the pressure equipment safety authority

9410 - 20 Ave N.W.
Edmonton, Alberta, Canada T6N 0A4
Tel: (780) 437-9100 / Fax: (780) 437-7787

April 20, 2021

Attention: Paul Bernard
CANADIAN ENGINEERING AND INSPECTION LTD
(CANEIL)
9637 45 AVENUE SUITE 201
EDMONTON, AB T6E 5Z8

The design submission, tracking number 2021-01913, originally received on April 09, 2021 was surveyed and accepted for registration as follows:

CRN : V2159.2
Accepted on: April 20, 2021
Reg Type: ALTERATION
A #: 0550316
Drawing No. : AB-230 & DOC # 2021-2410-5378-001 Rev 0
S/N: 10-3155A

Design registered in the name of : EXCHANGER INDUSTRIES (DIVISION OF PREMETALCO INC)

Description	**MAWP**	**Design Temperature**	**MDMT**
SS Internal Pressure	6205 kPa	220 °C	-29 °C
TS Internal Pressure	6205 kPa	220 °C	-29 °C

The registration is conditional on your compliance with the following notes:

- It is applicable to re-rate the pressure and temperature rating for both shell and tube sides from original design condition of 1860 psi at -20/428 ℉ to the new cond ition 900 psi at -20/428 ℉. No other physical chan ges to this unit.
- It is applicable to increase tube side corrosion allowance from 0.0625" to 0.078125".
- ABSA's SCO (Inspector) must be notified of this alteration procedure prior to the start of any field work and complete the AB-40 form.

An invoice covering survey and registration fees will be forwarded from our Revenue Accounts.

If you have any question don't hesitate to contact me by phone at (780) 433-0281 ext 3356 or fax (780) 437-7787 or e-mail Habteyes@absa.ca.

Sincerely,

HABTEYES, KASSA
DOP Cert. No. D00009639

ABSA
the pressure equipment safety authority

GENERAL ENGINEERING REQUIREMENTS FOR BOILERS AND PRESSURE VESSELS REPAIR AND ALTERATION PROCEDURE

REPAIR ☐
or
ALTERATION ☒

AB-230 2011-09

1. **Name and Address of Organization** performing Repair/Alteration Canadian Engineering & Inspectiong LTD. AQP No. & Expiry Date AQP-9047 EXP: 11/30/2021

   Location of Installation 14-03-073-08W6

2. **Name of Owner** Canadian Natural Resources Limited

   Address 855 2 Street Southwest #2100, Calgary, AB T2P 4J8

3. **Vessel Manufacturer's Name** Exchanger Industries **CRN** V2159.2

   A#: 550316 **National Board #:** ______ **Serial No.:** 10-3155A **Owner Equip No.:** E-200A

4. **Original Design Conditions:**
   i) Vessel/Shellside/Boiler: Max Allowable Working Press. 1860 Psi Min/Max Design Temp -20 F/428 F
   ii) Tubeside: Max Allowable Working Press. 1860 Psi Min/Max Design Temp -20 F/428 F
   iii) Other: Max Allowable Working Press. ______ Min/Max Design Temp ___/___

5. **Original ASME Code Edition and Addenda**: ASME Sec. VIII Year 2007 Addenda 2009

6. **Repair/Alter. Description of Work.** Step by step description of repair/alteration method. Attach additional sheets as needed. If added: Sheet # ____ thru ____.

   Reference Drawing #: 10-3155A/B

7a. **UT Report enclosed**: Yes: ☒ No: ☐ If no, explain: ______

7b. **Out of roundness report enclosed** (for external pressure only):
Yes: ☐ No: ☒ If no, explain: ______

8. **Heat Treatment**: Preheat Temp N/A Postweld HT (Temp./Time) N/A / N/A hr

9. **Non Destructive Examination** (Specify type and extent).

   Magnectic particle testing on all nozzle CAT D welds. UT on exchanger head, shell, nozzles and tubes.

10a. **Pressure Test**

	Vessel/Boiler/Shellside	Tubeside/Other
i) Hydrostatic	2418 psi	2418 psi
ii) Other Test		

10b. **Test procedure enclosed**: Yes: ☐ No: ☒ If no, explain: Owner to supply test procedure(s)

11 **ADDITIONAL REMARKS/COMMENTS**: ______

12. Anticipated completion date: April 8, 2021

SIGNATURE OF APPLICANT: [signature] DATE: April 8, 2021

PRINT NAME: Paul Bernard

For ABSA use only: Repair / Alteration Procedure accepted

CRN: V2159.2 **A#:** 0550316 **Signature:** [signature] **Date:** April 20, 2021

To:	Elizabeth Amos, E.I.T
From:	Paul Bernard, P.Eng Nathan Luong, E.I.T Adriana Rivolta, E.I.T
Reporting Date:	April 8, 2021
Location:	Pelican Lake
Re:	E-200A Re-rate Assessment
Reviewed By:	Arun Saha, P.Eng

E-200A Exchanger Re-rate Assessment		
Client: CNRL	**Document No.:** 2021-2410-5378-001	**Rev. No.**: 0

2021-01913
ABSA
SAFETY CODES ACT - PROVINCE OF ALBERTA
ACCEPTED: V2159.2
See acceptance letter for conditions of registration.
Date: 2021-04-20 By:
FOR ALTERATION OF:
(A)0550316
KASSA HABTEYES

This stamp and signature have been affixed electronically to this registered design as required by Section 19(1) of the Pressure Equipment Safety Regulation, in accordance with the Electronic Transactions Act.

201, 9637-45 Ave, Edmonton, AB T6E 5Z8. Tel: 780-434-9292, Fax: 780-434-9219

EXECUTIVE SUMMARY

- Canadian Engineering and Inspection Ltd. (CANEIL) was requested by CNRL to perform an assessment on exchanger E-200A to determine its suitability for operation in sour service by de-rating the pressure and increasing the corrosion allowance.
- Per CANEIL's analysis, the exchanger E-200A is acceptable for the re-rated MAWP of 900 psi for both the shell and tube side, and the tube side is acceptable for an increase in corrosion allowance from 0.0625in to 0.0.078125in given the provided information.
- Upon ABSA acceptance, an alteration nameplate shall be affixed adjacent to the original nameplate, and the original design pressure marked out but left legible. This will need to be witnessed by an ABSA Safety Code Officer.
- CNRL should ensure that the pressure safety valve attached to the inlet separator is adjusted to reflect the change in MAWP upon ABSA acceptance.
- It is the responsibility of the owner to determine an appropriate inspection and monitoring strategy to maintain the vessel's fitness-for-service.

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Table of Contents

201, 9637-45 Ave, Edmonton, AB T6E 5Z8. Tel: 780-434-9292, Fax: 780-434-9219

1 INTRODUCTION

1.1 Canadian Engineering and Inspection Ltd. (CANEIL) was requested by CNRL to perform an assessment on exchanger E-200A to determine its suitability for operation in sour service by de-rating the pressure and increasing the corrosion allowance.

2 REFERENCES

2.1 ASME BPVC Section VIII Div. 1 (2007) – *Rules For Construction of Pressure Vessels.*

2.2 ASME BPVC Section II Part D (2007) – *Properties (Customary) Materials*

2.3 TEMA Ninth Edition (2007) – *Standards of the Tubular Exchanger Manufacturers Association*

2.4 E-200A Drawing Package.

2.5 E-200A U1A.

2.6 E-200A Inspection Reports (Visual, UT, MPI)

3 BACKGROUND INFORMATION

3.1 It was proposed to decrease both the tube side and shell side pressures and increase the corrosion allowance for the tube side for exchanger E-200A to allow for it to operate in sour service.

3.2 CANEIL was asked to determine if the exchanger was suitable for operation in sour service on the tube side by decreasing the pressure and increasing the corrosion allowance. CANEIL was also asked to assist in preparing the ABSA submission package for the re-rating. The exchanger was modelled using PV-Elite and checked using calculations from ASME BPVC Section VIII Div. 1 to ensure the decreased pressure was acceptable.

3.3 Static data for E-200A is shown in Table 1 and Table 2 below.

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Table 1 - Exchanger Information

Variable	Specification
Equipment Name	BFW/Emulsion Exchanger
Provincial Reg. No.	A0550316
CRN	V2159.2
Manufacturer	Exchanger Industries
Mfg. Serial No.	10-355A
Year Built	2010

Table 2 - Shell and Tubeside Data

Variable	Value
Service	Sour
OD	16 in
Material	SA333-6 (Shell) SA516-70N (Head)
Length	269.5 in (Shell)
Thickness	1.219 in (Shell - nom) 1.125 in (Head - min)
C.A	0.125 in
RT	Full
MAWP	1860 psi
MAWT	428 °F
MDMT	-20 °F @ 1860 psi

Variable	Value
Service	Sweet
OD	16 in (Channel) 24 in (Tubesheet) 0.75 in (Tubes)
Material	SA333-6 (Channel) SA516-70N (Tubesheet) SA 179 (Tubes)
Length	12.875 in (Channel)
Thickness	1.219 in (Channel) 3.9375 in (Tubesheet) 0.109 in (Tubes – 12 BWG)
C.A	0.0625 in (Channel) 0.1875 in (Tubesheet)
RT	Full
MAWP	1860 psi
MAWT	428 °F
MDMT	-20 °F @ 1860 psi

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4 DISCUSSION AND RESULTS

4.1 The applicable code of construction is ASME BPVC Section VIII Div. 1 2007 Edition. In this edition of the code, impact testing was not required for materials used at temperatures of -20°F and greater. More recent editions of the code are stricter in their requirements for impact testing and temperature.

4.2 The exchanger E-200A was found to be acceptable for the rerated MAWP of 900psi on both the shell and tube side at 428°F as per ASME Sec VIII Div. 1. The tube side of each exchanger had the corrosion allowance increased from $^{1}/_{16}$ in to $^{5}/_{64}$ in. The PV-Elite calculations of these findings can be found in Appendix C.

4.3 MPI was performed on all accessible category D welds on the exchanger. The MT reports can be found attached in Appendix B. No relevant indications were found at the time of inspection.

4.4 UT was performed on the exchanger shellside inlet/outlet nozzles, tubeside inlet/outlet nozzles, shell and head and the tubes. The UT reports can be found attached in Appendix B. No concerns were noted at the time of inspection.

5 CONCLUSIONS/RECOMMENDATIONS

5.1 Per CANEIL's analysis, the exchanger E-200A is acceptable for the re-rated MAWP of 900 psi for both the shell and tube side, and the tube side is acceptable for an increase in corrosion allowance from 0.0625in to 0.0.078125in given the provided information.

5.2 Upon ABSA acceptance, an alteration nameplate shall be affixed adjacent to the original nameplate, and the original design pressure marked out but left legible. This will need to be witnessed by an ABSA Safety Code Officer.

5.3 CNRL should ensure that the pressure safety valve attached to the inlet separator is adjusted to reflect the change in MAWP upon ABSA acceptance.

5.4 It is the responsibility of the owner to determine an appropriate inspection and monitoring strategy to maintain the vessel's fitness-for-service.

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Written by:	Reviewed by:
Paul Bernard, P.Eng	A.S. Saha
Integrity Engineer	Arun Saha, P.Eng
	Senior Integrity Engineer

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APPENDICES

APPENDIX A: U1A

APPENDIX B: Visual, MT and UT Reports.

APPENDIX C: PVElite Model and Calculations

APPENDIX D: Drawings

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Appendix A:

U1A

201, 9637-45 Ave, Edmonton, AB T6E 5Z8. Tel: 780-434-9292, Fax: 780-434-9219

SEPT 10/18

(A) 550316

FORM U-1 MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS
As Required by the Provisions of the ASME Code Rules, Section VIII, Division 1

1. Manufactured and certified by: EXCHANGER INDUSTRIES (A Division of Premetalco Inc.) 5505 - 52 Street S.E., Calgary, AB T2C 2W8
(Name and address of Manufacturer)

2. Manufactured for: GRB Engineering Ltd., 1000, 707 - 7th Avenue S.W., Calgary, AB T2P 3H6
(Name and address of Purchaser)

3. Location of installation: Cenovus Energy, Pelican Lake SAGD - GRB Project #172, Pelican Lake, AB LSD# 12-7-82-22-W4M
(Name and address)

4. Type: Horizontal (Horiz., vert., or sphere) — Heat Exchanger (Tank, separator, jkt. vessel, heat exh., etc.) — 10-3155A (Mfg's serial No.)
V2159.2 (CRN) — 10-3155A/B Rev.2 (Drawing No.) — - (Nat'l. Bd No.) — 2010 (Year Built)

5. ASME Code, Section VIII, Div. 1: 2007-2009 (Edition and Addenda (date)) — - (Code Case No.) — - (Special Service per UG-120(d))

Items 6-11 incl. to be completed for single wall vessels, jackets of jacketed vessels, shell of heat exchangers, or chamber of multi-chamber vessels.

6. Shell (a) No. of Course(s): 1 (b) Overall length (ft & in.): 22' - 5 1/2"

Course(s)			Material	Thickness		Long. Joint (Cat.A)			Circum. Joint (Cat. A,B, & C)			Heat Treatment	
No.	Diameter, in.	Length (ft & in.)	Spec./Grade or Type	Nom.	Corr.	Type	Full,Spot,None	Eff.	Type	Full,Spot,None	Eff.	Temp.	Time
1	16"	22' - 5 1/2"	SA333-6	1.219"	1/8"	S	-	1.0	1	Full	1.0	1150°F	1.5 Hrs.

7. Heads: (a) ______ (Mat'l Spec. No., Grade or Type) H.T. - Time & Temp. (b) SA516-70N 1.5 Hrs. @ 1150°F (Mat'l Spec. No., Grade or Type) H.T. - Time & Temp.

	Location (Top, Bottom, Ends)	Thickness		Radius		Elliptical	Conical	Hemispherical	Flat	Side to Pressure		Category A		
		Min.	Corr.	Crown	Knuckle	Ratio	Apex Angle	Radius	Diameter	Convex	Concave	Type	Full,Spot,None	Eff.
(a)														
(b)	End	1.125"	1/8"			2:1					X			

If removable, bolts used (describe other fastening) ______ (Mat'l Spec. No., Grade, size, No.)

Type of jacket ______ Jacket closure ______ (Describe as ogee & weld, bar, etc)

If bar, give dimensions ______ If bolted, describe or sketch.

9. MAWP 1860 (internal) - (external) psi at max. temp. 428 (internal) - (external) °F Min. design metal temp. -20 °F at 1860 psi.

10. Impact test: No, nozzle necks, tubes & tubesheet exempt per UG-20(f)(1-5). at test temperature of N/A °F.
Covers exempt per UCS-66(a). Cylinder & flanges exempt per UCS-66(g).
(Indicate yes or no and the component(s) impact tested)

11. Hydro.,pneu.,or comb.test press. 2418 psi Proof test -

Items 12 and 13 to be completed for tube sections.

12. Tubesheet: SA516-70N (Stationary (Mat'l Spec. No.)) — 13.562" (Dia., in. (subject to press.)) — 3.9375" (Nom. thk. in.) — 3/16" (Corr. Allow., in.) — Bolted (Attachment (welded or bolted))
______ (Floating (Mat'l Spec. No.)) — ______ (Dia., in.) — ______ (Nom. thk., in.) — ______ (Corr. Allow., in.) — ______ (Attachment)

13. Tubes: SA 179 (Mat'l Spec. No., Grade or Type) — 3/4" (O.D., in.) — 12 BWG M/W (Nom. thk., in. or gauge) — 39 (Number) — U* (Type (Straight or U))

Items 14-18 incl. to be completed for inner chambers of jacketed vessels or channels of heat exchangers.

14. Shell (a) No. of course(s): 1 (b) Overall length (ft & in.): 1' - 7/8"

Course(s)			Material	Thickness		Long. Joint (Cat.A)			Circum. Joint (Cat. A,B, & C)			Heat Treatment	
No.	Diameter, in.	Length (ft & in.)	Spec./Grade or Type	Nom.	Corr.	Type	Full,Spot,None	Eff.	Type	Full,Spot,None	Eff.	Temp.	Time
1	16"	1' - 7/8"	SA333-6	1.219"	1/16"	S	-	1.0	1	Full	1.0	1150°F	1.5 Hrs.

15. Heads: (a) SA516-70N 1.5 Hrs. @ 1150°F (Mat'l Spec. No., Grade or Type) H.T. - Time & Temp. (b) ______ (Mat'l Spec. No., Grade or Type) H.T. - Time & Temp.

	Location (Top, Bottom, Ends)	Thickness		Radius		Elliptical	Conical	Hemispherical	Flat	Side to Pressure		Category A		
		Min.	Corr.	Crown	Knuckle	Ratio	Apex Angle	Radius	Diameter	Convex	Concave	Type	Full,Spot,None	Eff.
(a)	End	1.125"	1/16"			2:1					X			
(b)														

If removable, bolts used (describe other fastening). SA193-B7, 1 5/8" x 15" lg. (16 pcs.)
(Mat'l Spec. No., Grade, size, No.)

FORM U-1 (Back)

16. MAWP 1860 (internal) - (external) psi at max. temp. 428 (internal) - (external) °F Min. design metal temp. -20 °F at 1860 psi.

17. Impact test No, nozzle necks, tubes & tubesheet exempt per UG-20(f)(1-5). at test temperature of N/A °F.
Covers exempt per UCS-66(a). Cylinder & flanges exempt per UCS-66(g).
(Indicate yes or no and the component(s) impact tested)

18. Hydro., pneu., or comb. test press. 2418 psi Proof test -

19. Nozzles, inspection, and safety valve openings:

Purpose (Inlet, Outlet, Drain, etc.)	No.	Diameter or Size	Flange Type	Material Nozzle	Material Flange	Nozzle Thickness Nom.	Nozzle Thickness Corr.	Reinforcement Material	How attached Nozzle	How attached Flange	Location (Insp. Open.)
Channel Inlet	1	3" Cl.900	RFWN	SA266-4N	SA350-LF2	.875"	1/16"	None	UW16.1c	Welded	Bottom Channel
Channel Outlet	1	3" Cl.900	RFWN	SA266-4N	SA350-LF2	.875"	1/16"	None	UW16.1c	Welded	Top Channel
Shell Inlet	1	3" Cl.900	RFWN	SA266-4N	SA350-LF2	.875"	1/8"	None	UW16.1c	Welded	Top Shell
Shell Outlet	1	3" Cl.900	RFWN	SA266-4N	SA350-LF2	.875"	1/8"	None	UW16.1c	Welded	Bottom Shell

20. Supports: Skirt No (Yes/no) Lugs N/A (No.) Legs N/A (No.) Other Saddles (Describe) Attached Welded to Shell (Where and how)

21. Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors have been furnished for the following items of the report: (List the name of part, item number, mfg's. name and identifying number)

22. Remarks: Tema Flanges: MK.1 & MK.2: SA350-LF2, Cl.1 Thickness: 3.6875" & 3.8125" Tema type: "R"
SAFETY VALVES: P.S.V. on piping per UG-125 (g) to be installed by owner CUBIC CAPACITY: 23.23 cu.ft.
SURFACE AREA: 346.7 sq.ft.
SERVICE: BFW/Emulsion Exchanger *U-Bends stress relieved for 1 Hr. @ 1150°F.
ITEM #: E-200A Constructed to Drawing #10-3155A/B Rev.2

CERTIFICATE OF SHOP COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME Code for Pressure Vessels, Section VIII, Division 1.

U Certificate of Authorization No. 5983 Expires March 30 ,20 11

Date SEP 0 3 2010 Name Exchanger Industries (A Division of Prematalco Inc.) (Manufacturer) Signed [signature] (Representative)

CERTIFICATE OF SHOP INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of ALBERTA and employed by ABSA of CALGARY, ALBERTA have inspected the pressure vessel described in this Manufacturer's Data Report on SEP - 3 2010 ,20 , and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME Code, Section VIII, Division 1. By signing this certificate neither the Inspector nor his makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date SEP - 3 2010 Signed [signature] (Authorized Inspector) Commissions Alta #11 (Nat'l Board incl.endorsements,State,Prov.and

CERTIFICATE OF FIELD ASSEMBLY COMPLIANCE

We certify that the statements on this report are correct and that the field assembly construction of all parts of this vessel conforms with the requirements of ASME Code, Section VIII, Division 1.

U Certificate of Authorization No. Expires , 20

Date Name (Assembler) Signed (Representative)

CERTIFICATE OF FIELD ASSEMBLY INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province and employed by of have compared the statements in this Manufacturer's Data Report with the described pressure vessel and state that parts referred to as data not included in the certificate of shop inspection, have been inspected by me and to the best of my knowledge and belief, the Manufacturer has constructed and assembled this pressure vessel in accordance with ASME Code, Section VIII, Division 1. The described vessel was inspected and subjected to a hydrostatic test psi. By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with inspection.

Date Signed (Authorized Inspector) Commissions (Nat'l Board incl. endorsement, State, Province and No.)

Appendix B:

Visual, MT and UT Reports.

201, 9637-45 Ave, Edmonton, AB T6E 5Z8. Tel: 780-434-9292, Fax: 780-434-9219

EQUIPMENT INSPECTION REPORT

GENERAL DETAILS			
EQUIP. TAG NO.	E-200A	INSPECTOR(S)	Russel Vea
EQUIP. ASSET NO.	10-3155A	INSPECTION DATE(S)	March 20, 2021
EQUIP. NAME	Horizontal Heat Exchanger	SCOPE OF INSP.	☒ VE ☒ VI ☒ VI - Borescope
CLIENT	CNRL	DOCUMENT NO.	2021-2410-5386-001-RV-VI Rev. 0
FACILITY / LSD	09-10-082-W4M	EQUIP. STATUS	Out of service
EQUIP. LOCATION	Pad 26 SW		

<table>
<tr><th colspan="2">INSPECTION SUMMARY</th></tr>
<tr><td>INSPECTION SUMMARY:
Overview of major inspection findings and recommendations</td><td>External and Internal Inspection of the horizontal heat exchanger Tag 10-3155A was performed. Overall the heat exchanger was in good condition. No deficiencies were noted during the inspections. Routine NDE was performed. Data was gathered to set a baseline for future inspections.

This equipment is fit for continued service as per this inspection.

Findings:
1. Tube bends, shell flange gasket, and associated piping insulation/cladding were damaged during bundle pull, see Figure 26, Figures 11-12.
2. Exposed insulation found near fixed saddle support was wet, see Figures 4-5; wet insulation is a factor for CUI (corrosion under insulation).
3. Minor caulking failure at saddle support, see Figure 22.
Recommendations:
1. Ensure proper care of bundle removal to prevent future mishandling and damage to property.
2. Investigate cause for wet insulation; ensure proper mitigation factors to prevent wetting.
3. Repair all caulking failure found.</td></tr>
</table>

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EQUIPMENT DATA

MFR.	GRB Engineering Ltd.	ALT. OR REPAIR	☐ Y ☒ N
SERIAL NO.	10-3155A	CODE / STAMP	U
CRN	V2159.2	RT LEVEL	1
PROV. REG. NO.	550316	PWHT	☒ Y ☐ N
NB NO.	N/A	MANWAY	☐ Y - ☒ N
YEAR BUILT	2010	INSP. PORT	☒ Y - ☐ N
VOLUME	23.23 ft3	C.A.	1/8 in

SHELL SIDE (FLUID)

MAWP	1860 psi @ 428 °F	MAEWP	- psi @ - °F
MDMT	-20 °F @ 1860 psi		

TUBE SIDE (FLUID)

MAWP	1860 psi @ 428 °F	MAEWP	- psi @ - °F
MDMT	-20 °F @ 1860 psi		

	DIAMETER	*LENGTH / HT*	*MATERIAL*	*NOMINAL / MIN. NOM.*	*C.A.*
SHELL	16 in	268.125 in	SA333-6	1.219 in	1/8 in
SHELL HEAD	16 in	8 in	SA516-70N	1.125 in	1/16 in
CHANNEL	16 in	24.9375 in	SA333-6	1.125 in	1/8 in
TUBESHEET	13.562 in	3.4375 in	SA516-70N	3.9375 in	3/16 in
TUBES	3/4 in	279 in	SA 179	12 BWG M/W in	N/S in
CHANNEL COVER	- in	- in	-	- in	- in

COMMENTS	

PSV DATA

SHELL SIDE (FLUID)

PSV TAG NO.	PSV-2001A	INLET SIZE	1.5”
MANUFACTURER	Farris	OUTLET SIZE	2”
TYPE	Conventional	CONNECTION	Flanged
MODEL NO.	26DA15-120	CODE / STAMP	ASME VIII - UV
CRN	-	PSV LOCATION	Associated Piping
SERIAL NO.	558955-1-A10	RELIEF DESTINATION	Process piping
SET PRESSURE	Scratched psi	BLOCK VALVES	N/A
BACK PRESSURE	Scratched psi	DATE OF LAST SERVICE	April 21, 2015

201, 9637-45 Ave, Edmonton, AB T6E 5Z8. Tel: 780-434-9292, Fax: 780-434-9219

CAPACITY	118.2 M3-Min	SERVICE COMPANY	Apex Valve Services
SERVICE INTERVAL	Per AB-506	SERVICE REPORT REVIEWED?	No

TUBE SIDE (FLUID)

PSV TAG NO.	PSV-2000A	INLET SIZE	1.5”
MANUFACTURER	Farris	OUTLET SIZE	2”
TYPE	Conventional	CONNECTION	Flanged
MODEL NO.	26DA15-140	CODE / STAMP	ASME VIII - UV
CRN	-	PSV LOCATION	Associated Piping
SERIAL NO.	570787-4-A14	RELIEF DESTINATION	Flare
SET PRESSURE	12750 kPa	BLOCK VALVES	N/A
BACK PRESSURE	0 kPa	DATE OF LAST SERVICE	April 22, 2015
CAPACITY	632 L/Min	SERVICE COMPANY	Apex Valve Services
SERVICE INTERVAL	Per AB-506	SERVICE REPORT REVIEWED?	No

EXTERNAL INSPECTION CHECKLIST

NOTES: A = Acceptable, UA = Unacceptable, N/A = Not applicable, N/I = Not inspected

	A	UA	N/A	N/I	COMMENTS
GENERAL AREA & STRUCTURAL					
- HAZARDS & HOUSEKEEPING	☒	☐	☐	☐	
- AREA LIGHTING	☒	☐	☐	☐	
- BUILDING	☐	☐	☒	☐	
- FOUNDATION	☒	☐	☐	☐	Grade is exposed freezing and thawing, rain which makes the area muddy
- STRUCTURAL SUPPORTS	☒	☐	☐	☐	
- GROUNDING	☒	☐	☐	☐	
- SADDLES & SKIRTS	☒	☐	☐	☐	
- LADDERS & PLATFORMS	☐	☐	☒	☐	
- DAVIT / HINGE	☐	☐	☒	☐	
- OTHER:	☐	☐	☐	☐	
EXTERIOR					
- GENERAL	☒	☐	☐	☐	
- EXTERNAL COATING	☒	☐	☐	☐	Minor rusting under insulation
- INSULATION & CLADDING	☒	☐	☐	☐	Great condition however exposed insulation found at fixed saddle support was. Caulking failure at supports.

