection elements
    Inner fillet weld shear          =    31601 lbf
    Nozzle wall shear                =    56702 lbf
    Groove weld tension              =    63631 lbf
    Outer fillet weld shear          =    62029 lbf
 Possible paths of failure
    1-1        56702 + 62029         =    118731 lbf
    2-2        31601 + 63631         =    95232 lbf
    3-3        63631 + 62029         =    125660 lbf
 Welds strong enough if path greater than the smaller of W or W(path)
                           Path 1-1 > W or W11
                         118731 lbf > 35441 lbf                OK
                           Path 2-2 > W or W22
                          95232 lbf > 23473 lbf                OK
                           Path 3-3 > W or W33
                         125660 lbf > 0 lbf
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Jan 23, 2009**
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Heat Exchanger Mechanical Design **Teams 21.0**

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```
Component:  Nozzle N2A/B (Shellside 12")
ASME VIII-1 2007 A08 UG-27 Thickness of Cylinders under Internal Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-312 S31603 Grd TP316L Smls. pipe
Design pressure       P = 50 psi          Design temperature    T = 300 F
Radiography             = Full            Joint efficiency      E = 1
Design stress         S = 12700 psi
Inside corr.allow. cai = 0.0 in           Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0625 in        Minimum thickness tmin = 0.148 in
Outside diameter     OD = 12.75 in        Corroded radius      OR = 6.375 in
- Min. thk. not less than UG-45(a), UG-16(b), UG-45(b):
  - UG-45(a) Internal pressure:
             t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.0876 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol        t = 0.104 in
  - UG-16(b) minimum thickness+cai+cao+tol        t = 0.125 in
    UG-45(b) Smaller of:                          t = 0.148 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.3906 in
      - UG-45(b) Greater of:              t = 0.148 in
        - UG-45(b)(1)+cai+cao+tol = 0.148 in
        - UG-45(b)(2)+cai+cao+tol = 0.0881 in
                      Minimum thickness:              tmin = 0.148 in
                      Nominal thickness:              tnom = 0.5 in
ASME Section VIII-1 2007 A08 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-312 S31603 Grd TP316L Smls. pipe
Design pressure      PE = 15 psi          Design temperature  T = 300 F
Inside corr. allow. CAI = 0 in            Corrosion allow.  CAO = 0 in
Radiography             = Full            Material tol.     Tol = 0.0625 in
Cyl. outside dia.    Do = 12.75 in        Cylinder length EP  L = 12 in (max)
Nominal thickness  tnom = 0.5 in          (tnom-CAI-CAO-Tol)  t = 0.4375 in
L/Do ratio          Ldo = 0.9412          Do/t              Dot = 29.1429
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.009477        B factor HA-4       B = 10913
Max allowed external pressure: Pa = 4*B / (3*Dot)               = 499.29 psi
Actual external design pressure:                           PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0415 in )
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Jan 23, 2009**
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Heat Exchanger Mechanical Design **Teams 21.0**

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Component: Reinforcement Nozzle N2A/B (Shellside 12")

```
ASME Section VIII-1 2007 A08 UG-37  Reinforcement Required for Openings in
                                  Shells and Formed Heads
--- Design Conditions:
Int. design pressure PI = 50 psi        Ext. design press.  PE = 15 psi
Design temperature    T = 300 F         Fig.UW-16.1 Sketch (h)
Vessel material: SA-240 S31603 Grd 316L Plate(G5)
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 16700 psi     Joint efficiency      E = 1
Vessel outside dia   Do = 58.0 in       Corroded radius      IR = 28.5 in
Nominal thickness  tnom = 0.5 in        Reinforcement limit lp = 11.75 in
Req. tks. int.pres.  tr = 0.0855 in     Req. tks.ext.pres. tre = 0.436 in
Corroded thickness    t = 0.5 in        Reinf. efficiency    E1 = 1.0
Attachment Material: SA-312 S31603 Grd TP316L Smls. pipe
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 12700 psi     Joint efficiency      E = 1
Nozzle outside dia. Don = 12.75 in      Corroded radius      OR = 6.375 in
Nominal thickness  tnom = 0.5 in        Reinforcement limit ln = 1.25 in
Req.tks. int.pres.  trn = 0.0251 in     Req.tks.ext.pres. trne = 0.0415 in
Corroded thickness   tn = 0.5 in        Nozzle Projection    ha = 0.0 in
                                        Nozzle Proj. used     h = 0.0 in
Reinforcement element material: SA-240 S31603 Grd 316L Plate(G5)
Limit of reinf.      Dp = 17.0 in       Nominal thickness    te = 0.5 in
Outside diameter        = 17.0 in       Design stress        Se = 16700 psi
Minimum weld size tmin  = 0.5 in        Leg size(1/2*tmin)(Act)= 0.375 in
1/2 * tmin (minimum)    = 0.25 in       1/2 * tmin  (actual)   = 0.2625 in
Weld  tw   (minimum)    = 0.35 in       Weld tw     (actual)   = 0.2625 in
Weld  tc   (minimum)    = 0.25 in       Weld tc     (actual)   = 0.2625 in
    smaller |0.25 in   |                Leg size tw (actual)   = 0.375 in
 tc    of   |0.7 * tmin|                Leg size tc (actual)   = 0.375 in
Outward nozzle weld   L1 = 0.375 in     fr1 = Sn/Sv              = 0.7605
Outer element weld    L2 = 0.375 in     fr2 = Sn/Sv              = 0.7605
Inward nozzle weld    L3 = 0.0 in       fr3 = Sn/Sv or Se/Sv     = 0.7605
Inward nozzel weld new   = 0.0 in       fr4 = Se/Sv              = 1.0
Corroded int.proj.thk ti = 0.0 in
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Jan 23, 2009**
Job	**08-2953**	**Dsgn**	**WZ**
Item	**E-5868**	**Chkd**	KW
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Heat Exchanger Mechanical Design **Teams 21.0**

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```
Corroded inside diameter                                    d = 11.75 in
Vessel wall length available for reinforcement     2*Lp-d = 11.75 in
Plane correction factor (Fig.UG-37)                     F = 1.0
Offset distance from centerline                      doff = 0.0 in
Reinforcement areas (internal pressure condition) ASME 2007 A08 UG-37
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 4.7713 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.7297 in2
                                                          A1 = 4.7713 in2
A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t     | = 0.903 in2
     Smaller of:  | 2*(tn-trn)*(2.5*tn+te)*fr2 | = 1.2641 in2
                                                          A2 = 0.903 in2
A3 = Nozzle wall inward      | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:            | 5*ti*ti*fr2 | = 0.0 in2
                             | 2*h*ti*fr2  | = 0.0 in2
                                                          A3 = 0.0 in2
A41 = Outward nozzle weld = (L1**2)*fr3 = 0.1069 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.1406 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                          A4 = 0.2476 in2
JE = pad joint efficiency = 0.9
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4*JE       A5 = 1.9125 in2
Aa = Area Available = A1+A2+A3+A4+A5                      Aa = 7.8343 in2
A = Area required    = (d*tr*F)+2*tn*tr*F*(1-fr1)          A = 1.0249 in2
ASME VIII-1 2007 A08 Reinforcement areas (external pressure) UG-37(d)
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.7367 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.1127 in2
                                                          A1 = 0.7367 in2
A2 = Nozzle wall outward  | 5*(tn-trne)*fr2*t   | = 0.8717 in2
     Smaller of:  | 2*(tn-trne)*(2.5*tn+te)*fr2| = 1.2204 in2
                                                          A2 = 0.8717 in2
A3 = Nozzle wall inward      | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:            | 5*ti*ti*fr2 | = 0.0 in2
                             | 2*h*ti*fr2  | = 0.0 in2
                                                          A3 = 0.0 in2
A41 = Outward nozzle weld =   (L1**2)*fr3 = 0.1069 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.1406 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                          A4 = 0.2476 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4          A5 = 1.9125 in2
Aa = Area Available = A1+A2+A3+A4+A5                      Aa = 3.7685 in2
A = Area required    = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))    A = 2.6137 in2
```

Nozzle attachment weld loads - UG-41 - Strength of reinforcement

```
-
Total weld load (UG-41(b)(2))
  W = (A-A1+2*tn*fr1(E1*t-F*tr))*Sv                          W = -
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                           W(1-1) = 51153 lbf
Weld load for strength path 2-2 (UG-41(b)(1)
  W(2-2) = (A2+A3+A41+A43+2*tn*t*fr1)*Sv                W(2-2) = 23215 lbf
Weld load for strength path 3-3 (UG-41(b)(1)
  W(3-3) = (A2+A3+A5+A41+A42+A43+2*tn*t*fr1)*Sv         W(3-3) = 57503 lbf
Reinforcing element strength = A5 * Se                         = 31939 lbf
Nozzle attachment weld loads - ASME 2007 A08 UG-41 - Strength of reinforcement
 Unit stresses - UW15(c)and UG-45(c)
    Inner fillet weld shear            =     6223 psi
    Outer fillet weld shear            =     8183 psi
    Groove weld tension                =     9398 psi
    Groove weld shear                  =     7620 psi
    Nozzle wall shear                  =     8890 psi
 Strength of connection elements
    Inner fillet weld shear            =     46714 lbf
    Nozzle wall shear                  =     85489 lbf
    Groove weld tension                =     94063 lbf
    Outer fillet weld shear            =     81902 lbf
 Possible paths of failure
    1-1        85489 + 81902           =     167391 lbf
    2-2        46714 + 94063           =     140777 lbf
    3-3        94063 + 81902           =     175965 lbf
 Welds strong enough if path greater than the smaller of W or W(path)
                           Path 1-1 > W or W11
                         167391 lbf > 51153 lbf                OK
                           Path 2-2 > W or W22
                         140777 lbf > 23215 lbf                OK
                           Path 3-3 > W or W33
                         175965 lbf > 0 lbf
```

For	DPH for Encana FCCL Oil Sands Ltd.	Date	Jan 23, 2009
Job	08-2953	Dsgn	WZ
Item	E-5868	Chkd	KS
		Rev	0

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 11:16:15 AM

```
 Component: Nozzle N3 (Shellside 8")
ASME VIII-1 2007 A08 UG-27 Thickness of Cylinders under Internal Pressure
--- Calculations --- Cylinder Internal Pressure
Material: SA-312 S31603 Grd TP316L Smls. pipe
Design pressure      P = 50 psi          Design temperature   T = 300 F
Radiography            = Full            Joint efficiency     E = 1
Design stress        S = 12700 psi
Inside corr.allow. cai = 0.0 in          Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0625 in       Minimum thickness tmin = 0.3442 in
Outside diameter    OD = 8.625 in        Corroded radius     OR = 4.3125 in
- Min. thk. not less than UG-45(a), UG-16(b), UG-45(b):
  - UG-45(a) Internal pressure:
              t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.0795 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol        t = 0.096 in
  - UG-16(b) minimum thickness+cai+cao+tol        t = 0.125 in
    UG-45(b) Smaller of:                          t = 0.3442 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.3442 in
      - UG-45(b) Greater of:           t = 0.4085 in
        - UG-45(b)(1)+cai+cao+tol = 0.148 in
        - UG-45(b)(2)+cai+cao+tol = 0.4085 in
                        Minimum thickness:              tmin = 0.3442 in
                        Nominal thickness:              tnom = 0.5 in
ASME Section VIII-1 2007 A08 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material: SA-312 S31603 Grd TP316L Smls. pipe
Design pressure     PE = 15 psi          Design temperature  T = 300 F
Inside corr. allow. CAI = 0 in           Corrosion allow.  CAO = 0 in
Radiography            = Full            Material tol.     Tol = 0.0625 in
Cyl. outside dia.   Do = 8.625 in        Cylinder length EP  L = 12 in (MAX.)
Nominal thickness tnom = 0.5 in          (tnom-CAI-CAO-Tol)  t = 0.4375 in
L/Do ratio         Ldo = 1.3913          Do/t              Dot = 19.7143
(2*S) or (0.9*yield) SE = -              Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG  A = 0.011079        B factor HA-4       B = 11101
Max allowed external pressure: Pa = 4*B / (3*Dot)            = 750.8 psi
Actual external design pressure:                          PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0335 in )
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Jan 23, 2009**
Job	**08-2953**	**Dsgn**	**WZ**
Item	**E-5868**	**Chkd**	KW
		Rev	**0**

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 11:16:15 AM

```
Component: Reinforcement Nozzle N3 (Shellside 8")
ASME Section VIII-1 2007 A08 UG-37  Reinforcement Required for Openings in
                               Shells and Formed Heads
--- Design Conditions:
Int. design pressure PI = 50 psi        Ext. design press.  PE = 15 psi
Design temperature    T = 300 F         Fig.UW-16.1 Sketch (h)
Vessel material: SA-240 S31603 Grd 316L Plate(G5)
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 16700 psi     Joint efficiency     E = 1
Vessel outside dia   Do = 58.0 in       Corroded radius     IR = 28.5 in
Nominal thickness  tnom = 0.5 in        Reinforcement limit lp = 7.625 in
Req. tks. int.pres.  tr = 0.0855 in     Req. tks.ext.pres. tre = 0.436 in
Corroded thickness    t = 0.5 in        Reinf. efficiency   E1 = 1.0
Attachment Material: SA-312 S31603 Grd TP316L Smls. pipe
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 12700 psi     Joint efficiency     E = 1
Nozzle outside dia. Don = 8.625 in      Corroded radius     OR = 4.3125 in
Nominal thickness  tnom = 0.5 in        Reinforcement limit ln = 1.25 in
Req.tks. int.pres.  trn = 0.017 in      Req.tks.ext.pres. trne = 0.0335 in
Corroded thickness   tn = 0.5 in        Nozzle Projection   ha = 0.0 in
                                        Nozzle Proj. used    h = 0.0 in
Reinforcement element material: SA-240 S31603 Grd 316L Plate(G5)
Limit of reinf.      Dp = 12.875 in     Nominal thickness   te = 0.5 in
Outside diameter        = 12.875 in     Design stress       Se = 16700 psi
Minimum weld size tmin  = 0.5 in        Leg size(1/2*tmin)(Act)= 0.375 in
1/2 * tmin (minimum)    = 0.25 in       1/2 * tmin  (actual)   = 0.2625 in
Weld  tw   (minimum)    = 0.35 in       Weld tw     (actual)   = 0.2625 in
Weld  tc   (minimum)    = 0.25 in       Weld tc     (actual)   = 0.2625 in
    smaller |0.25 in    |               Leg size tw (actual)   = 0.375 in
 tc    of   |0.7 * tmin|                Leg size tc (actual)   = 0.375 in
Outward nozzle weld   L1 = 0.375 in     fr1 = Sn/Sv              = 0.7605
Outer element weld    L2 = 0.375 in     fr2 = Sn/Sv              = 0.7605
Inward nozzle weld    L3 = 0.0 in       fr3 = Sn/Sv or Se/Sv     = 0.7605
Inward nozzel weld new   = 0.0 in       fr4 = Se/Sv              = 1.0
Corroded int.proj.thk ti = 0.0 in
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Jan 23, 2009**
Job	**08-2953**	**Dsgn**	**WZ**
Item	**E-5868**	**Chkd**	UW
		Rev	**0**