	A	UA	N/A	N/I	COMMENTS
- SOIL TO AIR INTERFACE	☒	☐	☐	☐	Muddy and full of standing water
NAMEPLATE(S)					
- GENERAL	☒	☐	☐	☐	
- DESIGN REGISTRATION	☒	☐	☐	☐	
- EQUIPMENT REGISTRATION	☒	☐	☐	☐	
NOZZLES, PIPING & CONNECTIONS					
- GENERAL	☒	☐	☐	☐	
- INSULATION & CLADDING	☒	☐	☐	☐	
- LEAKAGE	☒	☐	☐	☐	
- ALIGNMENT	☒	☐	☐	☐	
- SUPPORTS	☒	☐	☐	☐	
- VIBRATION	☐	☐	☒	☐	Not in service
- GASKETS	☒	☐	☐	☐	
- BOLTING	☒	☐	☐	☐	
- INSTRUMENTATION & GAUGES	☒	☐	☐	☐	
- OTHER:	☐	☐	☐	☐	
PRESSURE RELIEF					
- GENERAL	☒	☐	☐	☐	
- NAMEPLATE	☒	☐	☐	☐	
- SERVICE TAG	☒	☐	☐	☐	
- SEALING WIRES	☒	☐	☐	☐	
- LIFTING LEVER	☒	☐	☐	☐	
- BELLOWS VENT	☒	☐	☐	☐	
- INLET PIPING	☒	☐	☐	☐	
- OUTLET PIPING	☒	☐	☐	☐	
- BLOCK VALVES (CARSEALED)	☒	☐	☐	☐	
OTHER					
-	☐	☐	☐	☐	
-	☐	☐	☐	☐	
-	☐	☐	☐	☐	
-	☐	☐	☐	☐	

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INTERNAL INSPECTION CHECKLIST

NOTES: A = Acceptable, UA = Unacceptable, N/A = Not applicable, N/I = Not inspected

	A	UA	N/A	N/I	COMMENTS
GENERAL					
- CLEANLINESS	☒	☐	☐	☐	
- ACCESSIBILITY	☒	☐	☐	☐	
SHELL SIDE					
- GENERAL	☒	☐	☐	☐	
- COATINGS / LININGS	☒	☐	☐	☐	
- INLET	☒	☐	☐	☐	
- DISCHARGE	☒	☐	☐	☐	
- WELDS	☒	☐	☐	☐	
- OTHER:	☐	☐	☐	☐	
TUBE SIDE					
- GENERAL	☒	☐	☐	☐	
- COATINGS / LININGS	☒	☐	☐	☐	
- INLET	☒	☐	☐	☐	
- DISCHARGE	☒	☐	☐	☐	
- WELDS	☒	☐	☐	☐	
- OTHER:	☐	☐	☐	☐	
NOZZLES & MANWAYS					
- GENERAL	☒	☐	☐	☐	
- CLEANLINESS & OBSTRUCTIONS	☒	☐	☐	☐	
- WELDS	☒	☐	☐	☐	
- OTHER:	☐	☐	☐	☐	
INTERNALS					
- INTERNAL PIPING	☒	☐	☐	☐	
- BAFFLES, DEFLECTOR PLATES, WEIR PLATES, VORTEX BREAKERS, ETC.	☒	☐	☐	☐	
- ATTACHMENT WELDS	☒	☐	☐	☐	
- OTHER:	☐	☐	☐	☐	
OTHER					
-	☐	☐	☐	☐	
-	☐	☐	☐	☐	
-	☐	☐	☐	☐	
-	☐	☐	☐	☐	

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INSPECTION REPORT

EXTERNAL INSPECTION

This external inspection was performed in accordance with inspection procedure CANEIL-INS-004 *External Inspection of Pressure Equipment*.

An external inspection of both the shell and channel were performed. The TEMA type BFU Exchanger equipment tag number, 10-3155A, is located in an exchanger bank outdoors at Pad 26 SW. It is mounted in the horizontal position oriented with the channel of the exchanger facing south.

The exchanger has been offline for several years and last inspection noted was 2010-11-08.

The exchanger is supported by steel saddles which are secured to grade. Mud, snow/ice, and standing water cover air to soil interface between saddles to grade. Channel-side is fixed saddle support while shell-head side is saddle support sliding.

Shell side is insulated/cladded. Insulation/cladding were in good condition. Inspection of both insulation/cladding determined they appeared to be installed using generally accepted good practice. There were no seams turned up to permit water ingress; areas around nozzles were sealed with flexible caulking. Minor caulking failure noted at saddle on channel side, see Figure 22. Insulation at fixed saddle support was found to be complete wet, see Figures 4-5. Cause for water ingress is unknown since insulation/cladding was removed prior to installation. Insulation at ports were dry as well as other exposed insulation at locations where insulation/cladding were removed for inspection purposes.

Areas of shell that were exposed showed minor signs of rusting, see Figure 6.

Grounding was found to be in good condition and connected tightly.

The channel and channel head were inspected and there were no findings. Insulation/cladding were removed to facilitate inspections and are anticipated to be re-installed after the unit is returned to service.

The nameplate was legible, easily accessible, and found to be in good condition.

Special note:

Insulation/cladding on piping near the channel were visibly damaged during bundle removal, see Figure 11. Gasket was also damaged, see Figure 12, however inspection of gasket face upon removal of gasket showed no damage, see Figure 13.

PIPING INSPECTION

Shell inlet and outlet nozzles (S1/S2) and the associated piping were inspected. These were properly supported and were found in good condition. There were no apparent issues with bolting or alignment. No maintenance was performed on the connection. Everything appeared to be in serviceable condition.

The Channel inlet and outlet nozzles (T1/T2) and the associated piping were inspected. These were supported properly and were found in serviceable condition. There were no apparent issues with bolting or alignment.

PSV INSPECTION

Inspection of pressure relief devices was performed in accordance with inspection procedure CANEIL-INS-005 *Inspection of Pressure Relief Devices*.

The shell side PSV tag 2001A and tube side PSV tag 2000A were found intact and generally in good condition. There were no apparent issues with bolting or alignment. Carseals were noted to be intact. PSV 2000A lever was found to be loose and not carsealed as per code.

INTERNAL INSPECTION

This internal inspection was performed in accordance with inspection procedure CANEIL-INS-009 *Internal Inspection of Pressure Equipment*.

Internal visual inspections of both the shell side and tube side were completed. No defects requiring remediation were found.

The shell side of the exchanger was pressure washed cleaned prior to inspection. Nozzle ID weld reinforcement on all nozzles were more than desirable and appeared not to be in violation of UW-35.

Shell internal inspection was limited to a few meters as ingress was not possible at the time.

As part of the internal inspection, all of the body flanges and exposed piping flange faces were examined. All sealing surfaces were found to be undamaged.

The bundle was inspected visually for signs of corrosion, fretting, or other mechanical damage. There were no findings of note to come from the visual inspection. The face of the tube sheet was inspected for damage and corrosion. There were no items to note. All flange faces and gasket surfaces were found to be undamaged.

The tube bundle was found to be in generally good condition; no mechanical damage, with exception to mechanical damage from the bundle pull, or visible corrosion was noted on the tubes and baffles. Tube bends R1C5, R1C6, R1C7, R2C8, and R4C8 were found to have minor damage, see Figure 26. No further investigation was needed due to damage being minor scratches on bends.

No borescope inspection of internal tubes were performed since the tube diameter proved to be too small for borescope entry. There were no tube to tubesheet seal welds and thus no Magnetic Particle Inspection was performed.

Internal inspection of the channel cylinder did not identify any areas of concern. The long baffle pass plate weep holes were open. The welds attaching the pass plates were inspected and no defects were found.

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NDE RESULTS

NDE on E-200A consisted of UT and MT.

CORROSION ASSESSMENT

Based upon the visual inspection and the NDE data gathered, this vessel does not appear to be experiencing measurable metal loss from corrosion or other means. At this time, remaining life does not appear to be governed by corrosion.

INTERVAL ASSIGNMENT

This interval assignment was performed in accordance with inspection procedure CANEIL-INS-003 *Inspection & PRD Service Intervals*. Recommended intervals are subject to review and acceptance by the client's Chief Inspector.

It is recommended to inspect this vessel on the maximum 4 years interval.

FINDINGS

1. Tube bends, shell flange gasket, and associated piping insulation/cladding were damaged during bundle pull, see Figure 26, Figures 11-12.
2. Exposed insulation found near fixed saddle support was wet, see Figures 4-5; wet insulation is a factor for CUI (corrosion under insulation).
3. Minor caulking failure found at saddle support, see Figure 22.

RECOMMENDATIONS

1. Ensure proper care of bundle removal to prevent future mishandling and damage to property.
2. Investigate cause for wet insulation; ensure proper mitigation factors to prevent wetting.
3. Repair all caulking failures found.

FITNESS FOR SERVICE

This equipment is fit for continued service as per this inspection.

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EQUIPMENT PICTURES

Figure 1. Overview of Exchanger E-200A north facing

Figure 2. Overview of Exchanger E-200A south facing

Figure 3. Overview of Nameplate

Figure 4. Overview of channel side saddle support (fixed)

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EQUIPMENT PICTURES	
	
Figure 5. Overview of wet insulation (water drops on support beam)	Figure 6. Overview of shell cylinder, S2, S1
	
Figure 7. Close up of S1(inlet)	Figure 8. Close up of S2 (outlet)

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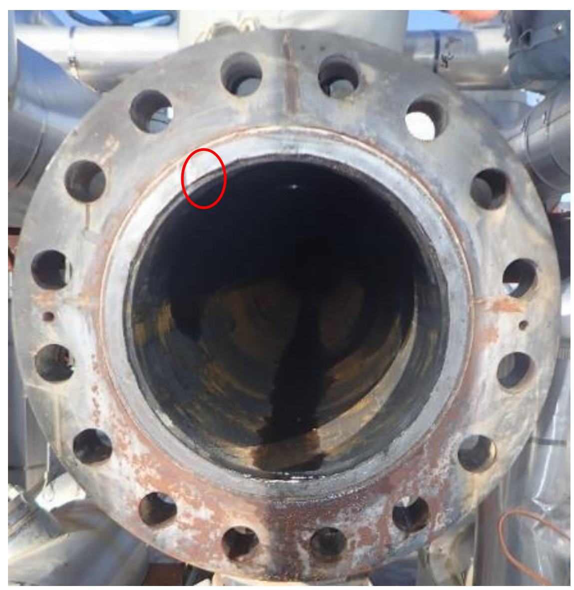
EQUIPMENT PICTURES	
	
Figure 9. Overview of shell head side saddle support (sliding)	Figure 10. Overview of air to soil interface for support
	
Figure 11. Overview of shell flange face; piping cladding damage due to bundle removal	Figure 12. Gasket damage due to bundle pull

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EQUIPMENT PICTURES	
	
Figure 13. No damage on gasket seating surface (post gasket removal)	Figure 14. Overview of Shell internal
	
Figure 15. Overview of shell internal	Figure 16. PSV 2001A

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EQUIPMENT PICTURES

Figure 17. PSV 2001A Nameplate

Figure 18. PSV 2001A Service Tag

Figure 19. Overview of PSV 2000A

Figure 20. Overview of PSV 2000A Nametag

EQUIPMENT PICTURES	
	
Figure 21. Overview of PSV 2000A Service Tag	Figure 22. Overview of caulking failure
	
Figure 23. Overview of Tube Bundle	Figure 24. Item no: E-200A

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EQUIPMENT PICTURES	
	
Figure 25. Overview of Tubesheet	Figure 26. Mechanical damage to bundle from bundle removal;

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ATTACHMENTS

- MT Report: 2021-2410-5387-MT-001-RV Exchanger 10-3155A
- UT Report: 2021-2410-5387-UT-004-SM Exchanger 10-3155A
- UT Report: 2021-2410-5387-UT-005-SM Exchanger 10-3155A

INSPECTION SIGN OFFS

Inspector:

Name: Russel Vea

Title: ABSA Pressure Equipment Inspector

Certification and No.:


Alberta ABSA
This is to certify that
Russell Vea
is a Registered holder of a
In-Service Pressure Equipment Inspector
Certificate of Competency which expires
May 13, 2024
File #: A-95711 Cert #: 000600

Signature

March 22, 2021
Date:

Client Representative:

Name:

Title

Signature

Date:

201, 9637-45 Ave, Edmonton, AB T6E 5Z8. Tel: 780-434-9292, Fax: 780-434-9219

MAGNETIC PARTICLE (MT) EXAMINATION REPORT

Canadian Engineering & Inspection Ltd.
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Edmonton, AB
Canada T6E 5Z8

Phone: (780) 434-9292
Fax: (780) 434-9219

CANEIL JOB NUMBER	P.O. NUMBER	CLIENT JOB NUMBER	REPORT NUMBER
2021-2410			2021-2410-5387-MT-001-RV REV. 0

JOB DESCRIPTION

CLIENT:	CNRL	EXAMINATION STD.:	ASME V Article 7
EXAMINATION DATE:	March 20, 2021	ACCEPTANCE STD.:	ASME VIII Div 1 App 6
WORK LOCATION / LSD:	Pad 26 SW	CANEIL PROCEDURE	CANEIL-INS-261 MT-2 REVISION: 6
ITEM(S) EXAMINED:	10-3155A	ITEM(S) DESCRIPTION	MT Cat D welds

TEST EQUIPMENT AND MATERIALS

UV LIGHT MFR.:	Spectronics	MODEL:	XR-1000	S/N:	1943770
LIGHT METER MFR.:		MODEL:		S/N:	

BLACK LIGHT INTENSITY BEFORE EXAM:	µW/cm²	WHITE LIGHT / BACKGROUND:	>100 fc
BLACK LIGHT INTENSITY AFTER EXAM:	µW/cm²	LIFTING TEST BLOCK S/N:	2381 BLOCK WT.: 10 lb

	TEST MEDIUM	MFG.	PRODUCT	BATCH NO	CONC.		EQUIPMENT	MFG.	MODEL	S/N
☐	DRY POWDER					☑	EM YOKE	Contour Probe	P2	CE101
☑	WET VISIBLE	Chemetell	Ardrox 8032	65071718		☐	PERM. MAGNET			
☐	WET FLOURESENT					☐				
☑	CONTRAST PAINT	Chemetell	Ardrox 8901W	65090518		☐				
☐						☐				
☐						☐				

CURRENT:	AC	TECHNIQUE:	CONTINUOUS	SUSPENSION:	OIL	COLOUR:	Black
MATERIAL:	Carbon Steel	SURFACE CONDITION:	bare metal	T_{NOM}: IN.			
DEMAGN. REQUIRED?:	NO	EXAM LIMITATIONS:					

PURPOSE/SCOPE

Wet Visible Black and White Contrast Magnetic Particle Inspection was carried out on Cat D welds for Nozzles S1, S2, T1, and T2 for re-rate purposes to determine if there are any defects present.

Results

No relevant indications were found at the time of inspection.

CONCLUSION

This examination is a complement to the Visual Inspection performed.

TECHNICIANS

INTERPRETATION IS IN ACCORANCE WITH THE ABOVE MENTIONED STANDSRDS, TO THE BEST OF MY PROFESSIONAL ABILITY

LEAD NAME: (PRINT) Russel Vea (SIGN) CGSB LEVEL: II REG. NO.: 20249

NAME: (PRINT) (SIGN) REG. NO.:

CWB INSPECTION **NO**

CWB Welding Inspection Supervisor

NAME: (PRINT) (SIGN) CWB LEVEL: REG. NO.:

CLIENT REPRESENTATIVE

THE ABOVE REPRESENTATION IS A PROFESSIONAL OPINION. FINAL INTERPRETATION IS THE RESPONSIBILITY OF THE CLIENT. I HAVE READ AND AM IN FULL AGREEMENT WITH THE CONTENTS OF THIS REPORT

NAME: (PRINT) (SIGN)

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Magnetic Particle (MT)
EXAMINATION REPORT

CANEIL JOB NUMBER	P.O. NUMBER	CLIENT JOB NUMBER	REPORT NUMBER
2020-2410			2021-2410-5387-MT-001-RV REV. 0

FIGURE 01: Overview of 10-3155A

FIGURE 02: Nameplate

FIGURE 03: MT on T2 (left), T1 (right) Cat D weld

FIGURE 04: MT on S1 (top), S2 (bottom) Cat D weld

ULTRASONIC THICKNESS (UT) EXAMINATION REPORT

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Phone: (780) 434-9292
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CANEIL JOB NUMBER	P.O. NUMBER	CLIENT JOB NUMBER	REPORT NUMBER
2021-2410			2021-2410-5387-UT-004-SM REV. 0

JOB DESCRIPTION

CLIENT:	CNRL	EXAMINATION STD.:	ASME V Article 5
EXAMINATION DATE:	March 26, 2021	ACCEPTANCE STD.:	For Client information only
WORK LOCATION / LSD:	PAD 26 SW	CANEIL PROCEDURE	CANEIL-INS-263 REVISION: 2
ITEM(S) EXAMINED:	10-3155A Tubes	ITEM(S) DESCRIPTION	TML Measurements
SCANNING METHOD:	Single point		

INSTRUMENT: Olympus MODEL: 38DL Plus S/N: 173031508 CALIBRATION DUE: Apr 18, 2021

	CAL BLOCK:	S/N:	TYPE:
1.	CS Imperial Step Wedge	2214E	
2.	CS Imperial Step Wedge	14-3143	
3.			

SETUP NO.	TRANSDUCER (MANUFACTURER / MODEL / SERIAL)	FREQ. (MHz)	CRYSTAL SIZE	PROBE TYPE	SCAN SENSITIVITY	CABLE (LENGTH / TYPE)	DELAY LINE	CAL. THICK	PRIMARY REFERENCE (REFLECTOR / AMPLITUDE / DISTANCE)
1.	Panametrics/D798-SM/998047	7.5	.283"	Dual	+0dB	5' LCMD-316-5B	NO	0.100" - .500"	BWE @80% FSH
2.	Panametrics/D790-SM/816558	5	.434	Dual	+0dB	5' LCMD-316-5B	NO	0.100" - .500"	BWE @80% FSH
3.									
4.									
5.									

MATERIAL:	Carbon Steel	SURFACE CONDITION:	Painted	SCAN LIMITATIONS:	Through Paint & Curved Surface
TNOM:	Various INCH	SURFACE TEMP:	< 0 °C	COUPLANT:	Lubriplate

Perform thickness measurement to ascertain material loss and remaining thickness of metal.

RESULTS

Lowest thickness reading is 0.098' found for R2C6 at the bend.

CONCLUSION

The survey was completed with all accessible points scanned.

TECHNICIANS

INTERPRETATION IS IN ACCORANCE WITH THE ABOVE MENTIONED STANDSRDS, TO THE BEST OF MY PROFESSIONAL ABILITY

LEAD NAME: (PRINT) Sri Madathil (SIGN) CGSB LEVEL: SNT-TC-1A LEVEL: II REG. NO.: 20586

NAME: (PRINT) (SIGN) REG. NO.:

CWB INSPECTION NO

CWB Welding Inspection Supervisor

NAME: (PRINT) (SIGN) CWB LEVEL: REG. NO.:

CLIENT REPRESENTATIVE

THE ABOVE REPRESENTATION IS A PROFESSIONAL OPINION. FINAL INTERPRETATION IS THE RESPONSIBILITY OF THE CLIENT. I HAVE READ AND AM IN FULL AGREEMENT WITH THE CONTENTS OF THIS REPORT

NAME: (PRINT) (SIGN)

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ULTRASONIC THICKNESS (UT) EXAMINATION REPORT

CANEIL JOB NUMBER	P.O. NUMBER	CLIENT JOB NUMBER	REPORT NUMBER
2021-2410			2021-2410-5387-UT-004-SM REV. 0

JOB DESCRIPTION

CLIENT:	CNRL	EXAMINATION ID:	10-3155A
EXAMINATION DATE:	March 26, 2021	TAG NO.:	E-200A
WORK LOCATION / LSD:	PAD 26 SW	SERIAL NO.:	10-3155A
AS TESTED TEMP.:	> 0 °C	ITEM(S) DESCRIPTION:	Tubes - TML Measurements
READING UNITS:	INCH		

TML	DESCRIPTION	TML DATA												DATA SUMMARY	
		1	2	3	4	5	6	7	8	9	10	11	12		
A	R1C1	0.113	0.113	0.100	0.116									AVERAGE:	0.110
	TNOM: 0.109 C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	0.100
B	R1C2	0.114	0.114	0.105	0.114									AVERAGE:	0.112
	TNOM: 0.109 C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	0.105
C	R2C1	0.114	0.116	0.105	0.112									AVERAGE:	0.112
	TNOM: 0.109 C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	0.105
D	R1C6	0.110	0.113	0.098	0.115									AVERAGE:	0.109
	TNOM: 0.109 C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	0.098
E	R1C7	0.109	0.112	0.101	0.106									AVERAGE:	0.107
	TNOM: 0.109 C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	0.101
F	R2C7	0.112	0.112	0.101	0.109									AVERAGE:	0.109
	TNOM: 0.109 C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	0.101
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.: 0	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.: 0	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.: 0	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.: 0	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	

COMMENTS

TMLs A1, B1, C1, D1, E1, F1: tubes are located at the top of the 1st baffle plate section starting at flange
TMLs A2, B2, C2, D2, E2, F2: tubes are located at the top of the 10th baffle plate section starting at flange
TMLs A3, B3, C3, D3, E3, F3: tubes are located at the ubend
TMLs A4, B4, C4, D4, E4, F4: tubes are located on the 16th baffle plate section starting at flange

Scans were made along the length of the tube within the baffle plate section.

ULTRASONIC THICKNESS (UT) EXAMINATION REPORT

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CANEIL JOB NUMBER	P.O. NUMBER	CLIENT JOB NUMBER	REPORT NUMBER
2021-2410			2021-2410-5387-UT-004-SM REV. 0

FIGURE 1: 10-3155A Tube Bundle

ULTRASONIC THICKNESS (UT) EXAMINATION REPORT

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Phone: (780) 434-9292
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2021-2410			2021-2410-5387-UT-005-SM	REV. 0

CLIENT:	CNRL	EXAMINATION STD.:	ASME V Article 5
EXAMINATION DATE:	March 26, 2021	ACCEPTANCE STD.:	For Client information only
WORK LOCATION / LSD:	PAD 26 SW	CANEIL PROCEDURE	CANEIL-INS-263 REVISION: 2
ITEM(S) EXAMINED:	10-3155A Vessel	ITEM(S) DESCRIPTION	TML Measurements
SCANNING METHOD:	Single point		

INSTRUMENT: Olympus MODEL: 38DL Plus S/N: 173031508 CALIBRATION DUE: Apr 18, 2021

	CAL BLOCK:		S/N:	TYPE:
1.	CAL BLOCK:	CS Imperial Step Wedge	2214E	
2.	CAL BLOCK:	CS Imperial Step Wedge	14-3143	
3.	CAL BLOCK:			

SETUP NO.	TRANSDUCER (MANUFACTURER / MODEL / SERIAL)	FREQ. (MHz)	CRYSTAL SIZE	PROBE TYPE	SCAN SENSITIVITY	CABLE (LENGTH / TYPE)	DELAY LINE	CAL. THICK	PRIMARY REFERENCE (REFLECTOR / AMPLITUDE / DISTANCE)
1.	Panametrics/D798-SM/998047	7.5	.283"	Dual	+0dB	5' LCMD-316-5B	NO	0.100" - .500"	BWE @80% FSH
2.	Panametrics/D790-SM/816558	5	.434	Dual	+0dB	5' LCMD-316-5B	NO	0.100" - .500"	BWE @80% FSH
3.									
4.									
5.									