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 11:16:15 AM

```
Corroded inside diameter                                     d = 7.625 in
Vessel wall length available for reinforcement      2*Lp-d = 7.625 in
Plane correction factor (Fig.UG-37)                        F = 1.0
Offset distance from centerline                         doff = 0.0 in
Reinforcement areas (internal pressure condition) ASME 2007 A08 UG-37
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 3.0614 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.7297 in2
                                                            A1 = 3.0614 in2
A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t    | = 0.9184 in2
     Smaller of:  | 2*(tn-trn)*(2.5*tn+te)*fr2 | = 1.2857 in2
                                                            A2 = 0.9184 in2
A3 = Nozzle wall inward    | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:          | 5*ti*ti*fr2 | = 0.0 in2
                           | 2*h*ti*fr2  | = 0.0 in2
                                                            A3 = 0.0 in2
A41 = Outward nozzle weld = (L1**2)*fr3 = 0.1069 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.1406 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                            A4 = 0.2476 in2
JE = pad joint efficiency = 0.9
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4*JE         A5 = 1.9125 in2
Aa = Area Available = A1+A2+A3+A4+A5                        Aa = 6.1398 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-fr1)             A = 0.6723 in2
ASME VIII-1 2007 A08 Reinforcement areas (external pressure) UG-37(d)
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.4727 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.1127 in2
                                                            A1 = 0.4727 in2
A2 = Nozzle wall outward  | 5*(tn-trne)*fr2*t   | = 0.8869 in2
     Smaller of:  | 2*(tn-trne)*(2.5*tn+te)*fr2| = 1.2417 in2
                                                            A2 = 0.8869 in2
A3 = Nozzle wall inward    | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:          | 5*ti*ti*fr2 | = 0.0 in2
                           | 2*h*ti*fr2  | = 0.0 in2
                                                            A3 = 0.0 in2
A41 = Outward nozzle weld =   (L1**2)*fr3 = 0.1069 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.1406 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                            A4 = 0.2476 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4            A5 = 1.9125 in2
Aa = Area Available = A1+A2+A3+A4+A5                        Aa = 3.5197 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))       A = 1.7145 in2
```

For	DPH for Encana FCCL Oil Sands Ltd.	Date	Jan 23, 2009
Job	08-2953	Dsgn	WZ
Item	E-5868	Chkd	KJ
		Rev	0

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 11:16:15 AM

```
Nozzle attachment weld loads - UG-41 - Strength of reinforcement
 -
Total weld load (UG-41(b)(2))
 W = (A-A1+2*tn*fr1(E1*t-F*tr))*Sv                          W = -
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                         W(1-1) = 51410 lbf
Weld load for strength path 2-2 (UG-41(b)(1)
  W(2-2) = (A2+A3+A41+A43+2*tn*t*fr1)*Sv              W(2-2) = 23473 lbf
Weld load for strength path 3-3 (UG-41(b)(1)
  W(3-3) = (A2+A3+A5+A41+A42+A43+2*tn*t*fr1)*Sv       W(3-3) = 57760 lbf
Reinforcing element strength = A5 * Se                       = 31939 lbf
Nozzle attachment weld loads - ASME 2007 A08 UG-41 - Strength of reinforcement
 Unit stresses - UW15(c)and UG-45(c)
    Inner fillet weld shear          =    6223 psi
    Outer fillet weld shear          =    8183 psi
    Groove weld tension              =    9398 psi
    Groove weld shear                =    7620 psi
    Nozzle wall shear                =    8890 psi
 Strength of connection elements
    Inner fillet weld shear          =    31601 lbf
    Nozzle wall shear                =    56702 lbf
    Groove weld tension              =    63631 lbf
    Outer fillet weld shear          =    62029 lbf
 Possible paths of failure
    1-1        56702 + 62029         =    118731 lbf
    2-2        31601 + 63631         =    95232 lbf
    3-3        63631 + 62029         =    125660 lbf
 Welds strong enough if path greater than the smaller of W or W(path)
                             Path 1-1 > W or W11
                           118731 lbf > 51410 lbf              OK
                             Path 2-2 > W or W22
                            95232 lbf > 23473 lbf              OK
                             Path 3-3 > W or W33
                           125660 lbf > 0 lbf
```

For	DPH for Encana FCCL Oil Sands Ltd.	Date	Oct 27, 2008
Job	08-2953	Dsgn	WZ
Item	E-5868	Chkd	KY
		Rev	0

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 11:16:15 AM

```
Component:  Nozzle N4 / N5 (Tubeside 8")
ASME VIII-1 2007 UG-27 Thickness of Cylinders under Internal Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-333 K03006 Grd 6 Smls. pipe
Design pressure      P = 334 psi        Design temperature    T = 399 F
Radiography            = Full           Joint efficiency      E = 1
Design stress        S = 17100 psi
Inside corr.allow. cai = 0.125 in       Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0625 in      Minimum thickness tmin = 0.4692 in
Outside diameter    OD = 8.625 in       Corroded radius     OR = 4.3125 in
- Min. thk. not less than UG-45(a), UG-16(b), UG-45(b):
  - UG-45(a) Internal pressure:
              t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.2711 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol        t = 0.221 in
  - UG-16(b) minimum thickness+cai+cao+tol        t = 0.25 in
    UG-45(b) Smaller of:                          t = 0.4692 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.4692 in
      - UG-45(b) Greater of:              t = 0.5291 in
        - UG-45(b)(1)+cai+cao+tol = 0.5291 in
        - UG-45(b)(2)+cai+cao+tol = 0 in
                        Minimum thickness:              tmin = 0.4692 in
                        Nominal thickness:              tnom = 0.5 in
```

For	DPH for Encana FCCL Oil Sands Ltd.	Date	Oct 27, 2008
Job	08-2953	Dsgn	WZ
Item	E-5868	Chkd	KW
		Rev	0

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 11:16:15 AM

```
Component: Reinforcement Nozzle N4 / N5 (Tubeside 8")
ASME Section VIII-1 2007 UG-37  Reinforcement Required for Openings in
                                Shells and Formed Heads
--- Design Conditions:
Int. design pressure PI = 334 psi       Ext. design press.  PE = 0 psi
Design temperature    T = 399 F         Fig.UW-16.1 Sketch (h)
Vessel material: SA-516 K02700 Grd 70 Plate
Inside corr. allow. CAI = 0.125 in      Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 20000 psi     Joint efficiency     E = 1
Vessel outside dia   Do = 41.25 in      Corroded radius     IR = 20.25 in
Nominal thickness  tnom = 0.5 in        Reinforcement limit lp = 7.875 in
Req. tks. int.pres.  tr = 0.3416 in     Req. tks.ext.pres. tre = 0.0 in
Corroded thickness    t = 0.375 in      Reinf. efficiency   E1 = 1.0
Attachment Material: SA-333 K03006 Grd 6 Smls. pipe
Inside corr. allow. CAI = 0.125 in      Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 17100 psi     Joint efficiency     E = 1
Nozzle outside dia. Don = 8.625 in      Corroded radius     OR = 4.3125 in
Nominal thickness  tnom = 0.5 in        Reinforcement limit ln = 0.9375 in
Req.tks. int.pres.  trn = 0.0836 in     Req.tks.ext.pres. trne = 0.0 in
Corroded thickness   tn = 0.375 in      Nozzle Projection   ha = 0.0 in
                                        Nozzle Proj. used    h = 0.0 in
Reinforcement element material: SA-516 K02700 Grd 70 Plate
Limit of reinf.      Dp = 12.875 in     Nominal thickness   te = 0.5 in (JE = 0.9 for A5)
Outside diameter        = 12.875 in     Design stress       Se = 20000 psi
Minimum weld size tmin  = 0.375 in      Leg size(1/2*tmin)(Act)= 0.375 in
1/2 * tmin (minimum)    = 0.1875 in     1/2 * tmin  (actual)   = 0.2625 in
Weld  tw   (minimum)    = 0.2625 in     Weld tw     (actual)   = 0.2625 in
Weld  tc   (minimum)    = 0.25 in       Weld tc     (actual)   = 0.2625 in
    smaller |0.25 in    |               Leg size tw (actual)   = 0.375 in
 tc    of   |0.7 * tmin|                Leg size tc (actual)   = 0.375 in
Outward nozzle weld   L1 = 0.375 in     fr1 = Sn/Sv              = 0.855
Outer element weld    L2 = 0.375 in     fr2 = Sn/Sv              = 0.855
Inward nozzle weld    L3 = 0.0 in       fr3 = Sn/Sv or Se/Sv     = 0.855
Inward nozzel weld new   = 0.0 in       fr4 = Se/Sv              = 1.0
Corroded int.proj.thk ti = 0.0 in
```