MATERIAL:	Carbon Steel	SURFACE CONDITION:	As found	SCAN LIMITATIONS:	Through Paint & Curved Surface
TNOM:	Various INCH	SURFACE TEMP:	< 0 °C	COUPLANT:	Lubriplate

Perform thickness measurement to ascertain material loss and remaining thickness of metal.

Lowest thickness reading found for Heads is 1.178' at Channel Head.

Lowest thickness reading found for Shell is 1.206' at TML B.

Lowest thickness reading found for Nozzles is 0.886' at Channel Inlet.

The survey was completed with all accessible points scanned.

INTERPRETATION IS IN ACCORANCE WITH THE ABOVE MENTIONED STANDSRDS, TO THE BEST OF MY PROFESSIONAL ABILITY

LEAD NAME: (PRINT) Sri Madathil (SIGN) CGSB LEVEL: SNT-TC-1A LEVEL: II REG. NO.: 20586

NAME: (PRINT) (SIGN) REG. NO.:

CWB INSPECTION **NO**

CWB Welding Inspection Supervisor

NAME: (PRINT) (SIGN) CWB LEVEL: REG. NO.:

CLIENT REPRESENTATIVE

THE ABOVE REPRESENTATION IS A PROFESSIONAL OPINION. FINAL INTERPRETATION IS THE RESPONSIBILITY OF THE CLIENT. I HAVE READ AND AM IN FULL AGREEMENT WITH THE CONTENTS OF THIS REPORT

NAME: (PRINT) (SIGN)

CANEIL

ULTRASONIC THICKNESS (UT) EXAMINATION REPORT

Canadian Engineering & Inspection Ltd.
201, 9637 - 45 Avenue NW
Edmonton, AB
Canada T6E 5Z8

Phone: (780) 434-9292
Fax: (780) 434-9219

CANEIL JOB NUMBER	P.O. NUMBER	CLIENT JOB NUMBER	REPORT NUMBER
2021-2410			2021-2410-5387-UT-005-SM REV. 0

JOB DESCRIPTION

CLIENT:	CNRL	EXAMINATION ID:	10-3155A
EXAMINATION DATE:	March 26, 2021	TAG NO.:	E-200A
WORK LOCATION / LSD:	PAD 26 SW	SERIAL NO.:	10-3155A
AS TESTED TEMP.:	> 0 °C	ITEM(S) DESCRIPTION:	Vessel - TML Measurements
READING UNITS:	INCH		

TML	DESCRIPTION	TML DATA 1	2	3	4	5	6	7	8	9	10	11	12	DATA SUMMARY	
A	Channel Head	1.196	1.197	1.180	1.183	1.199	1.178							AVERAGE:	1.189
	TNOM: C.A.: MIN.: 1.125	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	1.178
B	Shell	1.206	1.223	1.222	1.214	1.215	1.226							AVERAGE:	1.218
	TNOM: 1.219 C.A.: 0.125 MIN.: 1.094	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	1.206
C	Shell	1.261	1.258	1.236	1.226		1.209							AVERAGE:	1.238
	TNOM: 1.219 C.A.: 0.125 MIN.: 1.094	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	1.209
D	Shell	1.209	1.231	1.223	1.233	1.245	1.233							AVERAGE:	1.229
	TNOM: 1.219 C.A.: 0.125 MIN.: 1.094	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	1.209
E	Shell Head	1.221	1.185	1.222	1.205	1.197	1.181							AVERAGE:	1.202
	TNOM: C.A.: MIN.: 1.125	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	1.181
F	T2 Channel Outlet	0.902	0.902	0.912	0.912	0.912	0.887							AVERAGE:	0.905
	TNOM: 0.875 C.A.: 0.0625 MIN.: 0.8125	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	0.887
G	T1 Channel Inlet	0.886	0.913	0.909	0.908	0.910	0.898							AVERAGE:	0.904
	TNOM: 0.875 C.A.: 0.0625 MIN.: 0.8125	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	0.886
H	S1 Shell Inlet	0.905	0.911	0.883	0.907	0.878	0.911	0.876						AVERAGE:	0.896
	TNOM: 0.875 C.A.: 0.125 MIN.: 0.75	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	0.876
I	S2 Shell Outlet	0.915	0.920	0.915	0.912	0.903	0.905	0.904						AVERAGE:	0.911
	TNOM: 0.875 C.A.: 0.125 MIN.: 0.75	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	0.903
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.: 0	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.: 0	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.: 0	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.:	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	
														AVERAGE:	
	TNOM: C.A.: MIN.: 0	MATERIALS:				SCH.:		CLASS:		DIRECTION				MINIMUM:	

COMMENTS

ULTRASONIC THICKNESS (UT) EXAMINATION REPORT

CANEIL
Canadian Engineering & Inspection Ltd.
201, 9637 - 45 Avenue NW
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Canada T6E 5Z8

Phone: (780) 434-9292
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CANEIL JOB NUMBER	P.O. NUMBER	CLIENT JOB NUMBER	REPORT NUMBER
2021-2410			2021-2410-5387-UT-005-SM REV. 0

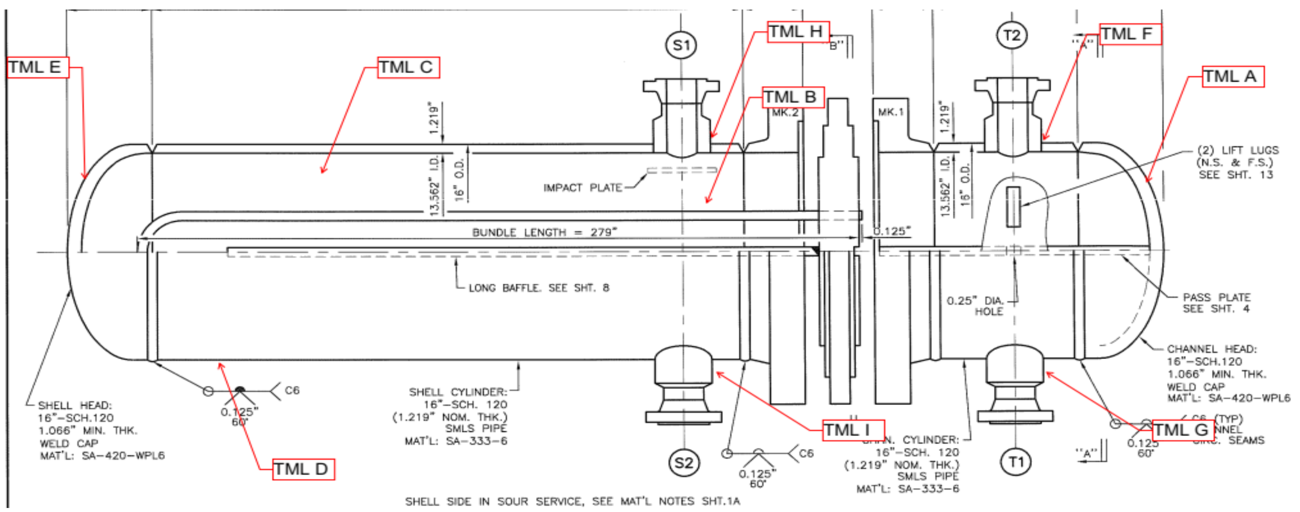


FIGURE 1: TML

PRESSURE VESSEL RECORD

Cenovus

District : CVE - EASTERN OIL BU
Field : EASTERN OIL
Facility : PELICAN LAKE FIELD **LSD:** **PV LSD:** 09-10-082-23W4M

Jur #	Equip #	Serial #	CRN #	Alt Jur #	Province	Description
A0550316		10-3155A	V2159.2			EMULSION / BFW EXCHANGER

Unit Name: PAD 26

Service
Process Fluid:
Sweet/Sour: SWEET
Environ Shell:
Environ Tube:

Radio/Hydro/Eff.
Radiography: FULL
Hydro:
Joint Eff: 1
PWHT:

Access
Manway:
Hand hole:
Internal access:

Summary
Status: IN SERVICE

Last Reg Insp	Insp Int Mths	Next Insp
2010-11-08	12	2011

Retirement Year
UT ☐ *
Last Insp Methods VE
No. of Linked Doc's 2
No. of DWGs 0
No. of Memo's 0
PSV Pressure Check Shell ☑

Last Periodic Insp	Periodic Int Mths	Next Periodic

Vessel Design
Equipment Type: EXCHANGER
Year Built: 2010 Capacity: 0.66 m3
Drawing #:
Diameter: 0.41 m Length: 6.85 m
ASME: SECTION VIII DIVISION Heating Surface: 32 m2
Model:
Dimension Comments:
Manufacturer: EXCHANGER INDUSTRIES

Registration
Subject to fee:
Registered: Y
Fee:
Commission date:
Vessel Owner: CENOVUS ENERGY INC

Acct. Code:
Jur. category:
Shutdown req:
Priority:
De-commission date:

Change Inspection Interval to
Change PSV Service Interval to

Report Reviewed and Accepted By:

REVIEWED & ACCEPTED
DWAYNE BUNCH
API #
JUL 0 6 2011
IPV FILE # A-63359
API-510 CERT # 26926
Dwayne Bunch

Print Name
PESL #

Vessel Shell Side			Vessel Tube Side	
MAWP:	12824 kPa		MAWP:	12824 kPa
MAWT:	220 C		MAWT:	220 C
MDMT:	-29 C		MDMT:	-29 C

PSV's Shell Side

Tag #	Serial #	Set Pressure	Set Temp.
	570787-2-A14	1849 psi	374 F
PSV Last Service Date:			
	570787-4-A14	1849 psi	374 F
PSV Last Service Date:			

PSV's Tube Side

COMPONENTS

ACCESS REQUIREMENTS

VESSEL COMMENTS
As per ABSA Cert, location to be 12-07-082-22 (Pelican Lake SAGD, GRB Project #172) kt oct 2010

VESSEL OFFLINE

VESSEL ONLINE

VESSEL LAST REGULATORY SUMMARY

Date	Methods		Primary Inspector	Secondary Inspector	Report #
2010-11-08	VE		HORACE GOPEESINGH	CHRIS HORKOFF	
		Company:	UNKNOWN	CENOVUS	

PRESSURE VESSEL RECORD

MAXITRAK V3 Rpt: PV-S-003
Report Date : 2011-07-06

Cenovus

District : CVE - EASTERN OIL BU
Field : EASTERN OIL
Facility : PELICAN LAKE FIELD **LSD:** **PV LSD:** 09-10-082-23W4M

Jur #	Equip #	Serial #	CRN #	Alt Jur #	Province	Description
A0550316		10-3155A	V2159.2			EMULSION / BFW EXCHANGER

External Inspection Items

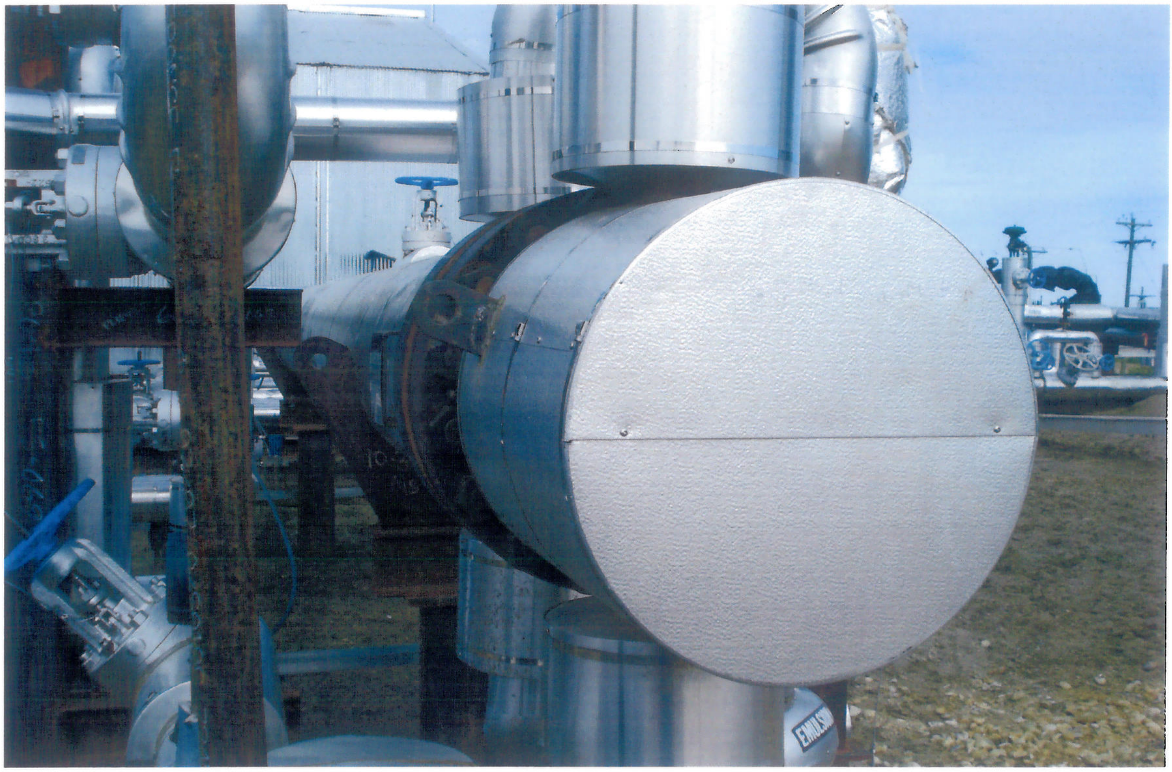
G = Good, F = Fair, P = Poor, N/A = Not Applicable

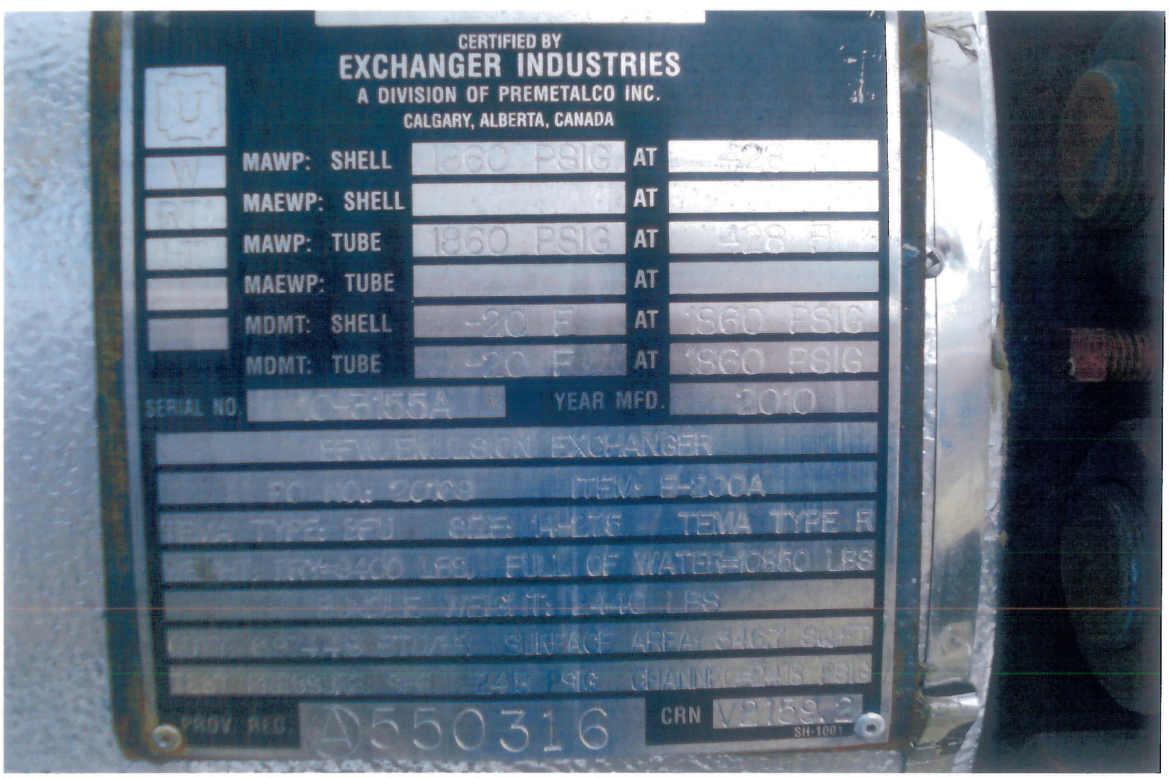
Item	G	F	P	N/A	Comments
Insulation - Verify sealed around manways, nozzles, no damage present, and there is no egress of moisture. Are straps secure?	✓				Good
External Condition - Assess paint condition, areas peeling, record any corrosion, damage, distortion etc (record location, size and depth of corrosion or damage)					No Access - ~~I~~ Insulated
Leakage - Record any leakage at flanges, threaded joints, weep holes on reads, etc.	✓				
Skirt/Saddle - Assess condition of paint, fire protection, concrete. Look for corrosion, buckling, dents, etc. Look at vessel surface area near supports. Verify no signs of leakage at attachment to vessel and attachment welds are acceptable. Is ground wire attached?	✓				Saddle on Piles.
Anchor Bolts - Hammer tap to ensure secure. Look for corrosion, cracking in threads or signs of deformation.				✓	
Concrete Foundation - Check for cracks, spalling , etc.				✓	
Ladder/Platform - Describe general condition, ensure support is secure to vessel, describe any hazards.				✓	
Nozzle - Assess paint, look for leakage, and ensure stud threads are fully engaged. Record any damage, deflection, etc. Are nozzles gusseted? Inspect gussets for cracking.	✓				
Gauges - Ensure gauges are visible, working, no leakage, and suitable for range of MAWP/Temp.				✓	
External Piping - Ensure pipe is well supported. All clamps, supports, shoes, etc. in place. Look for evidence of structural overload, deflection, etc. Paint condition, external corrosion?	✓				
Valving - Ensure no leaks are visible. Valves are properly supported and chained if necessary.	✓				
PSV - Ensure PSV is set at pressure at or below that of vessel. Discharge piping is same size as valve outlet and is properly supported and routed. Are PSV seals in place? Ensure no block valves between PSV and vessel, or if there are that they are locked/sealed open.					No Access See MT Information
NDE Methods - Was UT/ MPI done on vessel					

Other Observations: VE Done when verifying name plate Data. See Photos

REVIEWED & ACCEPTED
DWAYNE BUNCH
JUL 06 2011
IPV FILE # A-63359
API-510 CERT # 26926
Dwayne Bunch

Inspected By : ______ **Date :** ______
Print Name : ______ **PESL #** ______ **API #** ______




CERTIFIED BY
EXCHANGER INDUSTRIES
A DIVISION OF PREMETALCO INC.
CALGARY, ALBERTA, CANADA
MAWP: SHELL 1860 PSIG AT
MAEWP: SHELL AT
MAWP: TUBE 1860 PSIG AT 428 F
MAEWP: TUBE AT
MDMT: SHELL -20 F AT 1860 PSIG
MDMT: TUBE -20 F AT 1860 PSIG
SERIAL NO.
YEAR MFD. 2010
ITEM: E-200A
TEMA TYPE R
FULL OF WATER=10850 LBS
SURFACE AREA
PROV. REG. 550316
CRN V2159.2
SH-1001

Appendix C:

PV-Elite Model and Calculations

201, 9637-45 Ave, Edmonton, AB T6E 5Z8. Tel: 780-434-9292, Fax: 780-434-9219

Table of Contents

DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

ASME Code Version : 2015

Analysis Performed by : CANADIAN ENGINEERING & INSPECTION LTD

Job File : C:\USERS\PAUL\CANEIL.CA\GREG JOSS - GENERAL\JOB

Date of Analysis : Apr 7,2021 3:35pm

PV Elite 2016, January 2016

Title Page

Class From To : Basic Element Checks.
==

Class From To: Check of Additional Element Data
==

There were no geometry errors or warnings.

PV Elite Vessel Analysis Program: Input Data

Exchanger Design Pressures and Temperatures

Shell Side Design Pressure	900.00	psig
Channel Side Design Pressure	900.00	psig
Shell Side Design Temperature	428	°F
Channel Side Design Temperature	428	°F

Type of Hydrotest	User Entered Pressure	
Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0.0000	in.
Projection of Nozzle from Vessel Bottom	0.0000	in.
Type of Construction	Welded	
Special Service	Sour	
Degree of Radiography	RT 1	
Use Higher Longitudinal Stresses (Flag)	N	
Select t for Internal Pressure (Flag)	N	
Select t for External Pressure (Flag)	N	
Select t for Axial Stress (Flag)	N	
Select Location for Stiff. Rings (Flag)	N	
Consider Vortex Shedding	N	
Perform a Corroded Hydrotest	N	
Is this a Heat Exchanger	Yes	
User Defined Hydro. Press. (Used if > 0)	0.0000	psig
User defined MAWP	0.0000	psig
User defined MAPnc	0.0000	psig

Load Case 1	NP+EW+WI+FW+BW
Load Case 2	NP+EW+EE+FS+BS
Load Case 3	NP+OW+WI+FW+BW
Load Case 4	NP+OW+EQ+FS+BS
Load Case 5	NP+HW+HI
Load Case 6	NP+HW+HE
Load Case 7	IP+OW+WI+FW+BW
Load Case 8	IP+OW+EQ+FS+BS
Load Case 9	EP+OW+WI+FW+BW
Load Case 10	EP+OW+EQ+FS+BS
Load Case 11	HP+HW+HI
Load Case 12	HP+HW+HE
Load Case 13	IP+WE+EW
Load Case 14	IP+WF+CW
Load Case 15	IP+VO+OW
Load Case 16	IP+VE+EW
Load Case 17	NP+VO+OW
Load Case 18	FS+BS+IP+OW
Load Case 19	FS+BS+EP+OW

Wind Design Code		ASCE-7 93	
Basic Wind Speed	[V]	70.000	mile/hr
Surface Roughness Category		C: Open Terrain	
Importance Factor		1.0	

Type of Surface	Moderately Smooth	
Base Elevation	0.0000	ft.
Percent Wind for Hydrotest	33.0	
Using User defined Wind Press. Vs Elev.	N	
Damping Factor (Beta) for Wind (Ope)	0.0100	
Damping Factor (Beta) for Wind (Empty)	0.0000	
Damping Factor (Beta) for Wind (Filled)	0.0000	

Seismic Design Code	UBC 94
UBC Seismic Zone (1=1,2=2a,3=2b,4=3,5=4)	0.000
UBC Importance Factor	1.000
UBC Soil Type	S1
UBC Horizontal Force Factor	3.000
UBC Percent Seismic for Hydrotest	0.000

Design Nozzle for Des. Press. + St. Head	Y
Consider MAP New and Cold in Noz. Design	N
Consider External Loads for Nozzle Des.	Y
Use ASME VIII-1 Appendix 1-9	N

Material Database Year   Current w/Addenda or Code Year

Configuration Directives:

Do not use Nozzle MDMT Interpretation VIII-1 01-37	No
Use Table G instead of exact equation for "A"	Yes
Shell Head Joints are Tapered	Yes
Compute "K" in corroded condition	Yes
Use Code Case 2286	No
Use the MAWP to compute the MDMT	Yes
Using Metric Material Databases, ASME II D	No

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Elliptical	
Description	Shell side Head	
Distance "FROM" to "TO"	0.1667	ft.
Element Outside Diameter	16.000	in.
Element Thickness	1.1250	in.
Internal Corrosion Allowance	0.1250	in.
Nominal Thickness	1.1250	in.
External Corrosion Allowance	0.0000	in.
Design Internal Pressure	900.00	psig
Design Temperature Internal Pressure	428	°F
Design External Pressure	0.0000	psig
Design Temperature External Pressure	300	°F
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Allowable Stress, Ambient	20000.	psi
Allowable Stress, Operating	20000.	psi
Allowable Stress, Hydrotest	26000.	psi
Material Density	0.2800	lb./in³

P Number Thickness	1.2500	in.
Yield Stress, Operating	32080.	psi
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Elliptical Head Factor	2.0	