For	**DPH for Encana FCCL Oil Sands Ltd.**	**Date**	**Oct 27, 2008**
Job	**08-2953**	**Dsgn**	**WZ**
Item	**E-5868**	**Chkd**	KW
		Rev	**0**

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 11:16:15 AM

```
Reinforcement areas (internal pressure) Offset distance   doff = 5.0625 in
A1  = Vessel wall.  Larger of:
      |(2*Lp-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)|
      |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)|
A2  = Nozzle wall outward     | 5*(tn-trn)*fr2*t|
      Smaller of: | 2*(tn-trn)*(2.5*tn+te)*fr2 |   A2 = 0.4672 in2
A3  = Nozzle wall inward   | 5*t*ti*fr2 |
      Smallest of:         | 5*ti*ti*fr2|          A3 = 0.0 in2
                           | 2*h*ti*fr2 |
A41 = Outward nozzle weld = (L1**2)*fr3          A41 = 0.1202 in2
A42 = Outer element weld  = (L2**2)*fr4          A42 = 0.1406 in2
A43 = Inward nozzle weld  = (L3**2)*fr2          A43 = 0.0 in2
      Plane Direction:              Circumferential     Longitudinal
                                 Diameter d = 8.1398 in     d = 7.875 in
                                   Factor F = 1.0           F = 1.0
                                   Limit Dp = 13.1875 in   Dp = 12.875 in
                                   Limit Lp = 8.1398 in    Lp = 7.875 in
A1  = Vessel wall                        A1 = 0.2683 in2   A1 = 0.2594 in2
A5  = Repad Area = (Dp-d-2*tn)*te*fr4    A5 = 1.934 in2    A5 = 1.9125 in2
Aa  = Area Available = A1+A2+A3+A4+A5    Aa = 2.9303 in2   Aa = 2.9 in2
A   = Required = d*tr*F+2*tn*tr*F*(1-fr1) Ar = 2.8177 in2  Ar = 2.7272 in2
```

For	DPH for Encana FCCL Oil Sands Ltd.	Date	Oct 27, 2008
Job	08-2953	Dsgn	WZ
Item	E-5868	Chkd	KW
		Rev	0

Heat Exchanger Mechanical Design **Teams 21.0**

File name: 2953-1.BJT Date: 27/10/2008 Time: 11:16:15 AM

Nozzle attachment weld loads - UG-41 - Strength of reinforcement

```
Total weld load (UG-41(b)(2))
  W = (A-A1+2*tn*fr1(E1*t-F*tr))*Sv                        W = 51594 lbf
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                         W(1-1) = 52811 lbf
Weld load for strength path 2-2 (UG-41(b)(1)
  W(2-2) = (A2+A3+A41+A43+2*tn*t*fr1)*Sv              W(2-2) = 16558 lbf
Weld load for strength path 3-3 (UG-41(b)(1)
  W(3-3) = (A2+A3+A5+A41+A42+A43+2*tn*t*fr1)*Sv       W(3-3) = 57620 lbf
Reinforcing element strength = A5 * Se                       = 38250 lbf
Nozzle attachment weld loads - ASME 2007 UG-41 - Strength of reinforcement
 Unit stresses - UW15(c)and UG-45(c)
    Inner fillet weld shear          =    8379 psi
    Outer fillet weld shear          =    9800 psi
    Groove weld tension              =    12654 psi
    Groove weld shear                =    10260 psi
    Nozzle wall shear                =    11970 psi
 Strength of connection elements
    Inner fillet weld shear          =    42549 lbf
    Nozzle wall shear                =    58141 lbf
    Groove weld tension              =    64257 lbf
    Outer fillet weld shear          =    74286 lbf
 Possible paths of failure
    1-1        58141 + 74286         =    132427 lbf
    2-2        42549 + 64257         =    106806 lbf
    3-3        64257 + 74286         =    138543 lbf
 Welds strong enough if path greater than the smaller of W or W(path)
                           Path 1-1 > W or W11
                         132427 lbf > 51594 lbf              OK
                           Path 2-2 > W or W22
                         106806 lbf > 16558 lbf              OK
                           Path 3-3 > W or W33
                         138543 lbf > 51594 lbf              OK
```

EXCHANGER INDUSTRIES

Horizontal Saddle Calculation (L.P. Zick)

44-V2.03
Date January 23, 2009
Dsgn WZ
Chkd KW
File (.ZCK) 2953
Rev 0

For DPH for Encana FCCL Oil Sands Ltd
Job 08-2953
Item E-5868

Material SA-240-316L

Allowable Stress	16,700 psi	Span Between Saddles	242.125 inch
Elasticity (7)	27 x10^6 psi	Over Hang (1)	74.875 inch
Compressive Stress	7,624 psi	Head Depth (2)	5.625 inch
Design Temperature	300 °F	Saddle Web thickness	0.5 inch
Internal Pressure	50 psi	Support Length (4)	58 inch
Shell Type	Rolled Can	Saddle Width (5)	6 inch
Shell OD	58 inch		
Shell Thickness	0.5 inch	Unit Weight (6)	89,300 lbs
Head Thickness (3)	4.625 inch	Repad Thickness	0.25 inch
Corrosion	0 inch	Stiffening Ring	Not Included
Joint Efficiency	1	Seismic Load Wind Load	N/A

Stress Type / Location		Stress	Allowable
Bending at Saddle	Tension	3,584	16,700 psi
	Compression	155	-7,624 psi
Bending at Midspan	Tension	2,203	16,700 psi
	Compression	697	-7,624 psi
Tangential Shear at Shell		718	13,360 psi
Circumferential at Bottom of Shell		-4,780	-7,624 psi
	Horn of Saddle	-5,558	-25,050 psi
Horizontal Force (F = 14,199 lbs)		2,938	11,133 psi

Minimum Repad Size: Length
Width 8 inch

NOTES:

1) Heads, Tubesheets or Flanges act as lines of support. Do not include length beyond these items.
2) Use the depth of heads, thickness of TS or length of flanges.
3) Use the thickness of heads, TS or flanges.
4) Saddle Support Length is the horizontal projection of the line of contact between saddle and shell.
5) Saddle width includes gussets but not pads.
6) Use full unit weight as standard or use double the saddle reaction for special calculations.
7) Use the Elastic Modulus at operating condition.
8) Unit Weight = 2 * Max.Saddle Loads

Saddle Ear Lifting Lug Calculation

For	DPH for Encana FCCL Oil Sands Ltd	Date	January 23, 2009
Job	08-2953	Dsgn	WZ
Item	E-5868	Chkd	KW
		File	2953
		Rev	0

Lift Ear Material SA-516-70 N

Allowable Stress Cold	20,000	psi	Allowable Based on 1.5 shock factor per TEMA and Code Stress
Yield Stress	38,000	psi	
Design Load	15,300	lb	Maximum vertical load per ear. Includes Shock Factor
Shackle Pin Diameter	1 3/8	inch	(4 total) Load based on symetrical unit
Pin Hole Diameter	1 1/2	inch	Repad Thickness 0.25 inch c/w 3/16 Weld
Ear Outside Radius	2.75	inch	Double Repad Each side identical
Shell OD	58	inch	Pad Radius 2 1/2 inch. 4 1/4 inch below pin. A2
			Minimum Web Width below pad 1 3/4 inch
Distance Between Pin	69.5	inch (C-C)	
Ear Thickness	0.5	inch	
Insulation Thickness	2.5	inch	
Overall Saddle Width	75	inch (Outside of ear)	

Local Stress over half the pin diameter at Pin Hole = 11,754 psi (31% of yield)

Min / max outside radius of ear from center of pin A1 = 1.88 / 2.97 inch

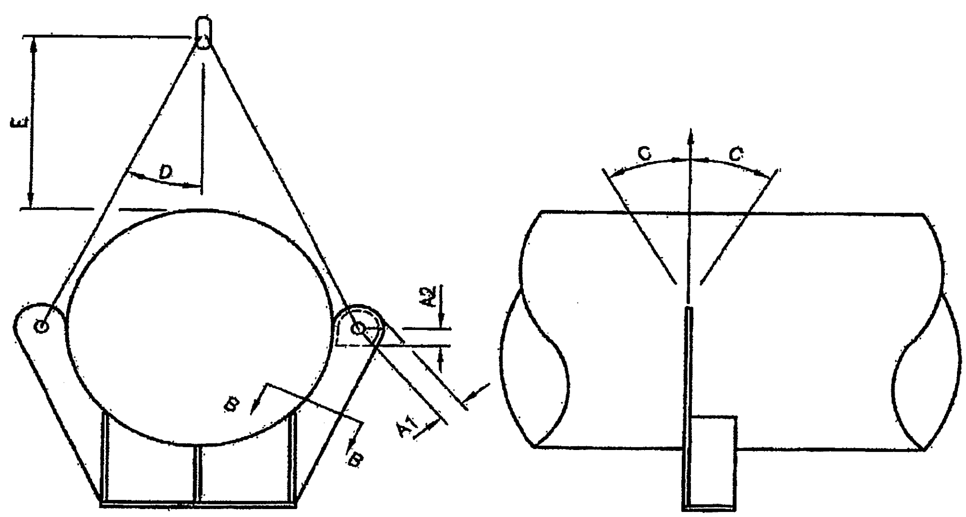
Minimum cross section of web below repads B = 0.7650 Sq in

Maximum off vertical for spreader bar (longitudinal view) C = 5.3 degree (1.10"/ft) (50% yield at pin)

Maximum sling half angle (circumferential view) D = 18.8 degree

Minimum distance from sling link to outside of insulation E = 5.7 ft (to clear by ½ pin dia.)

Minimum shackle and rope strength = 8.5 Ton



For	DPH for Encana FCCL Oil Sands Ltd.	Date	Oct 28, 2008
Job	08-2953	Dsgn	WZ
Item	E-5868	Chkd	WZ
		Rev	0

Heat Exchanger Mechanical Design — Teams 21.0

File name: 2953-1.BJT Date: 28/10/2008 Time: 9:01:16 AM

Maximum Allowable Working Pressures
* = Shell Side MAWP + = Tube Side MAWP

Component	Side	Design conditions Temp F	Design conditions Stress psi	Design conditions MAWP psi	New and cold Temp F	New and cold Stress psi	New and cold MAWP psi
Front Head Cylinder	T	399	20000	366.3	70	20000	486.6
Front Head Cover	T	399	20000	492.5	70	20000	615.3
Shell Cover	S	300	16700	292.4	70	16700	292.4
Front Tubesheet	S	399	15710	392.9	70	16700	445
Front Tubesheet	T	399	15710	392.9	70	16700	445
Front Head Flng At TS	T	399	20000	334+	70	20000	336+
Front Shell Flng	S	300	12700	50*	70	16700	56*
Tubes	T	399	20308	3782.3	70	21900	4078.8
Nozzle N1	S	300	12700	253.5	70	16700	253.5
Nozzle N2	S	300	12700	510	70	16700	510
Nozzle N3	S	300	12700	253.5	70	16700	253.5
Nozzle N4	T	399	17100	1276.1	70	17100	1808.2
Nozzle N5	T	399	17100	1276.1	70	17100	1808.2
Nozzle Flng N1	S	300	12700	175	70	16700	230
Nozzle Flng N2	S	300	12700	175	70	16700	230
Nozzle Flng N3	S	300	12700	175	70	16700	230
Nozzle Flng N4	T	399	20000	635.2	70	20000	740
Nozzle Flng N5	T	399	20000	635.2	70	20000	740
Nozzle Reinforcement N1	S	300	16700	120	70	16700	128
Nozzle Reinforcement N2	S	300	-	104	70	-	115
Nozzle Reinforcement N3	S	300	16700	120	70	16700	128
Nozzle Reinforcement N4	T	399	20000	336	70	20000	400
Nozzle Reinforcement N5	T	399	20000	336	70	20000	400
Front Hd Bolting At TS	T	399	20000	339.1	70	20000	339.1
Front Hd Bolting At TS	S	399	20000	354.4	70	20000	354.4
Eccentric Reducer	S	300	16700	252.7	70	16700	252.7
Kettle Cylinder	S	300	16700	289.9	70	16700	289.9

Hydrostatic Test Pressure - ASME VIII-1 2007 UG-99(b) Factor: 1.3

Shop @ 1.3* New and cold MAWP: Shell Side: 72.8 psi Tube Side: 436.8 psi
Field Shell Side: 65 psi Tube Side: 434.2 psi

Component	Material	Side	Design Temp F	Design Stress psi	Test Stress psi	Stress Ratio
Front Head Cylinder	SA-516 K02700 Grd 70 Plate	T	399	20000	20000	1+
Shell Cover	SA-240 S31603 Grd 316L Pla	S	300	16700	16700	1*
Front Tubesheet	SA-240 S31603 Grd 316L Pla	S	399	15710	16700	1.063
Front Head Flng At TS	SA-350 K03011 Grd LF2 Cls	T	399	20000	20000	1
Front Shell Flng	SA-182 S31603 Grd F316L Fo	S	300	12700	16700	1.315
Tubes	SA-789 S31803 Wld. tube	T	399	20308	21900	1.0784
Nozzle N2	SA-312 S31603 Grd TP316L S	S	300	12700	16700	1.315
Nozzle N4	SA-333 K03006 Grd 6 Smls.	T	399	17100	17100	1
Nozzle Flng N2	SA-182 S31603 Grd F316L Fo	S	300	12700	16700	1.315
Nozzle Flng N4	SA-350 K03011 Grd LF2 Cls	T	399	20000	20000	1
Nozzle Reinforcement N1	SA-240 S31603 Grd 316L Pla	S	300	16700	16700	1
Nozzle Reinforcement N4	SA-516 K02700 Grd 70 Plate	T	399	20000	20000	1
Front Hd Bolting At TS	SA-193 G41400 Grd B7M Bolt	T	399	20000	20000	1
Eccentric Reducer	SA-240 S31603 Grd 316L Pla	S	300	16700	16700	1
Kettle Cylinder	SA-240 S31603 Grd 316L Pla	S	300	16700	16700	1

CodeCalc (TM) - Design and Analysis of Vessels and Exchangers. VER 4.0 (Convert to Excel Sept 27,2000)
Local Stresses in Cylindrical Shells per WRC107 (Bijlaard Analysis).