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	Shell Side	
Distance "FROM" to "TO"	22.344	ft.
Element Outside Diameter	16.000	in.
Element Thickness	1.2190	in.
Internal Corrosion Allowance	0.1250	in.
Nominal Thickness	1.2190	in.
External Corrosion Allowance	0.0000	in.
Design Internal Pressure	900.00	psig
Design Temperature Internal Pressure	428	°F
Design External Pressure	0.0000	psig
Design Temperature External Pressure	428	°F
Effective Diameter Multiplier	1.2	
Material Name	SA-333 6	[Impact Tested]
Allowable Stress, Ambient	17100.	psi
Allowable Stress, Operating	17100.	psi
Allowable Stress, Hydrotest	22230.	psi
Material Density	0.2800	lb./in³
P Number Thickness	1.2500	in.
Yield Stress, Operating	29508.	psi
UCS-66 Chart Curve Designation	Impact Tested	
External Pressure Chart Name	CS-2	
UNS Number	K03006	
Product Form	Smls. & wld. pipe	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	

Element From Node	20	
Detail Type	Saddle	
Detail ID	Lft Sdl	
Dist. from "FROM" Node / Offset dist	4.0521	ft.
Width of Saddle	4.0000	in.
Height of Saddle at Bottom	16.000	in.
Saddle Contact Angle	180.0	
Height of Composite Ring Stiffener	0.0000	in.
Width of Wear Plate	6.0000	in.
Thickness of Wear Plate	0.2500	in.
Contact Angle, Wear Plate (degrees)	180.0	

Element From Node	20	

Detail Type	Saddle	
Detail ID	Sdl 2 Fr20	
Dist. from "FROM" Node / Offset dist	19.052	ft.
Width of Saddle	4.0000	in.
Height of Saddle at Bottom	16.000	in.
Saddle Contact Angle	180.0	
Height of Composite Ring Stiffener	0.0000	in.
Width of Wear Plate	6.0000	in.
Thickness of Wear Plate	0.2500	in.
Contact Angle, Wear Plate (degrees)	180.0	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	S1(Shell Inlet)	
Dist. from "FROM" Node / Offset dist	21.854	ft.
Nozzle Diameter	4.375	in.
Nozzle Schedule	160	
Nozzle Class	900	
Layout Angle	90.0	
Blind Flange (Y/N)	Y	
Weight of Nozzle (Used if > 0)	0.0000	lb.
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-266 4	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	S2(Shell Outlet	
Dist. from "FROM" Node / Offset dist	21.854	ft.
Nozzle Diameter	4.375	in.
Nozzle Schedule	160	
Nozzle Class	900	
Layout Angle	270.0	
Blind Flange (Y/N)	Y	
Weight of Nozzle (Used if > 0)	0.0000	lb.
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-266 4	

Element From Node	30	
Element To Node	40	
Element Type	Flange	
Description	Shell Side Flange	
Distance "FROM" to "TO"	0.4583	ft.
Flange Inside Diameter	13.562	in.
Element Thickness	3.8125	in.
Internal Corrosion Allowance	0.1250	in.
Nominal Thickness	1.2190	in.
External Corrosion Allowance	0.0000	in.
Design Internal Pressure	900.00	psig
Design Temperature Internal Pressure	428	°F
Design External Pressure	0.0000	psig
Design Temperature External Pressure	428	°F
Effective Diameter Multiplier	1.2	

Material Name	SA-350 LF2	[Impact Tested]
Allowable Stress, Ambient	20000.	psi
Allowable Stress, Operating	19888.	psi
Allowable Stress, Hydrotest	26000.	psi
Material Density	0.2800	lb./in³
P Number Thickness	1.2500	in.
Yield Stress, Operating	30380.	psi
UCS-66 Chart Curve Designation	Impact Tested	
External Pressure Chart Name	CS-2	
UNS Number	K03011	
Class / Thickness / Grade 1::		
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0.0000	lb.
Class of ANSI B16.5/B16.47 Flange		
Grade of ANSI B16.5/B16.47 Flange		

Element From Node	40	
Element To Node	50	
Element Type	Flange	
Description	Channel Flange	
Distance "FROM" to "TO"	0.4531	ft.
Flange Inside Diameter	13.562	in.
Element Thickness	3.6875	in.
Internal Corrosion Allowance	0.07813	in.
Nominal Thickness	3.6875	in.
External Corrosion Allowance	0.0000	in.
Design Internal Pressure	900.00	psig
Design Temperature Internal Pressure	428	°F
Design External Pressure	0.0000	psig
Design Temperature External Pressure	428	°F
Effective Diameter Multiplier	1.2	
Material Name	SA-350 LF2	[Impact Tested]
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0.0000	lb.
Class of ANSI B16.5/B16.47 Flange		
Grade of ANSI B16.5/B16.47 Flange		

Element From Node	50	
Element To Node	60	
Element Type	Cylinder	
Description	channel shell	
Distance "FROM" to "TO"	0.9583	ft.
Element Outside Diameter	16.000	in.
Element Thickness	1.2190	in.
Internal Corrosion Allowance	0.07813	in.
Nominal Thickness	1.2190	in.
External Corrosion Allowance	0.0000	in.
Design Internal Pressure	900.00	psig
Design Temperature Internal Pressure	428	°F

Design External Pressure	0.0000	psig
Design Temperature External Pressure	428	°F
Effective Diameter Multiplier	1.2	
Material Name	SA-333 6	[Impact Tested]
Allowable Stress, Ambient	17100.	psi
Allowable Stress, Operating	17100.	psi
Allowable Stress, Hydrotest	22230.	psi
Material Density	0.2800	lb./in³
P Number Thickness	1.2500	in.
Yield Stress, Operating	29508.	psi
UCS-66 Chart Curve Designation	Impact Tested	
External Pressure Chart Name	CS-2	
UNS Number	K03006	
Product Form	Smls. & wld. pipe	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	

Element From Node	50	
Detail Type	Nozzle	
Detail ID	T2(Channel Out)	
Dist. from "FROM" Node / Offset dist	0.4792	ft.
Nozzle Diameter	4.375	in.
Nozzle Schedule	160	
Nozzle Class	900	
Layout Angle	90.0	
Blind Flange (Y/N)	Y	
Weight of Nozzle (Used if > 0)	0.0000	lb.
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-266 4	

Element From Node	50	
Detail Type	Nozzle	
Detail ID	T1	
Dist. from "FROM" Node / Offset dist	0.4792	ft.
Nozzle Diameter	4.375	in.
Nozzle Schedule	160	
Nozzle Class	900	
Layout Angle	270.0	
Blind Flange (Y/N)	Y	
Weight of Nozzle (Used if > 0)	0.0000	lb.
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-266 4	

Element From Node	60	
Element To Node	70	
Element Type	Elliptical	
Description	channel head	
Distance "FROM" to "TO"	0.1667	ft.
Element Outside Diameter	16.000	in.
Element Thickness	1.1250	in.
Internal Corrosion Allowance	0.07813	in.
Nominal Thickness	1.1250	in.

External Corrosion Allowance	0.0000	in.
Design Internal Pressure	900.00	psig
Design Temperature Internal Pressure	428	°F
Design External Pressure	0.0000	psig
Design Temperature External Pressure	428	°F
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Allowable Stress, Ambient	20000.	psi
Allowable Stress, Operating	20000.	psi
Allowable Stress, Hydrotest	26000.	psi
Material Density	0.2800	lb./in³
P Number Thickness	1.2500	in.
Yield Stress, Operating	32080.	psi
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Elliptical Head Factor	2.0	

XY Coordinate Calculations

From	To	X (Horiz.) ft.	Y (Vert.) ft.	DX (Horiz.) ft.	DY (Vert.) ft.
Shell	side	0.16667	...	0.16667	...
Shell	Side	22.5105	...	22.3438	...
Shell	Side	22.9688	...	0.45833	...
Channel	Fl	23.7500	...	0.45312	...
channel	sh	24.7084	...	0.95833	...
channel	he	24.8750	...	0.16667	...

Flange Input Data Values   **Description: Shell FLANGE :**

Shell Side Flange

```
Description of Flange Geometry (Type)          Integral Weld Neck
Design Pressure                         P         900.00  psig
Design Temperature                                   428  °F
Internal Corrosion Allowance           ci         0.1250  in.
External Corrosion Allowance           ce         0.0000  in.
Use Corrosion Allowance in Thickness Calcs.           No

Flange Inside Diameter                  B         13.562  in.
Flange Outside Diameter                 A         24.000  in.
Flange Thickness                        t         3.8125  in.
Thickness of Hub at Small End          go         1.2190  in.
Thickness of Hub at Large End          g1         1.4690  in.
Length of Hub                           h         1.6875  in.

Flange Material                                SA-350 LF2
Flange Material UNS number                         K03011
Flange Allowable Stress At Temperature   Sfo    19888.00  psi
Flange Allowable Stress At Ambient       Sfa    20000.00  psi

Bolt Material                                  SA-193 B7
Bolt Allowable Stress At Temperature     Sb     25000.00  psi
Bolt Allowable Stress At Ambient         Sa     25000.00  psi

Diameter of Bolt Circle                 C         20.750  in.
Nominal Bolt Diameter                   a         1.6250  in.
Type of Threads                        TEMA Thread Series
Number of Bolts                                       16

Flange Face Outside Diameter          Fod         16.375  in.
Flange Face Inside Diameter           Fid         13.562  in.
Flange Facing Sketch                    1, Code Sketch 1a

Gasket Outside Diameter                Go         16.250  in.
Gasket Inside Diameter                 Gi         14.500  in.
Gasket Factor                           m         2.5000
Gasket Design Seating Stress            y       10000.00  psi

Column for Gasket Seating               2, Code Column II
Gasket Thickness                       tg         0.1750  in.
```

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Hub Small End Required Thickness due to Internal Pressure:

```
 = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
 = (900.00*(13.5620/2+0.1250))/(19888.00*1.00-0.6*900.00)+Ca
 = 0.4462 in.
```

Hub Small End Hub MAWP:

```
 = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
```

= (19888.00 * 1.00 * 1.0940)/(6.9060 + 0.6 * 1.0940)
= 2877.059 psig

Corroded Flange ID,	Bcor = B+2*Fcor	13.812	in.
Corroded Large Hub,	g1Cor = g1-ci	1.344	in.
Corroded Small Hub,	g0Cor = go-ci	1.094	in.
Code R Dimension,	R = ((C-Bcor)/2)-g1cor	2.125	in.
Gasket Contact Width,	N = (Go - Gi) / 2	0.875	in.
Basic Gasket Width,	bo = N / 2	0.438	in.
Effective Gasket Width,	b = sqrt(bo) / 2	0.331	in.
Gasket Reaction Diameter,	G = Go - 2 * b	15.589	in.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
= 0.785 * G^2 * Peq
= 0.785 * 15.5886^2 * 900.000
= 171768.891 lb.

Contact Load on Gasket Surfaces [Hp]:
= 2 * b * Pi * G * m * P
= 2 * 0.3307 * 3.1416 * 15.5886 * 2.5000 * 900.00
= 72883.203 lb.

Hydrostatic End Load at Flange ID [Hd]:
= Pi * $Bcor^2$ * P / 4
= 3.1416 * 13.8120^2 *900.0000/4
= 134848.328 lb.

Pressure Force on Flange Face [Ht]:
= H - Hd
= 171769 - 134848
= 36920.562 lb.

Operating Bolt Load [Wm1]:
= max(H + Hp + H'p, 0)
= max(171769 + 72883 + 0 , 0)
= 244652.094 lb.

Gasket Seating Bolt Load [Wm2]:
= y * b * Pi * G + yPart * bPart * lp
= 10000.00*0.3307*3.141*15.589+0.00*0.0000*0.00
= 161962.672 lb.

Required Bolt Area [Am]:
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 244652/25000 , 161963/25000
= 9.786 in^2

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
= 2a + 6t/(m + 0.5)
= 2 * 1.625 + 6 * 3.812/(2.50 + 0.5)
= 10.875 in.

Actual Circumferential Bolt Spacing [Bs]:
= C * sin(pi / n)
= 20.750 * sin(3.142/16)
= 4.048 in.

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:

```
= max( sqrt( Bs/( 2a + t )), 1 )
= max( sqrt( 4.048/( 2 * 1.625 + 3.812 )), 1 )
= 1.0000
```

Bolting Information for TEMA Imperial Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, in²	9.786	26.880	
Radial distance bet. hub and bolts	2.125	2.125	
Radial distance bet. bolts and the edge	1.625	1.625	
Circumferential spacing between bolts	3.500	4.048	10.875

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:

```
= Ab * Sa/( y * Pi * (Go + Gi) )
= 26.880 * 25000.00/(10000.00 * 3.14 * (16.250 + 14.50 ) )
= 0.696 in.
```

Flange Design Bolt Load, Gasket Seating [W]:

```
= Sa * ( Am + Ab ) / 2
= 25000.00 * ( 9.7861 + 26.8800 )/2
= 458326.06 lb.
```

Gasket Load for the Operating Condition [HG]:

```
= Wm1 - H
= 244652 - 171769
= 72883.20 lb.
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
= (C - G ) / 2
= ( 20.7500 - 15.5886 )/2
= 2.5807 in.
```

Distance to Face Pressure Reaction [ht]:

```
= ( R + g1 + hg ) / 2
= ( 2.1250 + 1.3440 + 2.5807 )/2
= 3.0249 in.
```

Distance to End Pressure Reaction [hd]:

```
= R + ( g1 / 2 )
= 2.1250 + ( 1.3440/2.0 )
= 2.7970 in.
```

Summary of Moments for Internal Pressure:

Loading		Force	Distance	Bolt Corr	Moment	
End Pressure,	Md	134848.	2.7970	1.0000	31431.	ft.lb.
Face Pressure,	Mt	36921.	3.0249	1.0000	9307.	ft.lb.
Gasket Load,	Mg	72883.	2.5807	1.0000	15674.	ft.lb.
Gasket Seating,	Matm	458326.	2.5807	1.0000	98568.	ft.lb.

```
Total Moment for Operation,      Mop                  56412. ft.lb.
Total Moment for Gasket seating, Matm                 98568. ft.lb.

Effective Hub Length, ho = sqrt(Bcor*goCor)           3.887  in.
```

```
Hub Ratio,          h/h0 = HL / H0                      0.434
Thickness Ratio,   g1/g0 = (g1Cor/goCor)                1.229
```

Flange Factors for Integral Flange:

```
Factor F                                                0.879
Factor V                                                0.416
Factor f                                                1.000
Factors from Figure 2-7.1                    K =        1.738
                    T =      1.610           U =        4.052
                    Y =      3.687           Z =        1.990
                    d =     45.259 in.³      e =       0.2262 in.^-1
Stress Factors                           ALPHA =        1.862
                 BETA =      2.150       GAMMA =        1.157
                DELTA =      1.224       Lamda =        2.381
```

Longitudinal Hub Stress, Operating [SHo]:

```
 = ( f * Mop / Bcor ) / ( L * g1² )
 = (1.0000*676941/13.8120)/(2.3813*1.3440²)
 = 11393.92 psi
```

Longitudinal Hub Stress, Seating [SHa]:

```
 = ( f * Matm / Bcor ) / ( L * g1² )
 = (1.0000*1182811/13.8120)/(2.3813*1.3440²)
 = 19908.45 psi
```

Radial Flange Stress, Operating [SRo]:

```
 = ( Beta * Mop / Bcor ) / ( L * t² )
 = (2.1498*676941/13.8120)/(2.3813*3.8125²)
 = 3044.03 psi
```

Radial Flange Stress, Seating [SRa]:

```
 = ( Beta * Matm/Bcor ) / ( L * t² )
 = (2.1498*1182811/13.8120)/(2.3813*3.8125²)
 = 5318.80 psi
```

Tangential Flange Stress, Operating [STo]:

```
 = ( Y * Mo / (t² * Bcor) ) - Z * SRo
 = (3.6870*676941/(3.8125²*13.8120))-1.9904*3044
 = 6373.16 psi
```

Tangential Flange Stress, Seating [STa]:

```
 = ( y * Matm / (t² * Bcor) ) - Z * SRa
 = (3.6870*1182811/(3.8125²*13.8120))-1.9904*5319
 = 11135.74 psi
```

Average Flange Stress, Operating [SAo]:

```
 = ( SHo + max( SRo, STo ) ) / 2
 = (11394+max(3044,6373))/2
 = 8883.54 psi
```

Average Flange Stress, Seating [SAa]:

```
 = ( SHa + max( SRa, STa ) ) / 2
 = (19908+max(5319,11136))/2
 = 15522.09 psi
```

Bolt Stress, Operating [BSo]:

```
 = ( Wm1 / Ab )
 = (244652/26.8800)
```

= 9101.64 psi

Bolt Stress, Seating [BSa]:

= (Wm2 / Ab)
= (161963/26.8800)
= 6025.40 psi

Flange Stress Analysis Results: psi

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	11394.	29832.	19908.	30000.
Radial Flange	3044.	19888.	5319.	20000.
Tangential Flange	6373.	19888.	11136.	20000.
Maximum Average	8884.	19888.	15522.	20000.
Bolting	9102.	25000.	6025.	25000.

Minimum Required Flange Thickness	3.134	in.
Estimated M.A.W.P. (Operating)	2014.9	psig
Estimated Finished Weight of Flange at given Thk.	358.5	lbm
Estimated Unfinished Weight of Forging at given Thk	474.2	lbm

<u>Flange Rigidity Based on Required Thickness [ASME]:</u>

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go^(2) * ho * Ki)
= 52.14 * 98567.6/1.0000 * 12.000 * 0.416/(1.741 * 29400000 * 1.094^(2) * 3.887 * 0.300)
= 0.359 (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc^(2) * ho * Ki)
= 52.14 * 56411.8/1.0000 * 12.000 * 0.416/(1.741 * 27732000 * 1.094^(2) * 3.887 * 0.300)
= 0.218 (should be <= 1)

<u>Flange Rigidity Based on Given Thickness [ASME]:</u>

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go^(2) * ho * Ki)
= 52.14 * 98567.6/1.0000 * 12.000 * 0.416/(2.381 * 29400000 * 1.094^(2) * 3.887 * 0.300)
= 0.263 (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc^(2) * ho * Ki)
= 52.14 * 56411.8/1.0000 * 12.000 * 0.416/(2.381 * 27732000 * 1.094^(2) * 3.887 * 0.300)
= 0.159 (should be <= 1)

Minimum Design Metal Temperature Results:

Note: This Material was specified as being supplied in the Impact Tested condition (Low Temperature Material).

Impact Test Temperature provided per Specification   -50 °F

Flange Input Data Values **Description: Chan FLANGE :**

Channel Flange

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	900.00	psig
Design Temperature		428	°F
Internal Corrosion Allowance	ci	0.0781	in.
External Corrosion Allowance	ce	0.0000	in.
Use Corrosion Allowance in Thickness Calcs.		No	
Flange Inside Diameter	B	13.562	in.
Flange Outside Diameter	A	24.000	in.
Flange Thickness	t	3.6875	in.
Thickness of Hub at Small End	go	1.2190	in.
Thickness of Hub at Large End	g1	1.4690	in.
Length of Hub	h	1.7500	in.
Flange Material		SA-350 LF2	
Flange Material UNS number		K03011	
Flange Allowable Stress At Temperature	Sfo	19888.00	psi
Flange Allowable Stress At Ambient	Sfa	20000.00	psi
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	25000.00	psi
Bolt Allowable Stress At Ambient	Sa	25000.00	psi
Diameter of Bolt Circle	C	20.750	in.
Nominal Bolt Diameter	a	1.6250	in.
Type of Threads		TEMA Thread Series	
Number of Bolts		16	
Flange Face Outside Diameter	Fod	16.375	in.
Flange Face Inside Diameter	Fid	13.562	in.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	16.250	in.
Gasket Inside Diameter	Gi	14.500	in.
Gasket Factor	m	2.5000	
Gasket Design Seating Stress	y	10000.00	psi
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	0.1750	in.

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Hub Small End Required Thickness due to Internal Pressure:
 = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
 = (900.00*(13.5620/2+0.0781))/(19888.00*1.00-0.6*900.00)+Ca
 = 0.3972 in.

Hub Small End Hub MAWP:
 = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)

```
 = (19888.00 * 1.00 * 1.1409 )/(6.8591 + 0.6 * 1.1409 )
 = 3007.791 psig

Corroded Flange ID,       Bcor = B+2*Fcor              13.718  in.
Corroded Large Hub,       g1Cor = g1-ci                 1.391  in.
Corroded Small Hub,       g0Cor = go-ci                 1.141  in.
Code R Dimension,             R = ((C-Bcor)/2)-g1cor    2.125  in.

Gasket Contact Width,         N = (Go - Gi) / 2         0.875  in.
Basic Gasket Width,          bo = N / 2                 0.438  in.
Effective Gasket Width,       b = sqrt(bo) / 2          0.331  in.
Gasket Reaction Diameter,     G = Go - 2 * b           15.589  in.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
 = 0.785 * G² * Peq
 = 0.785 * 15.5886² * 900.000
 = 171768.891 lb.
```
Contact Load on Gasket Surfaces [Hp]:
```
 = 2 * b * Pi * G * m * P
 = 2 * 0.3307 * 3.1416 * 15.5886 * 2.5000 * 900.00
 = 72883.203 lb.
```
Hydrostatic End Load at Flange ID [Hd]:
```
 = Pi * Bcor² * P  / 4
 = 3.1416 * 13.7183² *900.0000/4
 = 133023.953 lb.
```
Pressure Force on Flange Face [Ht]:
```
 = H - Hd
 = 171769 - 133024
 = 38744.938 lb.
```
Operating Bolt Load [Wm1]:
```
 = max( H + Hp + H'p, 0 )
 = max( 171769 + 72883 + 0 , 0 )
 = 244652.094 lb.
```
Gasket Seating Bolt Load [Wm2]:
```
 = y * b * Pi * G  + yPart * bPart * lp
 = 10000.00*0.3307*3.141*15.589+0.00*0.0000*0.00
 = 161962.672 lb.
```
Required Bolt Area [Am]:
```
 = Maximum of Wm1/Sb, Wm2/Sa
 = Maximum of 244652/25000 , 161963/25000
 = 9.786 in²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
 = 2a + 6t/(m + 0.5)
 = 2 * 1.625 + 6 * 3.688/(2.50 + 0.5)
 = 10.625 in.
```

Actual Circumferential Bolt Spacing [Bs]:
```
 = C * sin( pi / n )
 = 20.750 * sin( 3.142/16 )
 = 4.048 in.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(4.048/(2 * 1.625 + 3.688)), 1)
= 1.0000

Bolting Information for TEMA Imperial Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, in²	9.786	26.880	
Radial distance bet. hub and bolts	2.125	2.125	
Radial distance bet. bolts and the edge	1.625	1.625	
Circumferential spacing between bolts	3.500	4.048	10.625

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
= Ab * Sa/(y * Pi * (Go + Gi))
= 26.880 * 25000.00/(10000.00 * 3.14 * (16.250 + 14.50))
= 0.696 in.

Flange Design Bolt Load, Gasket Seating [W]:
= Sa * (Am + Ab) / 2
= 25000.00 * (9.7861 + 26.8800)/2
= 458326.06 lb.

Gasket Load for the Operating Condition [HG]:
= Wm1 - H
= 244652 - 171769
= 72883.20 lb.

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (20.7500 - 15.5886)/2
= 2.5807 in.

Distance to Face Pressure Reaction [ht]:
= (R + g1 + hg) / 2
= (2.1250 + 1.3909 + 2.5807)/2
= 3.0483 in.

Distance to End Pressure Reaction [hd]:
= R + (g1 / 2)
= 2.1250 + (1.3909/2.0)
= 2.8204 in.

Summary of Moments for Internal Pressure:

Loading		Force	Distance	Bolt Corr	Moment	
End Pressure,	Md	133024.	2.8204	1.0000	31265.	ft.lb.
Face Pressure,	Mt	38745.	3.0483	1.0000	9842.	ft.lb.
Gasket Load,	Mg	72883.	2.5807	1.0000	15674.	ft.lb.
Gasket Seating,	Matm	458326.	2.5807	1.0000	98568.	ft.lb.

Total Moment for Operation,   Mop   56782. ft.lb.
Total Moment for Gasket seating, Matm   98568. ft.lb.

Effective Hub Length, ho = sqrt(Bcor*goCor)   3.956 in.

```
Hub Ratio,           h/h0 = HL / H0                        0.442
Thickness Ratio,    g1/g0 = (g1Cor/goCor)                  1.219

Flange Factors for Integral Flange:
Factor F                                                   0.880
Factor V                                                   0.419
Factor f                                                   1.000
Factors from Figure 2-7.1                         K =      1.749
                    T =      1.605                U =      4.004
                    Y =      3.644                Z =      1.971
                    d =     49.172 in.³           e =     0.2223 in.^-1
Stress Factors                                ALPHA =      1.820
                 BETA =      2.093            GAMMA =      1.134
                DELTA =      1.020            Lamda =      2.154

Longitudinal Hub Stress, Operating [SHo]:
 = ( f * Mop / Bcor ) / ( L * g1² )
 = (1.0000*681383/13.7183)/(2.1537*1.3909²)
 = 11921.73 psi
Longitudinal Hub Stress, Seating [SHa]:
 = ( f * Matm / Bcor ) / ( L * g1² )
 = (1.0000*1182811/13.7183)/(2.1537*1.3909²)
 = 20694.90 psi

Radial Flange Stress, Operating [SRo]:
 = ( Beta * Mop / Bcor ) / ( L * t² )
 = (2.0931*681383/13.7183)/(2.1537*3.6875²)
 = 3550.07 psi
Radial Flange Stress, Seating [SRa]:
 = ( Beta * Matm/Bcor ) / ( L * t² )
 = (2.0931*1182811/13.7183)/(2.1537*3.6875²)
 = 6162.55 psi

Tangential Flange Stress, Operating [STo]:
 = ( Y * Mo / (t² * Bcor) ) - Z * SRo
 = (3.6439*681383/(3.6875²*13.7183))-1.9705*3550
 = 6314.84 psi
Tangential Flange Stress, Seating [STa]:
 = ( y * Matm / (t² * Bcor) ) - Z * SRa
 = (3.6439*1182811/(3.6875²*13.7183))-1.9705*6163
 = 10961.91 psi

Average Flange Stress, Operating [SAo]:
 = ( SHo + max( SRo, STo ) ) / 2
 = (11922+max(3550,6315))/2
 = 9118.28 psi
Average Flange Stress, Seating [SAa]:
 = ( SHa + max( SRa, STa ) ) / 2
 = (20695+max(6163,10962))/2
 = 15828.40 psi

Bolt Stress, Operating [BSo]:
 = ( Wm1 / Ab )
 = (244652/26.8800)
```

= 9101.64 psi

Bolt Stress, Seating [BSa]:

= (Wm2 / Ab)
= (161963/26.8800)
= 6025.40 psi

Flange Stress Analysis Results: psi

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	11922.	29832.	20695.	30000.
Radial Flange	3550.	19888.	6163.	20000.
Tangential Flange	6315.	19888.	10962.	20000.
Maximum Average	9118.	19888.	15828.	20000.
Bolting	9102.	25000.	6025.	25000.

```
Minimum Required Flange Thickness                        3.037  in.
Estimated M.A.W.P. ( Operating )                        1963.0  psig
Estimated Finished Weight of Flange at given Thk.        348.8  lbm
Estimated Unfinished Weight of Forging at given Thk      468.8  lbm
```

<u>Flange Rigidity Based on Required Thickness [ASME]:</u>

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go^(2) * ho * Ki)
= 52.14 * 98567.6/1.0000 * 12.000 * 0.419/(1.613 * 29400000 * 1.141^(2) * 3.956 * 0.300)
= 0.353   (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc^(2) * ho * Ki)
= 52.14 * 56781.9/1.0000 * 12.000 * 0.419/(1.613 * 27732000 * 1.141^(2) * 3.956 * 0.300)
= 0.216   (should be <= 1)

<u>Flange Rigidity Based on Given Thickness [ASME]:</u>

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go^(2) * ho * Ki)
= 52.14 * 98567.6/1.0000 * 12.000 * 0.419/(2.154 * 29400000 * 1.141^(2) * 3.956 * 0.300)
= 0.264   (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc^(2) * ho * Ki)
= 52.14 * 56781.9/1.0000 * 12.000 * 0.419/(2.154 * 27732000 * 1.141^(2) * 3.956 * 0.300)
= 0.161   (should be <= 1)

Minimum Design Metal Temperature Results:

Note: This Material was specified as being supplied in the Impact Tested condition (Low Temperature Material).

Impact Test Temperature provided per Specification   -50 °F

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd psig	Nominal Thickness in.	Total Corr Allowance in.	Element Diameter in.	Allowable Stress(SE) psi
Shell side		900.000	1.12500	0.12500	16.0000	20000.0
Shell Side		900.000	1.21900	0.12500	16.0000	17100.0
Shell Side		900.000	1.21900	0.12500	13.5620	19888.0
Channel Fl		900.000	3.68750	0.078125	13.5620	19888.0
channel sh		900.000	1.21900	0.078125	16.0000	17100.0
channel he		900.000	1.12500	0.078125	16.0000	20000.0

Element Required Thickness and MAWP :

From	To	Design Pressure psig	M.A.W.P. Corroded psig	M.A.P. New & Cold psig	Minimum Thickness in.	Required Thickness in.
Shell side		900.000	2631.58	3220.04	1.12500	0.46330
Shell Side		900.000	2473.74	2774.73	1.21900	0.53737
Shell Side		900.000	1872.79	2141.88	3.81250	3.13400
Channel Fl		900.000	1788.71	1998.27	3.68750	3.03700
channel sh		900.000	2586.14	2774.73	1.21900	0.49050
channel he		900.000	2761.75	3220.04	1.12500	0.41923

Summary of Heat Exchanger Maximum Allowable Working Pressures :

Note:
The MAWPs and MAPs for the Exchanger elements all appear to be zero or some could not be calculated. Please fill these values in on the main tubesheet tab.

Internal Pressure Calculation Results :

ASME Code, Section VIII, Division 1, 2015

Elliptical Head From 10 To 20 SA-516 70 , UCS-66 Crv. B at 428 °F

Shell side Head

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*Do*Kcor)/(2*S*E+2*P*(Kcor-0.1)) per Appendix 1-4 (c)
= (900.000*16.0000*0.977)/(2*20000.00*1.00+2*900.000*(0.977-0.1))
= 0.3383 + 0.1250 = 0.4633 in.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= (2*S*E*t)/(Kcor*Do-2*t*(Kcor-0.1)) per Appendix 1-4 (c)
= (2*20000.00*1.00*1.0000)/(0.977*16.0000-2*1.0000*(0.98-0.1))
= 2882.802 psig

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (2*S*E*t)/(K*Do-2*t*(K-0.1)) per Appendix 1-4 (c)
= (2*20000.00*1.00*1.1250)/(1.000*16.0000-2*1.1250*(1.000-0.1))
= 3220.036 psig

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*Do-2*t*(Kcor-0.1)))/(2*E*t)
= (900.000*(0.977*16.0000-2*1.0000*(0.977-0.1)))/(2*1.00*1.0000)
= 6243.924 psi

Straight Flange Required Thickness:
= (P*Ro)/(S*E+0.4*P) + ca   per Appendix 1-1 (a)(1)
= (900.000*8.0000)/(20000.00*1.00+0.4*900.000)+0.125
= 0.479 in.

Straight Flange Maximum Allowable Working Pressure:
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (20000.00 * 1.00 * 1.0000)/(8.0000 - 0.4 * 1.0000)
= 2631.579 psig

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))^(2))/6
= (2 + (14.000/(2 * 3.562))^(2))/6
= 0.976813

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 29.095 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 1.125 , tr = 0.676 , c = 0.1250 in. , E* = 1.00
Stress Ratio = tr * (E*)/(tg - c) = 0.676 , Temp. Reduction = 32 °F

Min Metal Temp. w/o impact per UCS-66, Curve B   37 °F
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit   7 °F
Min Metal Temp. at Required thickness (UCS 66.1)   -26 °F

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 1.125 , tr = 0.722 , c = 0.1250 in. , E* = 1.00
Stress Ratio = tr * (E*)/(tg - c) = 0.722 , Temp. Reduction = 28 °F

Min Metal Temp. w/o impact per UCS-66, Curve B   37 °F
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit   7 °F
Min Metal Temp. at Required thickness (UCS 66.1)   -21 °F

Cylindrical Shell From 20 To 30 SA-333 6 at 428 °F

Shell Side

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:
= (P*Ro) / (S*E+0.4*P) per Appendix 1-1 (a)(1)

```
 = (900.000*8.0000)/(17100.00*1.00+0.4*900.000)
 = 0.4124 + 0.1250 = 0.5374 in.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:

```
 = (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
 = (17100.00*1.00*1.0940)/(8.0000-0.4*1.0940)
 = 2473.739 psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
 = (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
 = (17100.00*1.00*1.2190)/(8.0000-0.4*1.2190)
 = 2774.732 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:

```
 = (P*(Ro-0.4*t))/(E*t)
 = (900.000*((8.0000-0.4*1.0940))/(1.00*1.0940)
 = 6221.353 psi
```

Minimum Design Metal Temperature Results:

Note: This Material was specified as being supplied in the Impact Tested condition (Low Temperature Material).

Impact Test Temperature provided per Specification   -50 °F

Cylindrical Shell From 50 To 60 SA-333 6 at 428 °F

channel shell

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:

```
 = (P*Ro) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
 = (900.000*8.0000)/(17100.00*1.00+0.4*900.000)
 = 0.4124 + 0.0781 = 0.4905 in.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:

```
 = (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
 = (17100.00*1.00*1.1409)/(8.0000-0.4*1.1409)
 = 2586.144 psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
 = (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
 = (17100.00*1.00*1.2190)/(8.0000-0.4*1.2190)
 = 2774.732 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:

```
 = (P*(Ro-0.4*t))/(E*t)
 = (900.000*((8.0000-0.4*1.1409))/(1.00*1.1409)
 = 5950.946 psi
```

Minimum Design Metal Temperature Results:

Note: This Material was specified as being supplied in the Impact Tested condition (Low Temperature Material).

Impact Test Temperature provided per Specification   -50 °F

Elliptical Head From 60 To 70 SA-516 70 , UCS-66 Crv. B at 428 °F

channel head

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
 = (P*Do*Kcor)/(2*S*E+2*P*(Kcor-0.1)) per Appendix 1-4 (c)
 = (900.000*16.0000*0.985)/(2*20000.00*1.00+2*900.000*(0.985-0.1))
 = 0.3411 + 0.0781 = 0.4192 in.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
 = (2*S*E*t)/(Kcor*Do-2*t*(Kcor-0.1)) per Appendix 1-4 (c)
 = (2*20000.00*1.00*1.0469)/(0.985*16.0000-2*1.0469*(0.99-0.1))
 = 3010.262 psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
 = (2*S*E*t)/(K*Do-2*t*(K-0.1)) per Appendix 1-4 (c)
 = (2*20000.00*1.00*1.1250)/(1.000*16.0000-2*1.1250*(1.000-0.1))
 = 3220.036 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
 = (P*(Kcor*Do-2*t*(Kcor-0.1)))/(2*E*t)
 = (900.000*(0.985*16.0000-2*1.0469*(0.985-0.1)))/(2*1.00*1.0469)
 = 5979.547 psi
```

Straight Flange Required Thickness:
```
 = (P*Ro)/(S*E+0.4*P) + ca   per Appendix 1-1 (a)(1)
 = (900.000*8.0000)/(20000.00*1.00+0.4*900.000)+0.078
 = 0.432 in.
```

Straight Flange Maximum Allowable Working Pressure:
```
 = (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
 = (20000.00 * 1.00 * 1.0469 )/(8.0000 - 0.4 * 1.0469 )
 = 2761.748 psig
```

Factor K, corroded condition [Kcor]:
```
 = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))^(2))/6
 = ( 2 + ( 13.906/( 2 * 3.516 ))^(2))/6
 = 0.985267
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro)   29.095 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 1.125 , tr = 0.653 , c = 0.0781 in. , E* = 1.00
Stress Ratio = tr * (E*)/(tg - c) = 0.624 , Temp. Reduction = 38 °F

Min Metal Temp. w/o impact per UCS-66, Curve B   37 °F

```
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit           7 °F
Min Metal Temp. at Required thickness (UCS 66.1)            -31 °F
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 1.125 , tr = 0.691 , c = 0.0781 in. , E* = 1.00
Stress Ratio = tr * (E*)/(tg - c) = 0.660 , Temp. Reduction = 34 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B               37 °F
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit           7 °F
Min Metal Temp. at Required thickness (UCS 66.1)            -27 °F
```

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
Pressure per UG99b      = 1.3 * M.A.W.P. * Sa/S        1170.000  psig
Pressure per UG99b[36]  = 1.3 * Design Pres * Sa/S     1170.000  psig
Pressure per UG99c      = 1.3 * M.A.P. - Head(Hyd)        0.000  psig
Pressure per UG100      = 1.1 * M.A.W.P. * Sa/S         990.000  psig
Pressure per PED        = 1.43 * MAWP                  1287.000  psig
Pressure per App 27-4   = 1.3 * M.A.W.P. * Sa/S        1170.000  psig
```

User defined Hydrostatic Test Pressures:

```
Shell Side  Test Pressure at  High Point               1170.000  psig
Channel Side Test Pressure at High Point               1170.000  psig
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
Pressure per UG99b      = 1.3 * M.A.W.P. * Sa/S        1170.000  psig
Pressure per UG99b[36]  = 1.3 * Design Pres * Sa/S     1170.000  psig
Pressure per UG99c      = 1.3 * M.A.P. - Head(Hyd)        0.000  psig
Pressure per UG100      = 1.1 * M.A.W.P. * Sa/S         990.000  psig
Pressure per PED        = 1.43 * MAWP                  1287.000  psig
Pressure per App 27-4   = 1.3 * M.A.W.P. * Sa/S        1170.000  psig
```

Horizontal Test performed per: User Hydro Pressure

Please note that Nozzle, Shell, Head, Flange, etc MAWPs are all considered when determining the hydrotest pressure for those test types that are based on the MAWP of the vessel.

Stresses on Elements due to Test Pressure:

From To	Stress	Allowable	Ratio	Pressure
Shell side Head	7270.6	26000.0	0.280	1170.58
Shell Side	7214.0	22230.0	0.325	1170.58
channel shell	7214.0	22230.0	0.325	1170.58
channel head	7270.6	26000.0	0.280	1170.58

Stress ratios for Nozzle and Pad Materials:

Description	Pad/Nozzle	Ambient	Operating	ratio
S1(Shell Inlet)	Nozzle	20000.00	19888.00	1.006
S2(Shell Outlet	Nozzle	20000.00	19888.00	1.006
T2(Channel Out)	Nozzle	20000.00	19888.00	1.006
T1	Nozzle	20000.00	19888.00	1.006
Minimum				1.006

Stress ratios for Vessel Elements:

Description	Ambient	Operating	ratio
Shell side Head	20000.00	20000.00	1.000
Shell Side	17100.00	17100.00	1.000
Shell Side Flange	20000.00	19888.00	1.006
Channel Flange	20000.00	19888.00	1.006
channel shell	17100.00	17100.00	1.000
channel head	20000.00	20000.00	1.000
Minimum			1.000

Stress ratios for Exchanger Materials:

Description	Ambient	Operating	ratio
Tube Material	13400.00	13400.00	1.000
Tubesheet Material	20000.00	20000.00	1.000
Minimum			1.000

Elements Suitable for Internal Pressure.

Element and Detail Weights

From	To	Element Metal Wgt. lb.	Element ID Volume in³	Corroded Metal Wgt. lb.	Corroded ID Volume in³	Extra due Misc % lb.
10	20	112.860	637.267	100.320	667.065	...
20	30	4249.66	38732.5	3846.14	40173.7	...
30	40	358.456	815.003	350.179	824.073	...
40	50	348.780	797.828	343.683	803.686	...
50	60	182.269	1661.25	171.489	1699.75	...
60	70	112.860	637.267	105.022	655.788	...
Total		**5364**	**43281**	**4916**	**44824**	**0**

For elements specified as shell side elements, the volume(s) shown above for those elements, reflects the displacement of the tubes.

Weight of Details

From	Type	Weight of Detail lb.	X Offset, Dtl. Cent. ft.	Y Offset, Dtl. Cent. ft.	Description
20	Sadl	8.94732	4.05208	0.88800	Lft Sdl
20	Sadl	8.94732	19.0521	0.88800	Sdl 2 Fr20
20	Nozl	187.013	21.8542	0.74738	S1(Shell Inlet)
20	Nozl	187.013	21.8542	0.74738	S2(Shell Outlet
50	Nozl	187.013	0.47917	0.74738	T2(Channel Out)
50	Nozl	187.013	0.47917	0.74738	T1
30	FTsh	479.764	0.65156	...	Tubesheet
30	Tube	677.879	-10.9031	...	

Total Weight of Each Detail Type

Total Weight of Saddles	17.9
Total Weight of Nozzles	748.1
Total Weight of Exchanger Components	1157.6
Sum of the Detail Weights	1923.6 lb.

Weight Summation: lb.

Fabricated	Shop Test	Shipping	Erected	Empty	Operating
5364.9	7288.5	5364.9	7288.5	5364.9	7288.5
17.9	1562.9	17.9	...	17.9	...
748.1	...	748.1	...	...	...
...	89.0	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	748.1	...
1157.6	...	1157.6	...	...	...
...	...	...	...	1157.6	...

7288.5	8940.4	7288.5	7288.5	7288.5	7288.5

Note:
The shipping total has been modified because some items have
been specified as being installed in the shop.

Weight Summary

Fabricated Wt.	- Bare Weight W/O Removable Internals	7288.5 lb.
Shop Test Wt.	- Fabricated Weight + Water (Full)	8940.4 lb.
Shipping Wt.	- Fab. Wt + Rem. Intls.+ Shipping App.	7288.5 lb.
Erected Wt.	- Fab. Wt + Rem. Intls.+ Insul. (etc)	7288.5 lb.
Ope. Wt. no Liq	- Fab. Wt + Intls. + Details + Wghts.	7288.5 lb.
Operating Wt.	- Empty Wt + Operating Liq. Uncorroded	7288.5 lb.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	6840.4 lb.
Field Test Wt.	- Empty Weight + Water (Full)	8940.4 lb.

Exchanger Tube Data

Volume of Exchanger tubes :	2465.3 in^3
Weight of Ope Liq in tubes :	0.0 lb.
Weight of Water in tubes :	89.0 lb.

Note:
The Corroded Weight and thickness are used in the Horizontal
Vessel Analysis (Ope Case) and Earthquake Load Calculations.

Outside Surface Areas of Elements

From	To	Surface Area in^2
10	20	378.031
20	30	13477.5
30	40	682.862
40	50	676.677
50	60	578.053
60	70	378.031

Total   16171.118 in^2 [112.3 Square Feet]

Nozzle Flange MAWP Results :

Nozzle Description	Flange Rating Operating psig	Flange Rating Ambient psig	Temperature °F	Class	Grade/Group
S1(Shell Inlet)	1874.8	2220.0	428	900	GR 1.1
S2(Shell Outlet	1874.8	2220.0	428	900	GR 1.1
T2(Channel Out)	1874.8	2220.0	428	900	GR 1.1
T1	1874.8	2220.0	428	900	GR 1.1

Shellside Flange Rating

Lowest Flange Pressure Rating was (Ope)[ShellSide]: 1874.800 psig
Lowest Flange Pressure Rating was (Amb)[ShellSide]: 2220.000 psig

Channelside Flange Rating

Lowest Flange Pressure Rating was (Ope)[TubeSide]: 1874.800 psig
Lowest Flange Pressure Rating was (Amb)[TubeSide]: 2220.000 psig

Note: ANSI Ratings are per ANSI/ASME B16.5 2013 Edition

Wind Analysis Results

```
User Entered Importance Factor is                          1.000
Gust Factor (Gh, Gbar) Static Dynamic                      1.330
Shape Factor (Cf) for the Vessel is                        0.669
User Entered Basic Wind Speed                               70.0    mile/hr
Exposure Category                                              C
Table Lookup Value Alpha from Table C6                    7.0000
Table Lookup Value Zg from Table C6                     900.0000
Table Lookup Value Do from Table C6                       0.0050
```

Wind Load Results per ASCE-7 93:

Sample Calculation for the First Element:

Rougness Factor = 1.000

Values [cf1] and [cf2]

```
 Because RoughFact = 1 and DQZ > 2.5 and H/D > 7.0
 Interpolating to find the final cf:
 Because H / D < 25.0
 CF = CF1 + (CF2-CF1) * ( H/D - 7.0 )/( 25.0 - 7.0 )
    = 0.600 + (0.700 -0.600 ) * ( 19.362 - 7.0 )/( 25.0 - 7.0 )
    = 0.669
```

Value of Alpha, Zg is taken from Table C6-2 [Alpha, Zg]

```
 For Exposure Category C:
 Alpha = 7.000 , Zg = 900.000 ft.
```

Height of Interest for First Element [z]

```
 = Centroid Hgt + Base Height
 = 1.333 + 0.000 = 1.333 ft.
 but: z = Max(15.000 , 1.333 ) = 15.000 ft.
```

Note: Because z < 15 feet, use 15 feet to compute kz.

Velocity Pressure Coefficient [kZ]:

```
 = 2.58( z/zg )^(2/Alpha)  : z is Elevation of First Element
 = 2.58( 15.000/900 )^(2/7.0 )
 = 0.801
```

Determine if Static or Dynamic Gust Factor Applies

Height to Diameter ratio :

```
 = Maximum Height(length)^2 / Sum of Area of the Elements
 = 25.255 (^2)/32.942
 = 19.362
```

Vibration Frequency = 33.000 Hz
Because H/D > 5 Or Freqency < 1.0: Dynamic Analysis Implemented

```
 Element O/Dia = 3 ft.
 Vibration Damping Factor (Operating) Beta = 0.01000
```

For Terrain Category C
S = 1.000 , Gamma = 0.230 , Drag Coeff. = 0.005 , Alpha = 7.000

Compute [fbar]
= 10.5 * Frequency(Hz) * Vessel Height(ft) / (S * Vr(mph))
= 10.5 * 33.000 (Hz) * 25.255 (ft)/S * 1.000 (mph)
= 125.014

Because FBAR > 40: FBAR = 40.000

Wind Pressure - (performed in Imperial Units) [qz]
Importance Factor: I = 1.000
Wind Speed = 70.000 mile/hr
qz = 0.00256 * kZ * (I * Vr)²
= 0.00256 * 0.801 *(1.000 * 70.000)² = 10.046 psf

Force on the First Element [Fz]
= qz * Gh * CF * Wind Area
= 10.046 * 1.330 * 0.669 * 95.734
= 5.939 lb.

Element	z ft.	GH	Area in²	qz psf	Force lb.
Shell side Head	1.3	1.330	95.7	10.0	5.9
Shell Side	1.3	1.330	5148.0	10.0	319.4
Shell Side Flan	1.3	1.330	89.5	10.0	5.6
Channel Flange	1.3	1.330	88.5	10.0	5.5
channel shell	1.3	1.330	220.8	10.0	13.7
channel head	1.3	1.330	95.7	10.0	5.9

Wind Load Calculation

From	To	Wind Height ft.	Wind Diameter ft.	Wind Area in²	Wind Pressure psf	Element Wind Load lb.
10	20	1.33333	1.60000	95.7341	10.0464	5.93920
20	30	1.33333	1.60000	5148.01	10.0464	319.375
30	40	1.33333	1.35620	89.5092	10.0464	5.55302
40	50	1.33333	1.35620	88.4921	10.0464	5.48991
50	60	1.33333	1.60000	220.800	10.0464	13.6981
60	70	1.33333	1.60000	95.7341	10.0464	5.93920

Earthquake Analysis Results

The UBC Zone Factor for the Vessel is 0.0000
The Importance Factor as Specified by the User is . 1.000
The UBC Frequency and Soil Factor (C) is 2.750
The UBC Force Factor as Specified by the User is .. 3.000
The UBC Total Weight (W) for the Vessel is .... 6840.4 lb.
The UBC Total Shear (V) for the Vessel is .... 0.0 lb.
The UBC Top Shear (Ft) for the Vessel is .... 0.0 lb.

Earthquake Load Calculation

From	To	Earthquake Height ft.	Earthquake Weight lb.	Element Ope Load lb.
10	20	0.57292	855.053	...
20	Sadl	0.56508	855.053	...
Sadl	30	0.56508	855.053	...
20	30	0.56508	855.053	...
30	40	0.56508	855.053	...
40	50	0.56508	855.053	...
50	60	0.56508	855.053	...
60	70	0.57292	855.053	...

Shop/Field Installation Options :

Note : The CG is computed from the first Element From Node

Center of Gravity of Saddles	11.719 ft.
Center of Gravity of Nozzles	23.125 ft.
Center of Gravity of Tubesheet(s)	23.162 ft.
Center of Gravity of Tubes	11.607 ft.
Center of Gravity of Bare Shell New and Cold	13.377 ft.
Center of Gravity of Bare Shell Corroded	13.510 ft.
Vessel CG in the Operating Condition	15.045 ft.
Vessel CG in the Fabricated (Shop/Empty) Condition	14.853 ft.
Vessel CG in the Test Condition	14.375 ft.

ASME Horizontal Vessel Analysis: Stresses for the Left Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Horizontal Vessel Stress Calculations : Operating Case

Note:
Wear Pad Bearing angle is less than saddle angle + saddle/12
degrees. The wear plate will be ignored.