Stress at 99% of Allowable | NOTES

Vessel				Item : E-5868
Component	N1 / N3 8 " 150# on Shellside			
Designer	WZ	Loads Per Spec	Job: 08-2953	
Date and Time	December 16, 2008	01:21 PM	FILE NAME : 2953	

RM	Mean Radius of Vessel Wall	in	28.75	(1)
TH	Thickness of Vessel Wall	in	0.5	
TYPE	Attachment Type (Round, Square, or Rectangle)		ROUND	
RO	Outside Radius of Round Attachment	in	4.3125	
C#1	Half of Rectangle in Circ. Direction	in	0	
C#2	Half of Rectangle in Long. Direction	in	0	
SA	Allowable Stress in Shell	psi	16700	
DP	Design Pressure	psi	50	(2)
P	Radial Load	Lbs	1210	
VC	Circumferential Shear Load	Lbs	1480	
VL	Longitudinal Shear Load	Lbs	1480	
MT	Torsional Moment	in-Lb	66840	
MC	Circumferential Moment	in-Lb	47280	
ML	Longitudinal Moment	in-Lb	47280	

Geometric Parameter, Gamma	57.5000	(3)
Geometric Parameter, Beta	0.1313	(4)

Circumferential (hoop) Stresses in Vessel Shell, psi: (5)

At Point-->	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
DP, Mem	2850	2850	2850	2850	2850	2850	2850	2850
P, Mem	-757	-757	-757	-757	-627	-627	-627	-627
P, Ben	-1581	1581	-1581	1581	-2501	2501	-2501	2501
MC, Mem	-	-	-	-	-1907	-1907	1907	1907
MC, Ben	-	-	-	-	-24454	24454	24454	-24454
ML, Mem	-5498	-5498	5498	5498	-	-	-	-
ML, Ben	-10245	10245	10245	-10245	-	-	-	-
Total	-15231	8422	16255	-1074	-26639	27272	26083	-17823

Longitudinal (axial) Stresses in Vessel Shell, psi: (6)

At Point-->	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
DP, Mem	1425	1425	1425	1425	1425	1425	1425	1425
P, Mem	-627	-627	-627	-627	-757	-757	-757	-757
P, Ben	-2569	2569	-2569	2569	-1568	1568	-1568	1568
MC, Mem	-	-	-	-	-3228	-3228	3228	3228
MC, Ben	-	-	-	-	-13104	13104	13104	-13104
ML, Mem	-1874	-1874	1874	1874	-	-	-	-
ML, Ben	-14666	14666	14666	-14666	-	-	-	-
Total	-18311	16160	14770	-9425	-17232	12112	15432	-7639

Shear Stresses in Vessel Shell, psi:

At Point-->	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
MT, Mem	1144	1144	1144	1144	1144	1144	1144	1144
VC, Mem	218	218	-218	-218	0	0	0	0
VL, Mem	0	0	0	0	-218	-218	218	218
Total	1362	1362	926	926	926	926	1362	1362

Total Stress Intensity, psi: (7)

At Point-->	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	18828	16392	16699	9526	26729	27328	26255	18002

CodeCalc (TM) -.Design and Analysis of Vessels and Exchangers. VER 4.0 (Convert to Excel Sept 27,2000)
Local Stresses in Cylindrical Shells per WRC107 (Bijlaard Analysis).

Stress at 63% of Allowable

NOTES

Vessel				Item : E-5868
Component	N2A/B 12 " 150# on Shellside			
Designer	WZ	Loads Per Spec	Job: 08-2953	
Date and Time	December.16, 2008	01:19 PM	FILE NAME :	2953

RM	Mean Radius of Vessel Wall	in	28.75	(1)
TH	Thickness of Vessel Wall	in	0.5	
TYPE	Attachment Type (Round, Square, or Rectangle)		ROUND	
RO	Outside Radius of Round Attachment	in	6.375	
C#1	Half of Rectangle in Circ. Direction	in	0	
C#2	Half of Rectangle in Long. Direction	in	0	
SA	Allowable Stress in Shell	psi	16700	
DP	Design Pressure	psi	50	(2)
P	Radial Load	Lbs	1480	
VC	Circumferential Shear Load	Lbs	1810	
VL	Longitudinal Shear Load	Lbs	1810	
MT	Torsional Moment	in-Lb	74640	
MC	Circumferential Moment	in-Lb	52800	
ML	Longitudinal Moment	in-Lb	52800	
	Geometric Parameter, Gamma		57.5000	(3)
	Geometric Parameter, Beta		0.1940	(4)

Circumferential (hoop) Stresses in Vessel Shell, psi: (5)

At Point-->	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
DP, Mem	2850	2850	2850	2850	2850	2850	2850	2850
P, Mem	-783	-783	-783	-783	-484	-484	-484	-484
P, Ben	-997	997	-997	997	-2134	2134	-2134	2134
MC, Mem	-	-	-	-	-1472	-1472	1472	1472
MC, Ben	-	-	-	-	-15589	15589	15589	-15589
ML, Mem	-3620	-3620	3620	3620	-	-	-	-
ML, Ben	-4729	4729	4729	-4729	-	-	-	-
Total	-7279	4172	9418	1955	-16829	18618	17293	-9616

Longitudinal (axial) Stresses in Vessel Shell, psi: (6)

At Point-->	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
DP, Mem	1425	1425	1425	1425	1425	1425	1425	1425
P, Mem	-484	-484	-484	-484	-783	-783	-783	-783
P, Ben	-2054	2054	-2054	2054	-1123	1123	-1123	1123
MC, Mem	-	-	-	-	-3168	-3168	3168	3168
MC, Ben	-	-	-	-	-7479	7479	7479	-7479
ML, Mem	-1530	-1530	1530	1530	-	-	-	-
ML, Ben	-7077	7077	7077	-7077	-	-	-	-
Total	-9719	8542	7494	-2551	-11128	6075	10166	-2546

Shear Stresses in Vessel Shell, psi:

At Point-->	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
MT, Mem	585	585	585	585	585	585	585	585
VC, Mem	181	181	-181	-181	0	0	0	0
VL, Mem	0	0	0	0	-181	-181	181	181
Total	765	765	404	404	404	404	765	765

Total Stress Intensity, psi: (7)

At Point-->	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	9939	8672	9500	4578	16857	18631	17374	9698

Tabular Results

Results were generated with the finite element program PE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Tue Dec 16 13:36:28 2008.

Model Notes

Input Echo:

Description:

```
        08-2953
        Tube Side 8"  300# Nozzle N4/N5
        Thickness are corroded

Model Type                     : Cylindrical Shell

Parent Outside Diameter        :      41.250 in.
        Thickness              :       0.375 in.
        Fillet Along Shell     :       0.375 in.

        Parent Properties:
        Cold Allowable         :     20000.0 psi
        Hot  Allowable         :     20000.0 psi
        Material ID #1         :  Low Carbon Steel
        Elastic Modulus (Amb)  :  29200000.0 psi
        Poissons Ratio         :       0.300
        Expansion Coefficient  :  0.6430E-05 in./in./deg.

Hillside Offset Distance       :       5.062 in.

Nozzle Outside Diameter        :       8.625 in.
        Thickness              :       0.375 in.
        Length                 :      10.000 in.
        Nozzle Weld Length     :       0.375 in.
        RePad Width            :       2.000 in.
        RePad Thickness        :       0.500 in.
        RePad Weld Leg         :       0.375 in.
        Nozzle Tilt Angle      :       0.000 deg.
        Distance from Top      :       8.500 in.
        Distance from Bottom   :       8.500 in.

        Nozzle Properties
        Cold Allowable         :     17100.0 psi
        Hot  Allowable         :     17100.0 psi
        Material ID #1         :  Low Carbon Steel
        Elastic Modulus (Amb)  :  29200000.0 psi
```

Poissons Ratio : 0.300
Expansion Coefficient : 0.6590E-05 in./in./deg.

Design Operating Cycles : 7000.
Ambient Temperature (Deg.) : 70.00
Nozzle Pressure : 334.0 psi
Vessel Pressure : 334.0 psi

User Defined Load Input Echo:
Loads are given at the End of Nozzle
Loads are defined in Global Coordinates

Forces(lb.) Moments(ft-lb

Load Case	FX	FY	FZ	MX	MY	MZ
OPER:	1670.0	1360.0	1670.0	4170.0	5900.0	4170.0

FEA Model Loads:
These are the actual loads applied to the FEA model.
These are the User Defined Loads translated to the
end of the nozzle and reported in global coordinates.

Forces(lb.) Moments(ft-lb

Load Case	FX	FY	FZ	MX	MY	MZ
OPER:	1670.0	1360.0	1670.0	4170.0	5900.0	4170.0

Both ends of the model are "fixed," except that one end
is free axially so that longitudinal pressure stresses
may be developed in the geometry.

Stresses ARE nodally AVERAGED.

The cylinder length or nozzle/branch location was adjusted
so that a better mesh could be generated at each end of the
cylinder. The nozzle is now located 9.46 in.
down the length of the cylinder and the total cylinder length
is 18.91 in.

Vessel Centerline Vector : 1.000 0.000 0.000
Nozzle Orientation Vector : 0.000 1.000 0.000

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Load Case Report

Inner and outer element temperatures are the same
throughout the model. No thermal ratcheting
calculations will be performed.

THE 7 LOAD CASES ANALYZED ARE:

1 Sustained

Sustained case run to satisfy Pl<1.5Sm limit, and
Qb, the bending stress due to primary loads must
be less than 3Smh as per Note 3 of Fig. NB-3222-1,
and Table 4-120.1

/-------- Loads in Case 1
Pressure Case 1

2 Operating (Fatigue Calc Performed)

Operating case run to compute the extreme operating
stress state to be used in the shakedown and peak
stress calculations.

```
    /-------- Loads in Case   2
    Pressure Case    1
    Force Case (Operating)

3   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.

    /-------- Loads in Case   3
    Force Case (Axial)

4   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.

    /-------- Loads in Case   4
    Force Case (Inplane)

5   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.

    /-------- Loads in Case   5
    Force Case (Outplane)

6   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.

    /-------- Loads in Case   6
    Force Case (Torsion)

7   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.

    /-------- Loads in Case   7
    Pressure Case    1
```

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```
Solution Data

Maximum Solution Row Size =    636
Number of Nodes           =   2243
Number of Elements        =    708
Number of Solution Cases  =      7

Largest On-Diagonal Stiffness   =    477742165753.
Smallest On-Diagonal Stiffness  =               6.