Minimum Wear Plate Angle [theta1]:
= 192.0 degrees

Note:
Wear Pad Width (0.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
```
 = min( b + 1.56*sqrt( Rm * t ), 2a )
 = min( 4.000 + 1.56*sqrt( 7.4530 * 1.0940 ), 2 * 6.000 )
 = 8.4545 in.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	7.45	in.
Stiffened Vessel Length per 4.15.6	L	22.97	ft.
Distance from Saddle to Vessel tangent	a	6.00	in.
Saddle Width	b	4.00	in.
Saddle Bearing Angle	theta	180.00	degrees
Inside Depth of Head	h2	0.30	ft.
Shell Allowable Stress used in Calculation		17100.00	psi
Head Allowable Stress used in Calculation		20000.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		2476.53	lb.

Horizontal Vessel Analysis Results:	Actual	Allowable	
Long. Stress at Top of Midspan	2263.79	17100.00	psi
Long. Stress at Bottom of Midspan	3867.56	17100.00	psi
Long. Stress at Top of Saddles	3074.39	17100.00	psi
Long. Stress at Bottom of Saddles	3060.43	17100.00	psi
Tangential Shear in Shell	164.81	13680.00	psi
Circ. Stress at Horn of Saddle	105.23	21375.00	psi
Circ. Compressive Stress in Shell	167.15	17100.00	psi

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

```
 = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
 = 3.00 * ( 356.0/2 + 0 ) * 16.0000/14.9060
 = 573.2 lb.
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

```
 = max( Fl, Friction Load, Sum of X Forces) * B / Ls
 = max( 16.83 , 0.00 , 0 ) * 16.0000/180.0002
 = 1.5 lb.
```

Load Combination Results for Q + Wind or Seismic [Q]:

```
 = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
 = 1903 + Max( 1 , 573 , 0 , 0 )
 = 2476.5 lb.
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	2485.48	lb.
Transverse Shear Load Saddle	178.00	lb.
Longitudinal Shear Load Saddle	16.83	lb.

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is not Welded to the Shell, k = 1.0

The Computed K values from Table 4.15.1:

K1 = 0.2286	K2 = 0.5771	K3 = 0.2597	K4 = 0.2157
K5 = 0.6243	K6 = 0.0174	K7 = 0.0123	K8 = 0.2500
K9 = 0.1396	K10 = 0.0146	K1* = 0.3799	

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:

```
 = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
 = -2477*0.50[1-(1-0.50/22.97+(0.621²-0.297²)/
   (2*0.50*22.97))/(1+(4*0.30)/(3*22.97))]
 = -31.7 ft.lb.
```

Moment per Equation 4.15.4 [M2]:

```
 = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
 = 2477*23.0/4(1+2(0.621²-0.297²)/(22.97²))/(1+(4*0.297)/
   (3*22.969))-4*0.50/22.97
 = 12757.3 ft.lb.
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

```
 = P * Rm/(2t) - M2/(pi*Rm²t)
 = 900.000 * 7.453/(2*1.094 ) - 153088.0/(pi*7.5²*1.094 )
 = 2263.79 psi
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

```
 = P * Rm/(2t) + M2/(pi * Rm² * t)
 = 900.000 * 7.453/(2 * 1.094 ) + 153088.0/(pi * 7.5² * 1.094 )
 = 3867.56 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:

```
 = P * Rm/(2t) - M1/(K1*pi*Rm²t)
```

```
 = 900.000*7.453/(2*1.094)--380.5/(0.2286*pi*7.5²*1.094)
 = 3074.39 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11)   [Sigma*4]:

```
 = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
 = 900.000*7.453/(2*1.094)+-380.5/(0.3799*pi*7.5²*1.094)
 = 3060.43 psi
```

Maximum Shear Force in the Saddle (4.15.5) [T]:

```
 = Q(L-2a)/(L+(4*h2/3))
 = 2477 ( 22.97 - 2 * 0.50 )/(22.97 + ( 4 * 0.30/3))
 = 2328.6 lb.
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:

```
 = K2 * T / ( Rm * t )
 = 0.5771 * 2328.58/( 7.4530 * 1.0940 )
 = 164.81 psi
```

Decay Length (4.15.22) [x1,x2]:

```
 = 0.78 * sqrt( Rm * t )
 = 0.78 * sqrt( 7.453 * 1.094 )
 = 2.227 in.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:

```
 = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
 = -0.6243 * 2477 * 1.0/( 1.094 * ( 4.00 + 2.23 + 2.23 ) )
 = -167.15 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:

```
 = -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
 = -2477/(4*1.094 *(4.000 +2.227 +2.227 )) -
    3*0.0123 *2477/(2*1.094²)
 = -105.23 psi
```

Effective reinforcing plate width (4.15.1) [B1]:

```
 = min( b + 1.56 * sqrt( Rm * t ), 2a  )
 = min( 4.00 + 1.56 * sqrt( 7.453 * 1.094 ), 2 * 6.000 )
 = 8.45 in.
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:

```
 = Alpha * Ls * ( Design Temperature - Ambient Temperature )
 = 0.716E-05 * 180.000 * ( 428.0 - 70.0 )
 = 0.461 in.
```

ASME Horizontal Vessel Analysis: Stresses for the Right Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Note:
Wear Pad Bearing angle is less than saddle angle + saddle/12
degrees. The wear plate will be ignored.

Minimum Wear Plate Angle [theta1]:

```
 = 192.0 degrees
```

Note:
Wear Pad Width (0.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:

```
 = min( b + 1.56*sqrt( Rm * t ), 2a )
 = min( 4.000 + 1.56*sqrt( 7.4530 * 1.0940 ), 2 * 6.000 )
 = 8.4545 in.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	7.45	in.
Stiffened Vessel Length per 4.15.6	L	22.97	ft.
Distance from Saddle to Vessel tangent	a	6.00	in.
Saddle Width	b	4.00	in.
Saddle Bearing Angle	theta	180.00	degrees
Shell Allowable Stress used in Calculation		17100.00	psi
Head Allowable Stress used in Calculation		19888.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		5510.25	lb.

Horizontal Vessel Analysis Results:	Actual	Allowable	
Long. Stress at Top of Midspan	1247.10	17100.00	psi
Long. Stress at Bottom of Midspan	4884.25	17100.00	psi
Long. Stress at Top of Saddles	3069.45	17100.00	psi
Long. Stress at Bottom of Saddles	3063.41	17100.00	psi
Tangential Shear in Shell	373.01	13680.00	psi
Circ. Stress at Horn of Saddle	234.14	21375.00	psi
Circ. Compressive Stress in Shell	37.19	17100.00	psi

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

```
 = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
 = 3.00 * ( 356.0/2 + 0 ) * 16.0000/14.9060
 = 573.2 lb.
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

```
 = max( Fl, Friction Load, Sum of X Forces) * B / Ls
 = max( 16.83 , 0.00 , 0 ) * 16.0000/180.0002
 = 1.5 lb.
```

Load Combination Results for Q + Wind or Seismic [Q]:

```
 = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
 = 4937 + Max( 1 , 573 , 0 , 0 )
 = 5510.3 lb.
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	5519.20	lb.
Transverse Shear Load Saddle	178.00	lb.
Longitudinal Shear Load Saddle	16.83	lb.

<u>Formulas and Substitutions for Horizontal Vessel Analysis:</u>

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

K1 = 0.2286	K2 = 0.5771	K3 = 0.2597	K4 = 0.2157
K5 = 0.6243	K6 = 0.0174	K7 = 0.0123	K8 = 0.2500
K9 = 0.1396	K10 = 0.0146	K1* = 0.3799	

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:
```
 = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
 = -5510*0.50[1-(1-0.50/22.97+(0.621²-0.000²)/
   (2*0.50*22.97))/(1+(4*0.00)/(3*22.97))]
 = -13.7 ft.lb.
```

Moment per Equation 4.15.4 [M2]:
```
 = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
 = 5510*23.0/4(1+2(0.621²-0.000²)/(22.97²))/(1+(4*0.000)/
   (3*22.969))-4*0.50/22.97
 = 28932.1 ft.lb.
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
 = P * Rm/(2t) - M2/(pi*Rm²t)
 = 900.000 * 7.453/(2*1.094 ) - 347185.4/(pi*7.5²*1.094 )
 = 1247.10 psi
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
 = P * Rm/(2t) + M2/(pi * Rm² * t)
 = 900.000 * 7.453/(2 * 1.094 ) + 347185.4/(pi * 7.5² * 1.094 )
 = 4884.25 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
 = P * Rm/(2t) - M1/(K1*pi*Rm²t)
 = 900.000*7.453/(2*1.094)--164.5/(0.2286*pi*7.5²*1.094)
 = 3069.45 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
 = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
 = 900.000*7.453/(2*1.094)+-164.5/(0.3799*pi*7.5²*1.094)
 = 3063.41 psi
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
 = Q(L-2a)/(L+(4*h2/3))
 = 5510 ( 22.97 - 2 * 0.50 )/(22.97 + ( 4 * 0.00/3))
 = 5270.4 lb.
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
 = K2 * T / ( Rm * t )
```

```
 = 0.5771 * 5270.35/( 7.4530 * 1.0940 )
 = 373.01 psi
```

Decay Length (4.15.22) [x1,x2]:

```
 = 0.78 * sqrt( Rm * t )
 = 0.78 * sqrt( 7.453 * 1.094 )
 = 2.227 in.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:

```
 = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
 = -0.6243 * 5510 * 0.1/( 1.094 * ( 4.00 + 2.23 + 2.23 ) )
 = -37.19 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:

```
 = -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
 = -5510/(4*1.094 *(4.000 +2.227 +2.227 )) -
   3*0.0123 *5510/(2*1.094²)
 = -234.14 psi
```

Effective reinforcing plate width (4.15.1) [B1]:

```
 = min( b + 1.56 * sqrt( Rm * t ), 2a  )
 = min( 4.00 + 1.56 * sqrt( 7.453 * 1.094 ), 2 * 6.000 )
 = 8.45 in.
```

ASME Horizontal Vessel Analysis: Stresses for the Left Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Horizontal Vessel Stress Calculations : Test Case

Note:
Wear Pad Bearing angle is less than saddle angle + saddle/12
degrees. The wear plate will be ignored.

Minimum Wear Plate Angle [theta1]:
= 192.0 degrees

Note:
Wear Pad Width (0.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
= min(b + 1.56*sqrt(Rm * t), 2a)
= min(4.000 + 1.56*sqrt(7.3905 * 1.2190), 2 * 6.000)
= 8.6823 in.

Input and Calculated Values:

Vessel Mean Radius	Rm	7.39	in.
Stiffened Vessel Length per 4.15.6	L	22.97	ft.
Distance from Saddle to Vessel tangent	a	6.00	in.
Saddle Width	b	4.00	in.
Saddle Bearing Angle	theta	180.00	degrees
Inside Depth of Head	h2	0.29	ft.
Shell Allowable Stress used in Calculation		33250.00	psi
Head Allowable Stress used in Calculation		33250.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		3077.76	lb.

Horizontal Vessel Analysis Results:	Actual	Allowable	
Long. Stress at Top of Midspan	2637.37	33250.00	psi
Long. Stress at Bottom of Midspan	4457.67	33250.00	psi
Long. Stress at Top of Saddles	3557.19	33250.00	psi
Long. Stress at Bottom of Saddles	3541.70	33250.00	psi
Tangential Shear in Shell	185.48	26600.00	psi
Circ. Stress at Horn of Saddle	111.58	49875.00	psi
Circ. Compressive Stress in Shell	181.54	33250.00	psi

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

```
 = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
 = 3.00 * ( 117.5/2 + 0 ) * 16.0000/14.7810
 = 190.7 lb.
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

```
 = max( Fl, Friction Load, Sum of X Forces) * B / Ls
 = max( 5.55 , 0.00 , 0 ) * 16.0000/180.0002
 = 0.5 lb.
```

Load Combination Results for Q + Wind or Seismic [Q]:

```
 = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
 = 2887 + Max( 0 , 191 , 0 , 0 )
 = 3077.8 lb.
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	3086.71	lb.
Transverse Shear Load Saddle	58.74	lb.
Longitudinal Shear Load Saddle	5.55	lb.

Hydrostatic Test Pressure at center of Vessel: 1170.267 psig

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is not Welded to the Shell, k = 1.0

The Computed K values from Table 4.15.1:

K1 = 0.2286	K2 = 0.5771	K3 = 0.2597	K4 = 0.2157
K5 = 0.6243	K6 = 0.0174	K7 = 0.0125	K8 = 0.2500
K9 = 0.1396	K10 = 0.0146	K1* = 0.3799	

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:

```
 = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
 = -3078*0.50[1-(1-0.50/22.97+(0.616²-0.286²)/
   (2*0.50*22.97))/(1+(4*0.29)/(3*22.97))]
 = -38.5 ft.lb.
```

Moment per Equation 4.15.4 [M2]:

```
 = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
 = 3078*23.0/4(1+2(0.616²-0.286²)/(22.97²))/(1+(4*0.286)/
   (3*22.969))-4*0.50/22.97
 = 15864.8 ft.lb.
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

```
 = P * Rm/(2t) - M2/(pi*Rm²t)
 = 1170.267 * 7.391/(2*1.219 ) - 190377.2/(pi*7.4²*1.219 )
 = 2637.37 psi
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

```
 = P * Rm/(2t) + M2/(pi * Rm² * t)
 = 1170.267 * 7.391/(2 * 1.219 ) + 190377.2/(pi * 7.4² * 1.219 )
 = 4457.67 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 1170.267*7.391/(2*1.219)--462.4/(0.2286*pi*7.4²*1.219)
= 3557.19 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 1170.267*7.391/(2*1.219)+-462.4/(0.3799*pi*7.4²*1.219)
= 3541.70 psi
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
= Q(L-2a)/(L+(4*h2/3))
= 3078 ( 22.97 - 2 * 0.50 )/(22.97 + ( 4 * 0.29/3))
= 2895.6 lb.
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
= K2 * T / ( Rm * t )
= 0.5771 * 2895.62/( 7.3905 * 1.2190 )
= 185.48 psi
```

Decay Length (4.15.22) [x1,x2]:
```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 7.391 * 1.219 )
= 2.341 in.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )
= -0.6243 * 3078 * 1.0/( 1.219 * ( 4.00 + 2.34 + 2.34 ) )
= -181.54 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:
```
= -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
= -3078/(4*1.219 *(4.000 +2.341 +2.341 )) -
  3*0.0125 *3078/(2*1.219²)
= -111.58 psi
```

Effective reinforcing plate width (4.15.1) [B1]:
```
= min( b + 1.56 * sqrt( Rm * t ), 2a )
= min( 4.00 + 1.56 * sqrt( 7.391 * 1.219 ), 2 * 6.000 )
= 8.68 in.
```

ASME Horizontal Vessel Analysis: Stresses for the Right Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Note:
Wear Pad Bearing angle is less than saddle angle + saddle/12
degrees. The wear plate will be ignored.

Minimum Wear Plate Angle [theta1]:
```
= 192.0 degrees
```

Note:
Wear Pad Width (0.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:

```
 = min( b + 1.56*sqrt( Rm * t ), 2a )
 = min( 4.000 + 1.56*sqrt( 7.3905 * 1.2190 ), 2 * 6.000 )
 = 8.6823 in.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	7.39	in.
Stiffened Vessel Length per 4.15.6	L	22.97	ft.
Distance from Saddle to Vessel tangent	a	6.00	in.
Saddle Width	b	4.00	in.
Saddle Bearing Angle	theta	180.00	degrees
Shell Allowable Stress used in Calculation		33250.00	psi
Head Allowable Stress used in Calculation		33250.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		6244.16	lb.

Horizontal Vessel Analysis Results:	Actual	Allowable	
Long. Stress at Top of Midspan	1666.69	33250.00	psi
Long. Stress at Bottom of Midspan	5428.36	33250.00	psi
Long. Stress at Top of Saddles	3551.64	33250.00	psi
Long. Stress at Bottom of Saddles	3545.04	33250.00	psi
Tangential Shear in Shell	382.55	26600.00	psi
Circ. Stress at Horn of Saddle	226.38	49875.00	psi
Circ. Compressive Stress in Shell	36.83	33250.00	psi

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

```
 = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
 = 3.00 * ( 117.5/2 + 0 ) * 16.0000/14.7810
 = 190.7 lb.
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

```
 = max( Fl, Friction Load, Sum of X Forces) * B / Ls
 = max( 5.55 , 0.00 , 0 ) * 16.0000/180.0002
 = 0.5 lb.
```

Load Combination Results for Q + Wind or Seismic [Q]:

```
 = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
 = 6053 + Max( 0 , 191 , 0 , 0 )
 = 6244.2 lb.
```

<u>Summary of Loads at the base of this Saddle</u>:

Vertical Load (including saddle weight)	6253.11	lb.
Transverse Shear Load Saddle	58.74	lb.
Longitudinal Shear Load Saddle	5.55	lb.

Hydrostatic Test Pressure at center of Vessel: 1170.267 psig

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

```
K1  = 0.2286     K2  = 0.5771     K3  = 0.2597     K4  = 0.2157
K5  = 0.6243     K6  = 0.0174     K7  = 0.0125     K8  = 0.2500
K9  = 0.1396     K10 = 0.0146     K1* = 0.3799
```

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:

```
 = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
 = -6244*0.50[1-(1-0.50/22.97+(0.616²-0.000²)/
   (2*0.50*22.97))/(1+(4*0.00)/(3*22.97))]
 = -16.4 ft.lb.
```

Moment per Equation 4.15.4 [M2]:

```
 = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
 = 6244*23.0/4(1+2(0.616²-0.000²)/(22.97²))/(1+(4*0.000)/
   (3*22.969))-4*0.50/22.97
 = 32784.7 ft.lb.
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

```
 = P * Rm/(2t) - M2/(pi*Rm²t)
 = 1170.267 * 7.391/(2*1.219 ) - 393416.2/(pi*7.4²*1.219 )
 = 1666.69 psi
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

```
 = P * Rm/(2t) + M2/(pi * Rm² * t)
 = 1170.267 * 7.391/(2 * 1.219 ) + 393416.2/(pi * 7.4² * 1.219 )
 = 5428.36 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:

```
 = P * Rm/(2t) - M1/(K1*pi*Rm²t)
 = 1170.267*7.391/(2*1.219)--196.9/(0.2286*pi*7.4²*1.219)
 = 3551.64 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:

```
 = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
 = 1170.267*7.391/(2*1.219)+-196.9/(0.3799*pi*7.4²*1.219)
 = 3545.04 psi
```

Maximum Shear Force in the Saddle (4.15.5) [T]:

```
 = Q(L-2a)/(L+(4*h2/3))
 = 6244 ( 22.97 - 2 * 0.50 )/(22.97 + ( 4 * 0.00/3))
 = 5972.3 lb.
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:

```
 = K2 * T / ( Rm * t )
 = 0.5771 * 5972.31/( 7.3905 * 1.2190 )
```

```
 = 382.55 psi
```

Decay Length (4.15.22) [x1,x2]:

```
 = 0.78 * sqrt( Rm * t )
 = 0.78 * sqrt( 7.391 * 1.219 )
 = 2.341 in.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:

```
 = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
 = -0.6243 * 6244 * 0.1/( 1.219 * ( 4.00 + 2.34 + 2.34 ) )
 = -36.83 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:

```
 = -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
 = -6244/(4*1.219 *(4.000 +2.341 +2.341 )) -
    3*0.0125 *6244/(2*1.219²)
 = -226.38 psi
```

Effective reinforcing plate width (4.15.1) [B1]:

```
 = min( b + 1.56 * sqrt( Rm * t ), 2a  )
 = min( 4.00 + 1.56 * sqrt( 7.391 * 1.219 ), 2 * 6.000 )
 = 8.68 in.
```

INPUT VALUES, Nozzle Description: S1(Shell Inlet) From : 20

Pressure for Reinforcement Calculations	P	900.000	psig
Temperature for Internal Pressure	Temp	428	°F
Shell Material [Impact Tested]		SA-333 6	
Shell Allowable Stress at Temperature	Sv	17100.00	psi
Shell Allowable Stress At Ambient	Sva	17100.00	psi
Inside Diameter of Cylindrical Shell	D	13.5620	in.
Shell Finished (Minimum) Thickness	t	1.2190	in.
Shell Internal Corrosion Allowance	c	0.1250	in.
Shell External Corrosion Allowance	co	0.0000	in.
Distance from Bottom/Left Tangent		22.0209	ft.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material		SA-266 4	
Material UNS Number		K03017	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	19888.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		4.3750	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.8750	in.
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	5.8750	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.3750	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.3750	in.
Inside Projection	h	0.0000	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
ASME Code Weld Type per UW-16		C	
Class of attached Flange		900	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)

```
                 |  |
                 |  |
                 |  |
                 |  |
  ______________/|  |
 |            \  |  |
 |             \ |  |
 |______________\|__|
```

Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: S1(Shell Inlet)

ASME Code, Section VIII, Div. 1, 2015, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation              4.375  in.
Actual Thickness Used in Calculation                     0.875  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
```
 = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
 = (900.00*6.9060)/(17100*1.00-0.6*900.00)
 = 0.3753 in.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
 = Ro(1 - exp( -P/( Sn*E ))) per Appendix 1-2 (a)(1)
 = 2.188(1-exp(-900.00/(19888.00*1.00)))
 = 0.0968 in.
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures       ta = 0.2218 in.
Wall Thickness per UG16(b),                        tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure       trb1 = 0.5003 in.
Wall Thickness                  tb1 = max(trb1, tr16b) = 0.5003 in.
Wall Thickness                  tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45                       tb3 = 0.3320 in.
```

Determine Nozzle Thickness candidate [tb]:
```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 0.332 , max( 0.5003 , 0.1875 ) ]
 = 0.3320 in.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
 = max( ta, tb )
 = max( 0.2218 , 0.3320 )
 = 0.3320 in.
```

Available Nozzle Neck Thickness = 0.8750 in. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

MDMT of the Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 0.875 , tr = 0.096 , c = 0.1250 in. , E* = 1.00
Stress Ratio = tr * (E*)/(tg - c) = 0.128 , Temp. Reduction = 140 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              24 °F
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit         -6 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -146 °F
Min Metal Temp. w/o impact per UG-20(f)                    -20 °F
```

MDMT of Nozzle-Shell/Head Weld for the Nozzle (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 0.875 , tr = 0.096 , c = 0.1250 in. , E* = 1.00
Stress Ratio = tr * (E*)/(tg - c) = 0.128 , Temp. Reduction = 140 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              24 °F
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit         -6 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -146 °F
Min Metal Temp. w/o impact per UG-20(f)                    -20 °F

Governing MDMT of all the sub-joints of this Junction  :  -146 °F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -20 °F
Flange MDMT with Temp reduction per UCS-66(b)(1)(b)        -55 °F
Flange MDMT with Temp reduction per UCS-66(b)(1)(c)       -155 °F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(b) is :
Design Pressure/Ambient Rating = 900.00/2220.00 = 0.405

Note: Using the minimum value from (b)(1)(b) and (b)(1)(c) above as the calculated nozzle flange MDMT.

Nozzle Calculations per App. 1-10: Internal Pressure Case:

Thickness of Nozzle [tn]:
```
 = thickness - corrosion allowance
 = 0.875 - 0.125
 = 0.750 in.
```

Effective Pressure Radius [Reff]:
```
 = Di/2 + corrosion allowance
 = 13.562/2 + 0.125
 = 6.906 in.
```

Effective Length of Vessel Wall [LR]:
```
 = 8 * t
 = 8 * 1.094
 = 8.752 in.
```

Thickness Limit Candidate [LH1]:
```
 = t + 0.78 * sqrt( Rn * tn )
 = 1.094 + 0.78 * sqrt( 1.438 * 0.750 )
```

```
 = 1.904 in.
```

Thickness Limit Candidate [LH2]:

```
 = Lpr1 + T
 = 5.875 + 1.094
 = 6.969 in.
```

Thickness Limit Candidate [LH3]:

```
 = 8( t + te )
 = 8( 1.094 + 0.000 )
 = 8.752 in.
```

Effective Nozzle Wall Length Outside the Vessel [LH]:

```
 = min[ LH1, LH2, LH3 ]
 = min[ 1.904 , 6.969 , 8.752 )
 = 1.904 in.
```

Effective Vessel Thickness [teff]:

```
 = t
 = 1.094 in.
```

Determine Parameter [Lamda]:

```
 = min( 10, ( Dn + Tn )/( sqrt( ( Di + teff ) * teff )) )
 = min( 10, (2.88 + 0.750 )/( sqrt((13.81 + 1.094 ) * 1.094 )) )
 = 0.898
```

Compute Areas A1-A43 (No Pad) or A1-A5 (With Pad) :

Area Contributed by the Vessel Wall [A1]:

```
 = t * LR * max( Lamda/4, 1 )
 = 1.094 * 8.752 * max( 0.898/4, 1 )
 = 9.575 in²
```

Area Contributed by the Nozzle Outside the Vessel Wall [A2]:

```
 = tn * LH
 = 0.750 * 1.904
 = 1.428 in²
```

Area Contributed by the Outside Fillet Weld [A41]:

```
 = 0.5 * Leg41^(2)
 = 0.5 * 0.375^(2)
 = 0.070 in²
```

The total area contributed by A1 through A43 [AT]:

```
 = A1 + frn( A2 + A3 ) + A41 + A42 + A43
 = 9.575+1.000(1.428+0.000)+0.070+0.000+0.000
 = 11.073 in²
```

Allowable Local Primary Membrane Stress [Sallow]:

```
 = 1.5 * S * E
 = 1.5 * 17100.000 * 1.000
 = 25650.0 psi
```

Determine Force acting on the Nozzle [fN]:

```
= P * Rn( LH - t )
= 900.000 * 1.438 ( 1.904 - 1.094 )
= 1047.8 lb.
```

Determine Force acting on the Shell [fS]:

```
= P * Reff( LR + tn )
= 900.000 * 6.906 ( 8.752 + 0.750 )
= 59058.7 lb.
```

Discontinuity Force from Internal Pressure [fY]:

```
= P * Reff * Rnc
= 900.000 * 6.906 * 1.438
= 8934.6 lb.
```

Area Resisting Internal Pressure [Ap]:

```
= Rn( LH - t ) + Reff( LR + tn + Rnc )
= 1.438 ( 1.904 - 1.094 ) + 6.906 ( 8.752 + 0.750 + 1.438 )
= 76.7 in²
```

Maximum Allowable Working Pressure Candidate [Pmax1]:

```
= Sallow /( 2 * Ap/AT - Rxs/teff )
= 25650.000/( 2 * 76.712/11.073 - 6.906/1.094 )
= 3400.4 psig
```

Maximum Allowable Working Pressure Candidate [Pmax2]:

```
= S[t/Reff]
= 17100.000 [1.094/6.906 ]
= 2708.9 psig
```

Maximum Allowable Working Pressure [Pmax]:

```
= min( Pmax1, Pmax2 )
= min( 3400.395 , 2708.862 )
= 2708.862 psig
```

Average Primary Membrane Stress [SigmaAvg]:

```
= ( fN + fS + fY ) / AT
= ( 1047.803 + 59058.730 + 8934.638 )/11.073
= 6235.136 psi
```

General Primary Membrane Stress [SigmaCirc]:

```
= P * Reff / teff
= 900.000 * 6.906/1.094
= 5681.4 psi
```

Maximum Local Primary Membrane Stress [PL]:

```
= max( 2 * SigmaAvg - SigmaCirc, SigmaCirc )
= max( 2 * 6235.136 - 5681.353 , 5681.353 )
= 6788.9 psi
```

Summary of Nozzle Pressure/Stress Results:

Allowed Local Primary Membrane Stress	Sallow	25650.00	psi
Local Primary Membrane Stress	PL	6788.92	psi
Maximum Allowable Working Pressure	Pmax	2708.86	psig

Strength of Nozzle Attachment Welds per 1-10 and U-2(g)

Discontinuity Force Factor [ky]:
```
 = ( Rnc + tn ) / Rnc
 = ( 1.438 + 0.750 )/1.438
 = 1.522 For set-in Nozzles
```

Weld Length of Nozzle to Shell Weld [Ltau]:
```
 = pi/2 * ( Rn + tn )
 = pi/2 * ( 1.438 + 0.750 )
 = 3.436 in.
```

Weld Throat Dimensions, (0.7071*Leg Dimensions) [L41T, L42T, L43T]:
```
 = 0.265,   0.000,   0.000, in.
```

Weld Load Value [fwelds]:
```
 = min( fy * ky, 1.5 * Sn( A2 + A3 ), pi/4*P*Rn^2*ky^2 )
 = min(8935*1.52,1.5*19888.0(1.428+0.000),pi/4*900.0*1.44^2*1.52^2)
 = 3382.427 lb.
```

Weld Stress Value [tau]:
```
 = fwelds/(Ltau(0.49*L41T + 0.6*tw1 + 0.49*L43T ) )
 = 3382.427/(3.436 (0.49*0.265 + 0.6*0.375 + 0.49*0.000 ) )
 = 2773.437 < or = to 17100.000 Weld Size is OK
```

Weld Size Calculations, Description: S1(Shell Inlet)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.7500  in.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.2500 = Min per Code	0.2651 = 0.7 * Wo in.

Maximum Allowable Pressure for this Nozzle at this Location:
```
Converged Max. Allow. Pressure in Operating case     2473.739  psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.3625 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.4565 in.

INPUT VALUES, Nozzle Description: S2(Shell Outlet From : 20

Pressure for Reinforcement Calculations	P	900.000	psig
Temperature for Internal Pressure	Temp	428	°F
Shell Material [Impact Tested]		SA-333 6	
Shell Allowable Stress at Temperature	Sv	17100.00	psi
Shell Allowable Stress At Ambient	Sva	17100.00	psi
Inside Diameter of Cylindrical Shell	D	13.5620	in.
Shell Finished (Minimum) Thickness	t	1.2190	in.
Shell Internal Corrosion Allowance	c	0.1250	in.
Shell External Corrosion Allowance	co	0.0000	in.
Distance from Bottom/Left Tangent		22.0209	ft.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material		SA-266 4	
Material UNS Number		K03017	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	19888.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		4.3750	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.8750	in.
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	5.8750	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.3750	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.3750	in.
Inside Projection	h	0.0000	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
ASME Code Weld Type per UW-16		C	
Class of attached Flange		900	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)

```
                 |   |
                 |   |
                 |   |
                 |   |
  ______________/|   |
 |            \  |   |
 |             \ |   |
 |______________\|___|
```

Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: S2(Shell Outlet

ASME Code, Section VIII, Div. 1, 2015, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation              4.375  in.
Actual Thickness Used in Calculation                     0.875  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]

```
 = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
 = (900.00*6.9060)/(17100*1.00-0.6*900.00)
 = 0.3753 in.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
 = Ro(1 - exp( -P/( Sn*E ))) per Appendix 1-2 (a)(1)
 = 2.188(1-exp(-900.00/(19888.00*1.00)))
 = 0.0968 in.
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

```
Wall Thickness for Internal/External pressures      ta = 0.2218 in.
Wall Thickness per UG16(b),                      tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure     trb1 = 0.5003 in.
Wall Thickness                  tb1 = max(trb1, tr16b) = 0.5003 in.
Wall Thickness                  tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45                     tb3 = 0.3320 in.
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 0.332 , max( 0.5003 , 0.1875 ) ]
 = 0.3320 in.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
 = max( ta, tb )
 = max( 0.2218 , 0.3320 )
 = 0.3320 in.
```

Available Nozzle Neck Thickness = 0.8750 in. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

MDMT of the Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 0.875 , tr = 0.096 , c = 0.1250 in. , E* = 1.00
Stress Ratio = tr * (E*)/(tg - c) = 0.128 , Temp. Reduction = 140 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              24 °F
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit         -6 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -146 °F
Min Metal Temp. w/o impact per UG-20(f)                    -20 °F
```

MDMT of Nozzle-Shell/Head Weld for the Nozzle (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 0.875 , tr = 0.096 , c = 0.1250 in. , E* = 1.00
Stress Ratio = tr * (E*)/(tg - c) = 0.128 , Temp. Reduction = 140 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              24 °F
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit         -6 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -146 °F
Min Metal Temp. w/o impact per UG-20(f)                    -20 °F

Governing MDMT of all the sub-joints of this Junction  :  -146 °F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -20 °F
Flange MDMT with Temp reduction per UCS-66(b)(1)(b)        -55 °F
Flange MDMT with Temp reduction per UCS-66(b)(1)(c)       -155 °F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(b) is :
Design Pressure/Ambient Rating = 900.00/2220.00 = 0.405

*Note: Using the minimum value from (b)(1)(b) and (b)(1)(c) above
as the calculated nozzle flange MDMT.*

Nozzle Calculations per App. 1-10: Internal Pressure Case:

Thickness of Nozzle [tn]:
 = thickness - corrosion allowance
 = 0.875 - 0.125
 = 0.750 in.

Effective Pressure Radius [Reff]:
 = Di/2 + corrosion allowance
 = 13.562/2 + 0.125
 = 6.906 in.

Effective Length of Vessel Wall [LR]:
 = 8 * t
 = 8 * 1.094
 = 8.752 in.

Thickness Limit Candidate [LH1]:
 = t + 0.78 * sqrt(Rn * tn)
 = 1.094 + 0.78 * sqrt(1.438 * 0.750)

= 1.904 in.

Thickness Limit Candidate [LH2]:
= Lpr1 + T
= 5.875 + 1.094
= 6.969 in.

Thickness Limit Candidate [LH3]:
= 8(t + te)
= 8(1.094 + 0.000)
= 8.752 in.

Effective Nozzle Wall Length Outside the Vessel [LH]:
= min[LH1, LH2, LH3]
= min[1.904 , 6.969 , 8.752)
= 1.904 in.

Effective Vessel Thickness [teff]:
= t
= 1.094 in.

Determine Parameter [Lamda]:
= min(10, (Dn + Tn)/(sqrt((Di + teff) * teff)))
= min(10, (2.88 + 0.750)/(sqrt((13.81 + 1.094) * 1.094)))
= 0.898

Compute Areas A1-A43 (No Pad) or A1-A5 (With Pad) :

Area Contributed by the Vessel Wall [A1]:
= t * LR * max(Lamda/4, 1)
= 1.094 * 8.752 * max(0.898/4, 1)
= 9.575 in²

Area Contributed by the Nozzle Outside the Vessel Wall [A2]:
= tn * LH
= 0.750 * 1.904
= 1.428 in²

Area Contributed by the Outside Fillet Weld [A41]:
= 0.5 * Leg41^(2)
= 0.5 * 0.375^(2)
= 0.070 in²

The total area contributed by A1 through A43 [AT]:
= A1 + frn(A2 + A3) + A41 + A42 + A43
= 9.575+1.000(1.428+0.000)+0.070+0.000+0.000
= 11.073 in²

Allowable Local Primary Membrane Stress [Sallow]:
= 1.5 * S * E
= 1.5 * 17100.000 * 1.000
= 25650.0 psi

Determine Force acting on the Nozzle [fN]:

```
 = P * Rn( LH - t )
 = 900.000 * 1.438 ( 1.904 - 1.094 )
 = 1047.8 lb.
```

Determine Force acting on the Shell [fS]:

```
 = P * Reff( LR + tn )
 = 900.000 * 6.906 ( 8.752 + 0.750 )
 = 59058.7 lb.
```

Discontinuity Force from Internal Pressure [fY]:

```
 = P * Reff * Rnc
 = 900.000 * 6.906 * 1.438
 = 8934.6 lb.
```

Area Resisting Internal Pressure [Ap]:

```
 = Rn( LH - t ) + Reff( LR + tn + Rnc )
 = 1.438 ( 1.904 - 1.094 ) + 6.906 ( 8.752 + 0.750 + 1.438 )
 = 76.7 in²
```

Maximum Allowable Working Pressure Candidate [Pmax1]:

```
 = Sallow /( 2 * Ap/AT - Rxs/teff )
 = 25650.000/( 2 * 76.712/11.073 - 6.906/1.094 )
 = 3400.4 psig
```

Maximum Allowable Working Pressure Candidate [Pmax2]:

```
 = S[t/Reff]
 = 17100.000 [1.094/6.906 ]
 = 2708.9 psig
```

Maximum Allowable Working Pressure [Pmax]:

```
 = min( Pmax1, Pmax2 )
 = min( 3400.395 , 2708.862 )
 = 2708.862 psig
```

Average Primary Membrane Stress [SigmaAvg]:

```
 = ( fN + fS + fY ) / AT
 = ( 1047.803 + 59058.730 + 8934.638 )/11.073
 = 6235.136 psi
```

General Primary Membrane Stress [SigmaCirc]:

```
 = P * Reff / teff
 = 900.000 * 6.906/1.094
 = 5681.4 psi
```

Maximum Local Primary Membrane Stress [PL]:

```
 = max( 2 * SigmaAvg - SigmaCirc, SigmaCirc )
 = max( 2 * 6235.136 - 5681.353 , 5681.353 )
 = 6788.9 psi
```

Summary of Nozzle Pressure/Stress Results:

Allowed Local Primary Membrane Stress	Sallow	25650.00	psi
Local Primary Membrane Stress	PL	6788.92	psi
Maximum Allowable Working Pressure	Pmax	2708.86	psig

Strength of Nozzle Attachment Welds per 1-10 and U-2(g)

Discontinuity Force Factor [ky]:
```
 = ( Rnc + tn ) / Rnc
 = ( 1.438 + 0.750 )/1.438
 = 1.522 For set-in Nozzles
```

Weld Length of Nozzle to Shell Weld [Ltau]:
```
 = pi/2 * ( Rn + tn )
 = pi/2 * ( 1.438 + 0.750 )
 = 3.436 in.
```

Weld Throat Dimensions, (0.7071*Leg Dimensions) [L41T, L42T, L43T]:
```
 = 0.265,   0.000,   0.000, in.
```

Weld Load Value [fwelds]:
```
 = min( fy * ky, 1.5 * Sn( A2 + A3 ), pi/4*P*Rn^2*ky^2 )
 = min(8935*1.52,1.5*19888.0(1.428+0.000),pi/4*900.0*1.44^2*1.52^2)
 = 3382.427 lb.
```

Weld Stress Value [tau]:
```
 = fwelds/(Ltau(0.49*L41T + 0.6*tw1 + 0.49*L43T ) )
 = 3382.427/(3.436 (0.49*0.265 + 0.6*0.375 + 0.49*0.000 ) )
 = 2773.437 < or = to 17100.000 Weld Size is OK
```

Weld Size Calculations, Description: S2(Shell Outlet

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.7500  in.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          0.2500 = Min per Code 0.2651 = 0.7 * Wo in.
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
Converged Max. Allow. Pressure in Operating case     2473.739  psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.3625 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.4565 in.

INPUT VALUES, Nozzle Description: T2(Channel Out) From : 50

Pressure for Reinforcement Calculations	P	900.000	psig
Temperature for Internal Pressure	Temp	428	°F
Shell Material [Impact Tested]		SA-333 6	
Shell Allowable Stress at Temperature	Sv	17100.00	psi
Shell Allowable Stress At Ambient	Sva	17100.00	psi
Inside Diameter of Cylindrical Shell	D	13.5620	in.
Shell Finished (Minimum) Thickness	t	1.2190	in.
Shell Internal Corrosion Allowance	c	0.0781	in.
Shell External Corrosion Allowance	co	0.0000	in.
Distance from Bottom/Left Tangent		24.2292	ft.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material		SA-266 4	
Material UNS Number		K03017	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	19888.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		4.3750	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.8750	in.
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	5.8750	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.3750	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.3750	in.
Inside Projection	h	0.0000	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
ASME Code Weld Type per UW-16		None	
Class of attached Flange		900	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)

```
                    |   |
                    |   |
                    |   |
                    |   |
  ________________/|   |
 |              \  |   |
 |               \ |   |
 |________________\|___|
```

Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: T2(Channel Out)

ASME Code, Section VIII, Div. 1, 2015, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation               4.375  in.
Actual Thickness Used in Calculation                      0.875  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]

```
 = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
 = (900.00*6.8591)/(17100*1.00-0.6*900.00)
 = 0.3728 in.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
 = Ro(1 - exp( -P/( Sn*E ))) per Appendix 1-2 (a)(1)
 = 2.188(1-exp(-900.00/(19888.00*1.00)))
 = 0.0968 in.
```

Note:

Taking a UG-36(c)(3)(a) exemption for nozzle: T2(Channel Out). This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation or force the Appendix 1-10 computation in Nozzle Design Options.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

```
Wall Thickness for Internal/External pressures      ta = 0.2218 in.
Wall Thickness per UG16(b),                     tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure    trb1 = 0.4509 in.
Wall Thickness               tb1 = max(trb1, tr16b) = 0.4509 in.
Wall Thickness               tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45                    tb3 = 0.3320 in.
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 0.332 , max( 0.4509 , 0.1875 ) ]
 = 0.3320 in.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
 = max( ta, tb )
 = max( 0.2218 , 0.3320 )
 = 0.3320 in.
```

Available Nozzle Neck Thickness = 0.8750 in. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

MDMT of the Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 0.875 , tr = 0.096 , c = 0.1250 in. , E* = 1.00
Stress Ratio = tr * (E*)/(tg - c) = 0.128 , Temp. Reduction = 140 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B                24 °F
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit           -6 °F
Min Metal Temp. at Required thickness (UCS 66.1)            -146 °F
Min Metal Temp. w/o impact per UG-20(f)                      -20 °F
```

MDMT of Nozzle-Shell/Head Weld for the Nozzle (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 0.875 , tr = 0.096 , c = 0.1250 in. , E* = 1.00
Stress Ratio = tr * (E*)/(tg - c) = 0.128 , Temp. Reduction = 140 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B                24 °F
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit           -6 °F
Min Metal Temp. at Required thickness (UCS 66.1)            -146 °F
Min Metal Temp. w/o impact per UG-20(f)                      -20 °F

Governing MDMT of all the sub-joints of this Junction   :   -146 °F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)       -20 °F
Flange MDMT with Temp reduction per UCS-66(b)(1)(b)          -55 °F
Flange MDMT with Temp reduction per UCS-66(b)(1)(c)         -155 °F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(b) is :
Design Pressure/Ambient Rating = 900.00/2220.00 = 0.405

Note: Using the minimum value from (b)(1)(b) and (b)(1)(c) above as the calculated nozzle flange MDMT.

Weld Size Calculations, Description: T2(Channel Out)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.7500  in.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
Nozzle Weld           0.2500 = Min per Code 0.2651 = 0.7 * Wo in.
```

NOTE : Skipping the nozzle attachment weld strength calculations.
Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a)

(small nozzles) do not require a weld strength check.

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case     2586.144  psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.3625 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.4565 in.

INPUT VALUES, Nozzle Description: T1   From : 50

Pressure for Reinforcement Calculations	P	900.000	psig
Temperature for Internal Pressure	Temp	428	°F
Shell Material [Impact Tested]		SA-333 6	
Shell Allowable Stress at Temperature	Sv	17100.00	psi
Shell Allowable Stress At Ambient	Sva	17100.00	psi
Inside Diameter of Cylindrical Shell	D	13.5620	in.
Shell Finished (Minimum) Thickness	t	1.2190	in.
Shell Internal Corrosion Allowance	c	0.0781	in.
Shell External Corrosion Allowance	co	0.0000	in.
Distance from Bottom/Left Tangent		24.2292	ft.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material		SA-266 4	
Material UNS Number		K03017	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	19888.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		4.3750	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.8750	in.
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	5.8750	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.3750	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.3750	in.
Inside Projection	h	0.0000	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
ASME Code Weld Type per UW-16		None	
Class of attached Flange		900	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)

```
               |  |
               |  |
               |  |
               |  |
  ____________/|  |
 |          \  |  |
 |           \ |  |
 |____________\|__|
```

Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: T1

ASME Code, Section VIII, Div. 1, 2015, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation             4.375  in.
Actual Thickness Used in Calculation                    0.875  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]

```
 = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
 = (900.00*6.8591)/(17100*1.00-0.6*900.00)
 = 0.3728 in.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
 = Ro(1 - exp( -P/( Sn*E ))) per Appendix 1-2 (a)(1)
 = 2.188(1-exp(-900.00/(19888.00*1.00)))
 = 0.0968 in.
```

Note:

Taking a UG-36(c)(3)(a) exemption for nozzle: T1.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation or force the Appendix 1-10 computation in Nozzle Design Options.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

```
Wall Thickness for Internal/External pressures      ta = 0.2218 in.
Wall Thickness per UG16(b),                     tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure    trb1 = 0.4509 in.
Wall Thickness                 tb1 = max(trb1, tr16b) = 0.4509 in.
Wall Thickness                 tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45                    tb3 = 0.3320 in.
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 0.332 , max( 0.4509 , 0.1875 ) ]
 = 0.3320 in.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
 = max( ta, tb )
 = max( 0.2218 , 0.3320 )
 = 0.3320 in.
```

Available Nozzle Neck Thickness = 0.8750 in. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

MDMT of the Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 0.875 , tr = 0.096 , c = 0.1250 in. , E* = 1.00
Stress Ratio = tr * (E*)/(tg - c) = 0.128 , Temp. Reduction = 140 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              24 °F
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit         -6 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -146 °F
Min Metal Temp. w/o impact per UG-20(f)                    -20 °F
```

MDMT of Nozzle-Shell/Head Weld for the Nozzle (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 0.875 , tr = 0.096 , c = 0.1250 in. , E* = 1.00
Stress Ratio = tr * (E*)/(tg - c) = 0.128 , Temp. Reduction = 140 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              24 °F
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit         -6 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -146 °F
Min Metal Temp. w/o impact per UG-20(f)                    -20 °F

Governing MDMT of all the sub-joints of this Junction  :  -146 °F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -20 °F
Flange MDMT with Temp reduction per UCS-66(b)(1)(b)        -55 °F
Flange MDMT with Temp reduction per UCS-66(b)(1)(c)       -155 °F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(b) is :
```
Design Pressure/Ambient Rating = 900.00/2220.00 = 0.405
```

Note: Using the minimum value from (b)(1)(b) and (b)(1)(c) above as the calculated nozzle flange MDMT.

Weld Size Calculations, Description: T1

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.7500  in.
```

Results Per UW-16.1:

```
                       Required Thickness     Actual Thickness
Nozzle Weld          0.2500 = Min per Code 0.2651 = 0.7 * Wo in.
```

NOTE : Skipping the nozzle attachment weld strength calculations.
Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a)

(small nozzles) do not require a weld strength check.

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case   2586.144 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.3625 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.4565 in.

Nozzle Schedule:

Description	Nominal Size in.	Flange Sch/Type Cls		Noz. O/Dia in.	Wall Thk in.	ODia in.	Re-Pad Thick in.	Cut Length in.
S1(Shell Inlet)	4.375	900	WNF	4.375	0.875	-	-	7.46
S2(Shell Outlet	4.375	900	WNF	4.375	0.875	-	-	7.46
T2(Channel Out)	4.375	900	WNF	4.375	0.875	-	-	7.46
T1	4.375	900	WNF	4.375	0.875	-	-	7.46

General Notes for the above table:

The Cut Length is the Outside Projection + Inside Projection + Drop + In Plane Shell Thickness. This value does not include weld gaps, nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must be increased. The Re-Pad WIDTH around the nozzle is calculated as follows: Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller and thinner section.

Nozzle Material and Weld Fillet Leg Size Details:

Nozzle	Material	Shl Grve Weld in.	Noz Shl/Pad Weld in.	Pad OD Weld in.	Pad Grve Weld in.	Inside Weld in.
S1(Shel	SA-266 4	0.375	0.375	-	-	-
S2(Shel	SA-266 4	0.375	0.375	-	-	-
T2(Chan	SA-266 4	0.375	0.375	-	-	-
T1	SA-266 4	0.375	0.375	-	-	-

Note: The Outside projections below do not include the flange thickness.

Nozzle Miscellaneous Data:

Nozzle	Elevation/Distance From Datum ft.	Layout Angle deg.	Projection Outside in.	Projection Inside in.	Installed In Component
S1(Shell Inlet)	21.854	90.00	5.88	0.00	Shell Side
S2(Shell Outlet	21.854	270.00	5.88	0.00	Shell Side
T2(Channel Out)	24.063	90.00	5.88	0.00	channel shel
T1	24.063	270.00	5.88	0.00	channel shel

Input Echo, TubeSheet Item 1, Description: Tubesheet

Tubesheet Design Code		TEMA	
Shell Desc.		Shell Side	
Shell Design Pressure	Ps	500.00	psig
Shell Temperature for Internal Pressure	TEMPS	428.00	°F
Shell Material		SA-333 6	
Shell Material UNS Number		K03006	
Shell Allowable Stress at Temperature	Sos	17100.00	psi
Shell Allowable Stress at Ambient	Sas	17100.00	psi
Shell Thickness	Ts	1.2190	in.
Shell Internal Corrosion Allowance	Cas	0.1250	in.
Inside Diameter of Shell	Ds	13.562	in.
Channel Desc.		channel shell	
Channel Design Pressure	Pc	500.00	psig
Channel Temperature for Internal Pressure	TEMPC	428.00	°F
Channel Material		SA-333 6	
Channel Material UNS Number		K03006	
Channel Allowable Stress at Temperature	Soc	17100.00	psi
Channel Allowable Stress at Ambient	Sac	17100.00	psi
Channel Thickness	Tc	1.2190	in.
Channel Corrosion Allowance	Cac	0.0781	in.
Inside Diameter of Channel	Dc	13.562	in.
Tube Design Temperature	Tubtmp	428.00	°F
Tube Material		SA-179	
Tube Material UNS Number		K01200	
Is This a Welded Tube		No	
Tube Material Specification used		Smls. tube	
Tube Allowable Stress at Temperature	Sot	13400.00	psi
Tube Allowable Stress At Ambient	Sat	13400.00	psi
Tube Yield Stress At Operating Temperature	Syt	21920.00	psi
Tube Wall Thickness	Tt	0.1090	in.
Tube Corrosion Allowance	Catt	0.0781	in.
Number of Tubes Holes	Ntubs	39	
Tube Layout Pattern		Square	
Tube Outside Diameter	do	0.7500	in.
Tube Pitch (Center to Center Spacing)	PTube	1.0000	in.
Total Straight Tube Length	Lt	273.375	in.
Straight Tube Length, bet. inner tubsht faces	RL	269.438	in.
Length of Expanded Portion of Tube	l	2.5000	in.