Largest Off-Diagonal Stiffness  =    211671477394.
Smallest Off-Diagonal Stiffness =               1.
```

Summation of Loads per Case

Case #	FX	FY	FZ
1	430272.	-1585.	0.
2	431942.	-225.	1670.
3	0.	219098.	0.
4	0.	0.	0.
5	0.	0.	0.
6	0.	0.	0.
7	430272.	-1585.	0.

Equation Coefficient (Stiffness) Distribution)

OnDiagonal Percentile	Number of Coefficients	Average Stiffness
90-to-100%	24	474730838550.
70-to-90%	0	0.
50-to-70%	28	250400786795.
30-to-50%	188	185787757453.
10-to-30%	120	123889275985.
1-to-10%	156	12437688174.
.1-to- 1%	168	2977827201.
.01-to-.1%	2175	103912569.
.001-to-.01%	6271	23849020.
.0001-TO-.001%	4328	1617464.

OFF Diagonal Percentile	Number of Coefficients	Average Stiffness
90-to-100%	48	209930099386.
70-to-90%	0	0.
50-to-70%	0	0.
30-to-50%	228	84375206176.
10-to-30%	1580	37062166950.
1-to-10%	6408	6273051558.
.1-to- 1%	6399	908276128.
.01-to-.1%	9157	68253948.
.001-to-.01%	72878	5707496.
.0001-TO-.001%	504160	299208.

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ASME Code Stress Output Plots

1) Pl < 1.5(k)Smh (SUS,Membrane) Case 1
2) Qb < 3(Smh) (SUS,Bending) Case 1
3) Pl+Pb+Q < 3(Smavg) (OPE,Inside) Case 2
4) Pl+Pb+Q < 3(Smavg) (OPE,Outside) Case 2
5) Pl+Pb+Q+F < Sa (EXP,Inside) Case 2
6) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2
7) Pl+Pb+Q+F < Sa (SIF,Outside) Case 3
8) Pl+Pb+Q+F < Sa (SIF,Outside) Case 4
9) Pl+Pb+Q+F < Sa (SIF,Outside) Case 5
10) Pl+Pb+Q+F < Sa (SIF,Outside) Case 6
11) Pl+Pb+Q+F < Sa (SIF,Outside) Case 7

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ASME Overstressed Areas

*** NO OVERSTRESSED NODES IN THIS MODEL ***

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Highest Primary Stress Ratios

Header/Pad at Junction

Pl	1.5(k)Smh	Primary Membrane Load Case 1
16,695	30,000	Plot Reference:
psi	psi	1) Pl < 1.5(k)Smh (SUS, Membrane) Case 1

55%

Branch at Junction

Qb	3(Smh)	Primary Bending Load Case 1
21,269	51,300	Plot Reference:
psi	psi	2) Qb < 3(Smh) (SUS, Bending) Case 1

41%

Branch Transition

Pl	1.5(k)Smh	Primary Membrane Load Case 1
6,548	25,650	Plot Reference:
psi	psi	1) Pl < 1.5(k)Smh (SUS, Membrane) Case 1

25%

Pad Outer Edge Weld

Pl	1.5(k)Smh	Primary Membrane Load Case 1
22,674	30,000	Plot Reference:
psi	psi	1) Pl < 1.5(k)Smh (SUS, Membrane) Case 1

75%

Header/Pad removed from Junction

Pl	1.5(k)Smh	Primary Membrane Load Case 1
26,799	30,000	Plot Reference:
psi	psi	1) Pl < 1.5(k)Smh (SUS, Membrane) Case 1

89%

Branch removed from Junction

Pl	1.5(k)Smh	Primary Membrane Load Case 1
6,633	25,650	Plot Reference:
psi	psi	1) Pl < 1.5(k)Smh (SUS, Membrane) Case 1

25%

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Highest Secondary Stress Ratios

Header/Pad at Junction

Pl+Pb+Q	3(Smavg)	Primary+Secondary (Inner) Load Case 2
34,441	60,000	Plot Reference:
psi	psi	3) Pl+Pb+Q < 3(Smavg) (OPE, Inside) Case 2

57%

Branch at Junction

Pl+Pb+Q	3(Smavg)	Primary+Secondary (Outer) Load Case 2

45,449	51,300	Plot Reference:
psi	psi	4) Pl+Pb+Q < 3(Smavg) (OPE,Outside) Case 2
88%		

Branch Transition

Pl+Pb+Q	3(Smavg)	Primary+Secondary (Inner) Load Case 2
11,739	51,300	Plot Reference:
psi	psi	3) Pl+Pb+Q < 3(Smavg) (OPE,Inside) Case 2
22%		

Pad Outer Edge Weld

Pl+Pb+Q	3(Smavg)	Primary+Secondary (Outer) Load Case 2
57,325	60,000	Plot Reference:
psi	psi	4) Pl+Pb+Q < 3(Smavg) (OPE,Outside) Case 2
95%		

Header/Pad removed from Junction

Pl+Pb+Q	3(Smavg)	Primary+Secondary (Outer) Load Case 2
31,642	60,000	Plot Reference:
psi	psi	4) Pl+Pb+Q < 3(Smavg) (OPE,Outside) Case 2
52%		

Branch removed from Junction

Pl+Pb+Q	3(Smavg)	Primary+Secondary (Inner) Load Case 2
10,980	51,300	Plot Reference:
psi	psi	3) Pl+Pb+Q < 3(Smavg) (OPE,Inside) Case 2
21%		

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Highest Fatigue Stress Ratios

Header/Pad at Junction

Pl+Pb+Q+F	Sa	Primary+Secondary+Peak (Inner) Load Case 2
23,248	41,711	Stress Concentration Factor = 1.350
psi	psi	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 44528.6
55%		"B31" Fatigue Stress Allowable = 50000.0
		Markl Fatigue Stress Allowable = 41701.0
		WRC 474 Mean Cycles to Failure = 235993.
		WRC 474 99% Probability Cycles = 54824.
		WRC 474 95% Probability Cycles = 76118.
		BS5500 Allowed Cycles(Curve F) = 52416.
		Membrane-to-Bending Ratio = 0.761
		Bending-to-PL+PB+Q Ratio = 0.568
		Plot Reference:
		5) Pl+Pb+Q+F < Sa (EXP,Inside) Case 2

Branch at Junction

Pl+Pb+Q+F	Sa	Primary+Secondary+Peak (Outer) Load Case 2
30,678	41,711	Stress Concentration Factor = 1.350
psi	psi	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 19005.0
73%		"B31" Fatigue Stress Allowable = 42750.0

Markl Fatigue Stress Allowable = 41701.0
WRC 474 Mean Cycles to Failure = 196873.
WRC 474 99% Probability Cycles = 45736.
WRC 474 95% Probability Cycles = 63500.
BS5500 Allowed Cycles(Curve F) = 22986.
Membrane-to-Bending Ratio = 0.326
Bending-to-PL+PB+Q Ratio = 0.754
Plot Reference:
6) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2

Branch Transition

Pl+Pb+Q+F	Sa	Primary+Secondary+Peak (Inner) Load Case 2
7,924	41,711	Stress Concentration Factor = 1.350
psi	psi	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1000000.0
18%		"B31" Fatigue Stress Allowable = 42750.0
		Markl Fatigue Stress Allowable = 41701.0
		WRC 474 Mean Cycles to Failure = 11469939.
		WRC 474 99% Probability Cycles = 2664622.
		WRC 474 95% Probability Cycles = 3699544.
		BS5500 Allowed Cycles(Curve F) = 1333989.
		Membrane-to-Bending Ratio = 7.683
		Bending-to-PL+PB+Q Ratio = 0.115
		Plot Reference:
		5) Pl+Pb+Q+F < Sa (EXP,Inside) Case 2

Pad Outer Edge Weld

Pl+Pb+Q+F	Sa	Primary+Secondary+Peak (Outer) Load Case 2
38,695	41,711	Stress Concentration Factor = 1.350
psi	psi	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 8746.4
92%		"B31" Fatigue Stress Allowable = 50000.0
		Markl Fatigue Stress Allowable = 41701.0
		WRC 474 Mean Cycles to Failure = 88468.
		WRC 474 99% Probability Cycles = 20552.
		WRC 474 95% Probability Cycles = 28535.
		BS5500 Allowed Cycles(Curve F) = 11455.
		Membrane-to-Bending Ratio = 0.498
		Bending-to-PL+PB+Q Ratio = 0.668
		Plot Reference:
		6) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2

Header/Pad removed from Junction

Pl+Pb+Q+F	Sa	Primary+Secondary+Peak (Outer) Load Case 2
15,821	41,711	Stress Concentration Factor = 1.000
psi	psi	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 214181.0
37%		"B31" Fatigue Stress Allowable = 50000.0
		Markl Fatigue Stress Allowable = 41701.0
		WRC 474 Mean Cycles to Failure = 516017.
		WRC 474 99% Probability Cycles = 119878.
		WRC 474 95% Probability Cycles = 166438.
		BS5500 Allowed Cycles(Curve F) = 68116.
		Membrane-to-Bending Ratio = 13.976
		Bending-to-PL+PB+Q Ratio = 0.067
		Plot Reference:
		6) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2

Branch removed from Junction

Pl+Pb+Q+F	Sa	Primary+Secondary+Peak (Inner) Load Case 2
5,490	41,711	Stress Concentration Factor = 1.000
psi	psi	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1000000.0
13%		"B31" Fatigue Stress Allowable = 42750.0
		Markl Fatigue Stress Allowable = 41701.0
		WRC 474 Mean Cycles to Failure = 14206413.

WRC 474 99% Probability Cycles = 3300342.
WRC 474 95% Probability Cycles = 4582174.
BS5500 Allowed Cycles(Curve F) = 1629902.
Membrane-to-Bending Ratio = 4.502
Bending-to-PL+PB+Q Ratio = 0.182
Plot Reference:
5) Pl+Pb+Q+F < Sa (EXP, Inside) Case 2

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Stress Intensification Factors

Branch/Nozzle Sif Summary

	Peak	Primary	Secondary
Axial :	5.676	4.984	8.409
Inplane :	2.776	1.743	4.112
Outplane:	4.716	3.281	6.986
Torsion :	1.933	2.157	2.863
Pressure:	1.232	1.459	1.825

The above stress intensification factors are to be used in a beam-type analysis of the piping system. Inplane, Outplane and Torsional sif's should be used with the matching branch pipe whose diameter and thickness is given below. The axial sif should be used to intensify the axial stress in the branch pipe calculated by F/A. The pressure sif should be used to intensify the nominal pressure stress in the PARENT or HEADER, calculated from PD/2T.

Pipe OD :	8.625	in.
Pipe Thk:	0.375	in.
Z approx:	20.046	cu. in.
Z exact :	19.214	cu. in.

B31.3		
Peak Stress Sif	0.000	Axial
	4.391	Inplane
	5.522	Outplane
	1.000	Torsional
B31.1		
Peak Stress Sif	0.000	Axial
	5.522	Inplane
	5.522	Outplane
	5.522	Torsional
WRC 330		
Peak Stress Sif	0.000	Axial
	5.522	Inplane
	5.522	Outplane
	5.522	Torsional

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Allowable Loads

SECONDARY Load Type (Range):		Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force	(lb.)	65641.	10197.	15295.
Inplane Moment	(in. lb.)	239710.	28197.	59816.
Outplane Moment	(in. lb.)	144958.	17052.	36172.
Torsional Moment	(in. lb.)	344241.	57266.	85899.
Pressure	(psi)	597.63	334.00	334.00

PRIMARY Load Type:	Maximum Individual	Conservative Simultaneous	Realistic Simultaneous

		Occuring	Occuring	Occuring
Axial Force	(lb.)	58501.	2081.	3121.
Inplane Moment	(in. lb.)	282701.	8397.	17814.
Outplane Moment	(in. lb.)	175702.	4419.	9373.
Torsional Moment	(in. lb.)	228525.	16883.	25324.
Pressure	(psi)	373.89	334.00	334.00

NOTES:

1) Maximum Individual Occuring Loads are the maximum allowed values of the respective loads if all other load components are zero, i.e. the listed axial force may be applied if the inplane, outplane and torsional moments, and the pressure are zero.

2) The Conservative Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A conservative stress combination equation is used that typically produces stresses within 50-70% of the allowable stress.

3) The Realistic Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A more realistic stress combination equation is used based on experience at Paulin Research. Stresses are typically produced within 80-105% of the allowable.

4) Secondary allowable loads are limits for expansion and operating piping loads.

5) Primary allowable loads are limits for weight, primary and sustained type piping loads.

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Flexibilities

The following stiffnesses should be used in a piping, "beam-type" analysis of the intersection. The stiffnesses should be inserted at the surface of the branch/header or nozzle/vessel junction. The general characteristics used for the branch pipe should be:

Outside Diameter = 8.625 in.
Wall Thickness = 0.375 in.

Axial Translational Stiffness	=	2900917.	lb./in.
Inplane Rotational Stiffness	=	1475137.	in.lb./deg
Outplane Rotational Stiffness	=	557007.	in.lb./deg

The following stiffness(es) were not generated because of errors in input or because the finite element model is stiffer than the piping model.

Torsional Rotational Stiffness

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