Tubesheet type: U-tube, Gasketed both Sides

Tubesheet Design Metal Temperature	TEMPTS	428.00	°F
Tubesheet Material (Not Normalized)		SA-516 70	
Tubesheet Material UNS Number		K02700	
Tubesheet Allowable Stress at Temperature	Sots	20000.00	psi
Tubesheet Allowable Stress at Ambient	Sats	20000.00	psi
Thickness of Tubesheet	Tts	3.9375	in.
Tubesheet Corr. Allowance (Shell side)	Cats	0.1875	in.

Tubesheet Corr. Allowance (Channel side)	Catc	0.1875	in.
Depth of Groove in Tube Sheet	hg	0.0000	in.
TEMA Tubesheet class			R

Additional Data for Gasketed Tubesheets:

Flange Face Outside Diameter	Fod	16.375	in.
Flange Face Inside Diameter	Fid	13.562	in.
Flange Facing Sketch	Code	Sketch 1a	
Gasket Outside Diameter	Go	16.250	in.
Gasket Inside Diameter	Gi	14.500	in.
Small end Hub thk.	g0	1.2190	in.
Large end Hub thk.	g1	1.4690	in.
Gasket Factor,	m	2.5000	
Gasket Design Seating Stress	y	10000.00	psi
Column for Gasket Seating	Code	Column II	
Gasket Thickness	tg	0.1750	in.
Full face Gasket Flange Option	Program	Selects	
Tubesheet Gasket on which Side	Side	BOTH	

Vacuum Pressures:

Shell side Vacuum Pressure	Pexts	0.0000	psig
Channel side Vacuum Pressure	Pextc	0.0000	psig

Intermediate Calculations For Gasketed Tubesheets:

ASME Code, Section VIII, Division 1, 2015

Gasket Contact Width,	N = (Goc-Gic) / 2	0.875	in.
Basic Gasket Width,	b0 = N / 2.0	0.438	in.
Effective Gasket Width,	b = SQRT(b0) * 0.5	0.331	in.
Gasket Reaction Diameter,	G = Go-2.0*b	15.589	in.

Tubesheet Analysis, Tubesheet number   1,Description:Tubesheet
TEMA Standards, Ninth Edition, 2007, Appendix A, Tubesheets

TEMA R-7.131/A.131 Minimum Tubesheet Thickness for R-type:

```
   TMIN = MAX( do, CONST - ( CATS + CATC ) )
   TMIN = MAX( 0.750 , 0.750 - ( 0.188 + 0.188 ) )
   TMIN = 0.7500 in.
Min. Thickness + CATS + CATC
   TREQMIN = 1.1250 in.
```

Shellside Fixity Factor, F, per RCB 7.132	FS	1.2500	
Shellside Effective Diameter, per RCB 7.132	GS	15.589	in.
Tubeside Fixity Factor, F, per RCB 7.132	FC	1.2500	
Tubeside Effective Diameter, per RCB 7.132	GC	15.589	in.
TEMA Eta factor used in calculation	ETA	0.5584	

Shellside Effective Pressure, Bending,	PSU	500.0000	psig
Tubeside Effective Pressure, Bending,	PTU	500.0000	psig

TEMA RCB-7.132/A.131 Required Thickness for Shellside Pressure [Trs]:

```
   = FS * GS * SQRT ( PSU / ( ETA * SOTS ) ) / 3.0
```

= 1.2500 * 15.5886 * SQRT(500.00 / (0.5584 * 20000)) / 3.0
= 1.3743 in.

TEMA RCB-7.132/A.131 Required Thickness for Tubeside Pressure [Trc]:
= FC * GC * SQRT (PTU / (ETA * SOTS)) / 3.0
= 1.2500 * 15.5886 * SQRT(500.00 / (0.5584 * 20000)) / 3.0
= 1.3743 in.

TEMA RCB-7.132/A.131 Reqd Thickness for Bending + Cats + MAX(Catc,hg) [Treq]:
= 1.7493 in.

No Shear Calculation, since Pressure is less than 2000.0000 psig

Summary of Tubesheet Results:

Condition	Req Thk (+CA)	Actual Thk (in.)	Actual Stress	Allow (psi)	Result
Bending	1.749	3.938	4464.44	30000.00	Ok

Minimum Design Metal Temperature Results Summary :

Description	Notes	Curve	Basic MDMT °F	Reduced MDMT °F	UG-20(f) MDMT °F	Thickness ratio	Gov Thk in.	E*
Shell Side Fl	[11]	!	-50	-50		0.924	1.219	1.000
Shell side He	[10]	B	7	-26		0.676	1.125	1.000
Shell side Hea	[7]	B	7	-21		0.722	1.125	1.000
Shell Side	[8]	!	-50	-50		0.767	1.219	1.000
S1(Shell Inlet	[1]	B	-6	-146	-20	0.128	0.875	1.000
Nozzle Flg	[4]		-20	-155		0.128		
S2(Shell Outle	[1]	B	-6	-146	-20	0.128	0.875	1.000
Nozzle Flg	[4]		-20	-155		0.128		
Channel Flang	[11]	!	-50	-50		0.906	1.219	1.000
channel shell	[8]	!	-50	-50		0.704	1.219	1.000
channel head	[10]	B	7	-31		0.624	1.125	1.000
channel head	[7]	B	7	-27		0.660	1.125	1.000
T2(Channel Out	[1]	B	-6	-146	-20	0.128	0.875	1.000
Nozzle Flg	[4]		-20	-155		0.128		
T1	[1]	B	-6	-146	-20	0.128	0.875	1.000
Nozzle Flg	[4]		-20	-155		0.128		

Exchanger Side	Computed MDMT °F	Required MDMT °F	Pass/Fail
Shell	-21	-20	Pass
Channel/Tube	-27	-20	Pass

Notes:
[!] - This was an impact tested material.
[1] - Governing Nozzle Weld.
[4] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(c).
[5] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(b).
[6] - MDMT Calculations at the Shell/Head Joint.
[7] - MDMT Calculations for the Straight Flange.
[8] - Cylinder/Cone/Flange Junction MDMT.
[9] - Calculations in the Spherical Portion of the Head.
[10] - Calculations in the Knuckle Portion of the Head.
[11] - Calculated (Body Flange) Flange MDMT.
[12] - Calculated Flat Head MDMT per UCS-66.3
[13] - Tubesheet MDMT, shell side, if applicable
[14] - Tubesheet MDMT, tube side, if applicable
[15] - Nozzle Material
[16] - Shell or Head Material
[17] - Impact Testing required

UG-84(b)(2) was not considered.
UCS-66(g) was not considered.
UCS-66(i) was not considered.

Notes:
Impact test temps were not entered in and not considered in the analysis.
UCS-66(i) applies to impact tested materials not by specification and
UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).
The Basic MDMT includes the (30F) PWHT credit if applicable.

ASME Code, Section VIII, Division 1, 2015

Diameter Spec : 16.000 in. OD		
Vessel Design Length, Tangent to Tangent	24.88	ft.
Specified Datum Line Distance	0.17	ft.
Shell Material	SA-333 6 [Impact Tested]	
Head Material	SA-516 70	
Nozzle Material	SA-266 4	
Shell Side Design Temperature	428	°F
Channel Side Design Temperature	428	°F
Shell Side Design Pressure	900.000	psig
Channel Side Design Pressure	900.000	psig
Shell Side Hydrostatic Test Pressure	1170.000	psig
Channel Side Hydrostatic Test Pressure	1170.000	psig
Wind Design Code	ASCE-93	
Earthquake Design Code	UBC-94	

Element Pressures and MAWP: psig

Element Desc	Design Pres. + Stat. head	External Pressure	M.A.W.P	Corrosion Allowance
Shell side Head	900.000	0.000	2631.579	0.1250
Shell Side	900.000	0.000	2473.739	0.1250
Shell Side Flange	900.000	0.000	1872.790	0.1250
Channel Flange	900.000	0.000	1788.710	0.0781
channel shell	900.000	0.000	2586.144	0.0781
channel head	900.000	0.000	2761.748	0.0781

Element Type	"To" Elev ft.	Length ft.	Element Thk in.	Reqd Thk Int.	Reqd Thk Ext.	Joint Eff Long	Joint Eff Circ
Ellipse	0.00	0.167	1.125	0.463	0.188	1.00	1.00
Cylinder	22.34	22.344	1.219	0.537	No Calc	1.00	1.00
Body Flg	22.80	0.458	3.812	3.134	3.134	1.00	1.00
Body Flg	23.58	0.453	3.688	3.037	3.037	1.00	1.00
Cylinder	24.54	0.958	1.219	0.490	No Calc	1.00	1.00
Ellipse	24.71	0.167	1.125	0.419	0.141	1.00	1.00

Element thicknesses are shown as Nominal if specified, otherwise are Minimum

Saddle Parameters:

Saddle Width	4.000	in.
Saddle Bearing Angle	180.000	deg.
Centerline Dimension	16.000	in.
Wear Pad Width	6.000	in.
Wear Pad Thickness	0.250	in.
Wear Pad Bearing Angle	180.000	deg.

Distance from Saddle to Tangent	6.000	in.

Summary of Maximum Saddle Loads, Operating Case :

Maximum Vertical Saddle Load	5519.20	lb.
Maximum Transverse Saddle Shear Load	178.00	lb.
Maximum Longitudinal Saddle Shear Load	16.83	lb.

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	6253.11	lb.
Maximum Transverse Saddle Shear Load	58.74	lb.
Maximum Longitudinal Saddle Shear Load	5.55	lb.

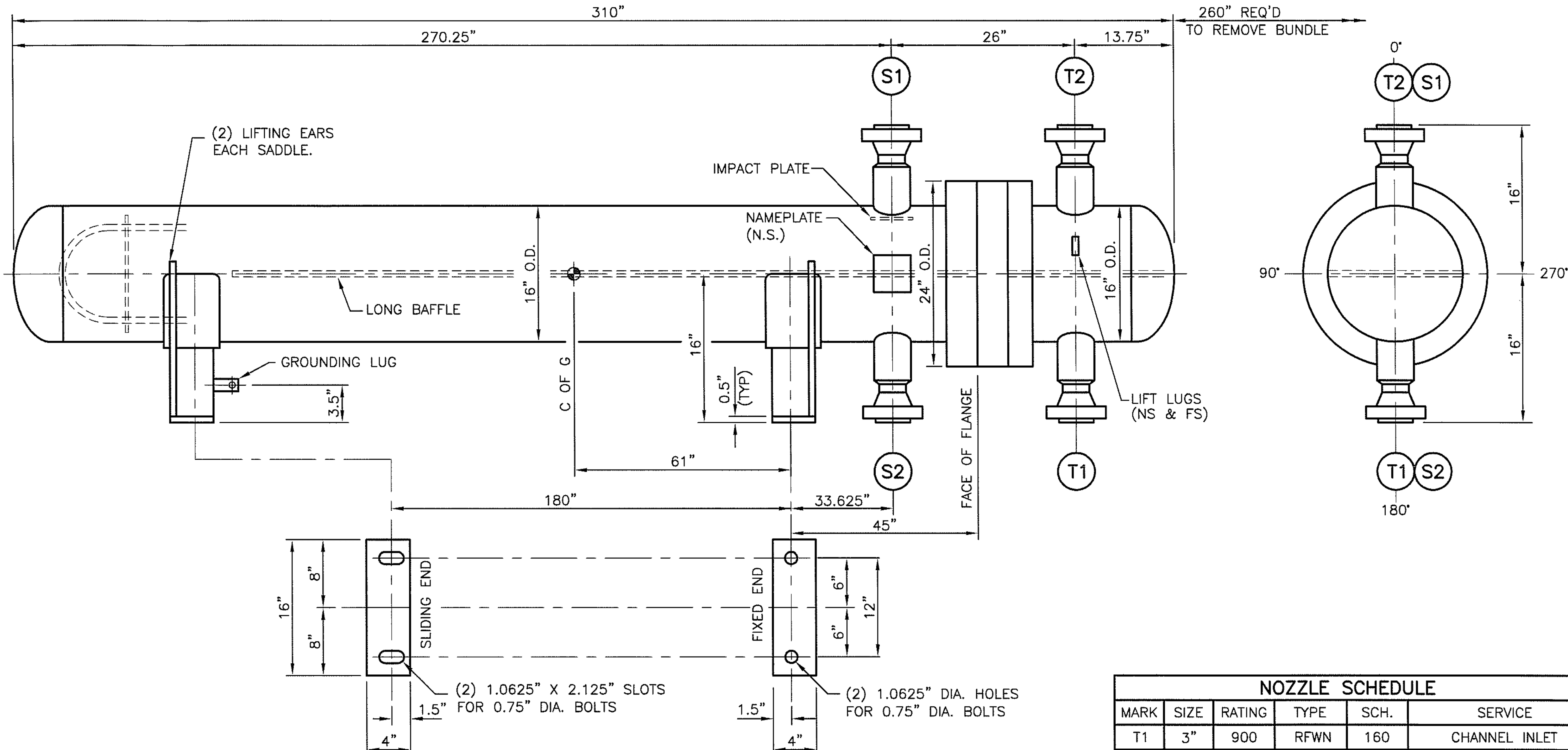
Weights:

Fabricated - Bare W/O Removable Internals	7288.5	lbm
Shop Test - Fabricated + Water (Full)	8940.4	lbm
Shipping - Fab. + Rem. Intls.+ Shipping App.	7288.5	lbm
Erected - Fab. + Rem. Intls.+ Insul. (etc)	7288.5	lbm
Empty - Fab. + Intls. + Details + Wghts.	7288.5	lbm
Operating - Empty + Operating Liquid (No CA)	7288.5	lbm
Field Test - Empty Weight + Water (Full)	8940.4	lbm

Appendix D:

Drawings

201, 9637-45 Ave, Edmonton, AB T6E 5Z8. Tel: 780-434-9292, Fax: 780-434-9219



NOZZLE SCHEDULE

MARK	SIZE	RATING	TYPE	SCH.	SERVICE
T1	3"	900	RFWN	160	CHANNEL INLET
T2	3"	900	RFWN	160	CHANNEL OUTLET
S1	3"	900	RFWN	160	SHELL INLET
S2	3"	900	RFWN	160	SHELL OUTLET

REVISION CONTROL BOX ⊙Denotes DCR & Rev.# Added to This Sheet Only
⚠1 PER CUST MARK-UP & E.I. JUNE 17/10 (FX) ⊙

CUSTOMER: CENOVUS ENERGY INC.
FOR: PELICAN LAKE SAGD-GRB PROJECT# 172, AB.
P.O. NO.: 20169
TEMA TYPE: BFU
SIZE: 14-275
SERVICE: BFW / EMULSION EXCHANGER

SHELL & TUBE EXCHANGER OUTLINE DRAWING

NO. OF EXCHANGERS REQ'D: TWO

DWN FX | CKD KW | ITEM E-200A/B

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWG NO. 10-3155A/B
SHEET 1 OF 14

MATERIAL LIST

LINE	PART	MATERIAL
	CHANNEL	
1	COVER/HEAD	SA-420-WPL6
2	TEMA FLANGE	SA-350-LF2 CL.1
3	CYLINDER	SA-333-6
4	NOZZLE FLANGE	SA-350-LF2 CL.1
5	NOZZLE NECK	SA-266-4N
6	NOZZLE REINFORCEMENT PAD	–
7	COUPLING/THREDOLET/PLUG	–
8	PASS PLATE	SA-516-70N
9	STUDBOLTS	SA-193-B7M
10	NUTS	SA-194-2HM
11		
12		
	SHELL	
13	TEMA FLANGE	SA-350-LF2 CL.1
14	CYLINDER	SA-333-6
15	COVER/HEAD	SA-420-WPL6
16	CONE	–
17	NOZZLE FLANGE	SA-350-LF2 CL.1
18	NOZZLE NECK	SA-266-4N
19	NOZZLE REINFORCEMENT PAD	–
20	COUPLING/THREDOLET/PLUG	–
21	SUPPORT WRAPPER PLATE	SA-516-70N
22	SUPPORT	SA-516-70N
23	STUDBOLTS	SA-193-B7M
24	NUTS	SA-194-2HM
25		
26		
27		
	FLOATING HEAD	
28	FLANGE	–
29	DISH	–
30	SPLIT RING	–
31	PASS PLATE	–
32	STUDBOLTS	–
33	NUTS	–
34		
35		
36		

LINE	PART	MATERIAL
	TUBE BUNDLE	
37	TUBESHEET	SA-516-70N
38	TUBES	SA-179
39	BAFFLE/SUPPORT PLATES	SA-36
40	IMPINGEMENT PLATE	SA-36
41	TIE-ROD/NUT/SPACER	CARBON STEEL
42		
43		
	GASKETS	
44	CHANNEL	316 SS SPIRAL WOUND
45	SHELL	316 SS SPIRAL WOUND
46	FLOATING HEAD	–
47	CHANNEL NOZZLE	–
48	SHELL NOZZLE	–
49		
50		

MATERIAL NOTES

SHELL SIDE IN CLASS 2 SOUR SERVICE (CUSTOMER TO CONFIRM).

(1) TUBES, TUBESHEET & SHELL SIDE MATERIAL TO BE IDENTFIED WITH HEAT NUMBERS AND TO NACE MR 0175 & CUSTOMER'S SPEC. TR-43-SPC-00-032-01.

(2) ALL COMPONENTS IN CONTACT WITH THE SOUR PROCESS FLUID SHALL BE FABRICATED FROM FULLY KILLED, LOW CARBON STEEL. WHEN THESE COMPONENTS ARE INTENDED FOR WELDING, THEY SHALL ALSO MEET THE FOLLOWING PROPERTIES:
WHEN TRACE ELEMENTS ARE SHOWN ON THE MATERIAL TEST REPORT (MTR) THE CARBON EQUIVALENT (CE) SHALL BE LESS THAN OR EQUAL TO 0.45%. THE CE IS DEFINED AS FOLLOWS:
CE = %C + %Mn/6 + (%Cr + %Mo + %V)/5 + (%Ni + %Cu)/15

(3) MTR'S REQ'D FOR ALL PRESSURE PART MATERIALS.

(4) E.I. TO SUPPLY TWO SETS OF SPARE GASKETS.

(5) TEMA FLANGES: CARBON CONTENT ≤ 0.30%.

CONSTRUCTION NOTES

(1) CONSTRUCTION TO BE PER ASME CODE SECTION VIII DIVISION 1 2007 EDITION 2009 ADDENDA, TEMA CLASS "R" 9th EDITION, API 660 & 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: NOZZLE NECK, TUBE & TUBESHEET EXEMPT PER UG-20(F)1-5.
CYLINDER & FLANGES EXEMPT PER UCS-66(G)
WELD METAL IS EXEMPT PER UCS-67(a)(2)

(5) STRESS RELIEVE: SHELL & CHANNEL AT 1150°F $\pm^{25}_{0}$°F FOR (1.5) HOUR
"U" BENDS AT 1150°F $\pm^{25}_{0}$°F FOR (1) HOUR

(6) RADIOGRAPHY: RT1 CHANNEL & SHELL.

(7) WELD PROCEDURES: C5, C3 & C6.

(8) PAINT: TBD

(9) INSULATION: TBD. BY OTHERS

(10) 100% UT CAT. "D". Before and after PWHT R

(11) 100% MT ALL LIFT LUGS, & All cat. D welds

Add Hardness on process side (6.1.7 Sour Serv. Spec)

Hardness testing table 2 10.0 Class 2

⚠1 * REGISTER @ MAWP C&H R

DESIGN CONDITIONS	SHELL SIDE	CHANNEL SIDE
PROCESS DESIGN PRESSURE* ⚠1	1850 PSIG	1850 PSIG
EXTERNAL PRESSURE	–	–
DESIGN TEMPERATURE	428 °F	428 °F
MDMT	-20° F	-20° F
C&H MAWP	⚠1 1860 PSIG	⚠1 1860 PSIG
C&H MAWP LIMITED BY	⚠1 TEMA FLANGE	⚠1 TEMA FLANGE
HYDRO TEST PRESSURE	⚠1 2418 PSIG	⚠1 2418 PSIG
CORROSION ALLOWANCE	0.125"	0.0625"
N&C MAX. PRESS.	⚠1 1860 PSIG	⚠1 1860 PSIG
N&C M.P. LIMITED BY	⚠1 TEMA FLANGE	⚠1 TEMA FLANGE
SHOP HYDRO TEST PRESS.	⚠1 2418 PSIG	⚠1 2418 PSIG
NUMBER OF PASSES	F-SHELL	TWO
SURFACE AREA	346.7 SQ. FT	
SHIPPING WEIGHT	9400 lbs	
WEIGHT FULL OF WATER	10850 lbs	
BUNDLE WEIGHT	2440 lbs	
CHANNEL WEIGHT	800 lbs	
CAPACITY	23.23 CU. FT	

REVISIONS

⚠1 PER CUST MARK-UP & E.I. JUNE 17/10 (FX)

MATERIALS & DESIGN CONDITIONS

NO. OF EXCHANGERS REQ'D: TWO

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWN FX	CKD KW	ITEM E-200A/B	DWG NO. 10-3155A/B
			SHEET 1A OF 14

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 coupling) 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.

3. For removable-bundle heat exchangers, the permissible out-of-roundness of a completed shell, after all welding and heat treatment, shall allow a metal template to pass through the entire shell length without binding. The template shall consist of two rigid disks (each with a diameter equal to the diameter of the transverse baffle or support plate), rigidly mounted perpendicularly on a shaft and spaced not less than 300 mm (12") apart.

4. Welds attaching non-pressure attachments (such as lugs or structural steel supports, except for insulation support rings) shall be continuous.

5. All repads to be air soap suds tested to 170 kPa (25 psig).

6. All exposed flange gasket surfaces shall be coated with an easily removable rust preventative and shall be protected by a wood, ~~plastic~~, or steel cover complete with rubber gasket and (4) four bolts minimum.

7. All threaded connections shall be protected by metal plugs or caps of compatible material.

8. The item number, shipping weight, and purchase order number shall be painted on the exchanger.

9. All boxes, crates, or packages shall be identified with the purchaser's order and equipment number.

10. Stencil "DO NOT WELD" (in two places 180° apart as a minimum) on equipment that has been P.W.H.T.

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

See 8.1.7 See note
nipple needs to project past insulation

10. UT - Ultrasonic examination and criteria for acceptance shall comply with appendix 12 of section VIII, Div 1, ASME code.

11. MPI - Magnetic particle examination and criteria for acceptance shall comply with appendix 6 of section VIII, Div 1, ASME code.

13. 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 200 Brinell.
d) Hardness shall be determined using Microdur.
e) Two circumferential welds, and each connection-to-component weld where the connection is NPS 2 or larger shall be tested.
f) If more than one welding procedure is used to fabricate longitudinal or circumferential welds, hardness readings shall be made of welds deposited by each procedure.
g) All finished welds in material of ferromagnetic steel shall be examined after postweld heat treatment (unless the ASME Code specifies examination after hydrostatic testing) by the magnetic-particle method.

14. Machined contact surfaces, including any threaded connections, shall be suitably protected to prevent scaling or loss of finish during heat treatment.

15. An independent hydrostatic test of the shell side and the tube side shall be performed, using potable water. The test pressure shall be maintained for at least 1 hour.

8.2.5 Stamp item # also on channel & bundle flanges along with job # R

17. All NDE shall be done before & after PWHT.

18. Welding:
a) All pressure retaining weld shall be full penetration weld joints (Shell side).
b) The back side of the root pass shall be 100% MT examined after back gouging to sound metal. This applies to category "D" welds
c) All arc strikes, starts, and stops shall be confined to the welding groove. Arc strikes outside the welding groove shall be removed by grinding and the area examined by MT method.
d) Backing strips and consumable inserts are not permitted.
e) No welding, heating, hammering or deformation shall be permitted after post weld heat treatment.

19. The following parts shall be stamped with the manufacturer's serial number: shell and channel flanges, tubesheet. △1

REVISIONS		
△1 PER E.I. JUNE 17/10 (FX)		

API 660 NOTES & CUSTOMER SPECIFICATION

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWN FX	CKD KW	ITEM E-200A/B	DWG NO. 10-3155A/B
			SHEET 1B OF 14

0.03125" THK X 6" X 6.25"
MAT'L: STAINLESS STEEL

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

U				
W	MAWP: SHELL	1860 PSIG	AT	428 °F
RT1	MAEWP: SHELL	–	AT	–
HT	MAWP: TUBE	1860 PSIG	AT	428 °F
–	MAEWP: TUBE	–	AT	–
–	MDMT: SHELL	–20 °F	AT	1860 PSIG
	MDMT: TUBE	–20 °F	AT	1860 PSIG

SERIAL NO. 10–3155* YEAR MFD. 2010

BFW/EMULSION EXCHANGER

PO NO.: 20169 ITEM: E–200*

TEMA TYPE: BFU SIZE: 14–275 TEMA CLASS "R"

WEIGHT: DRY=9400 LBS, FULL OF WATER=10850 LBS

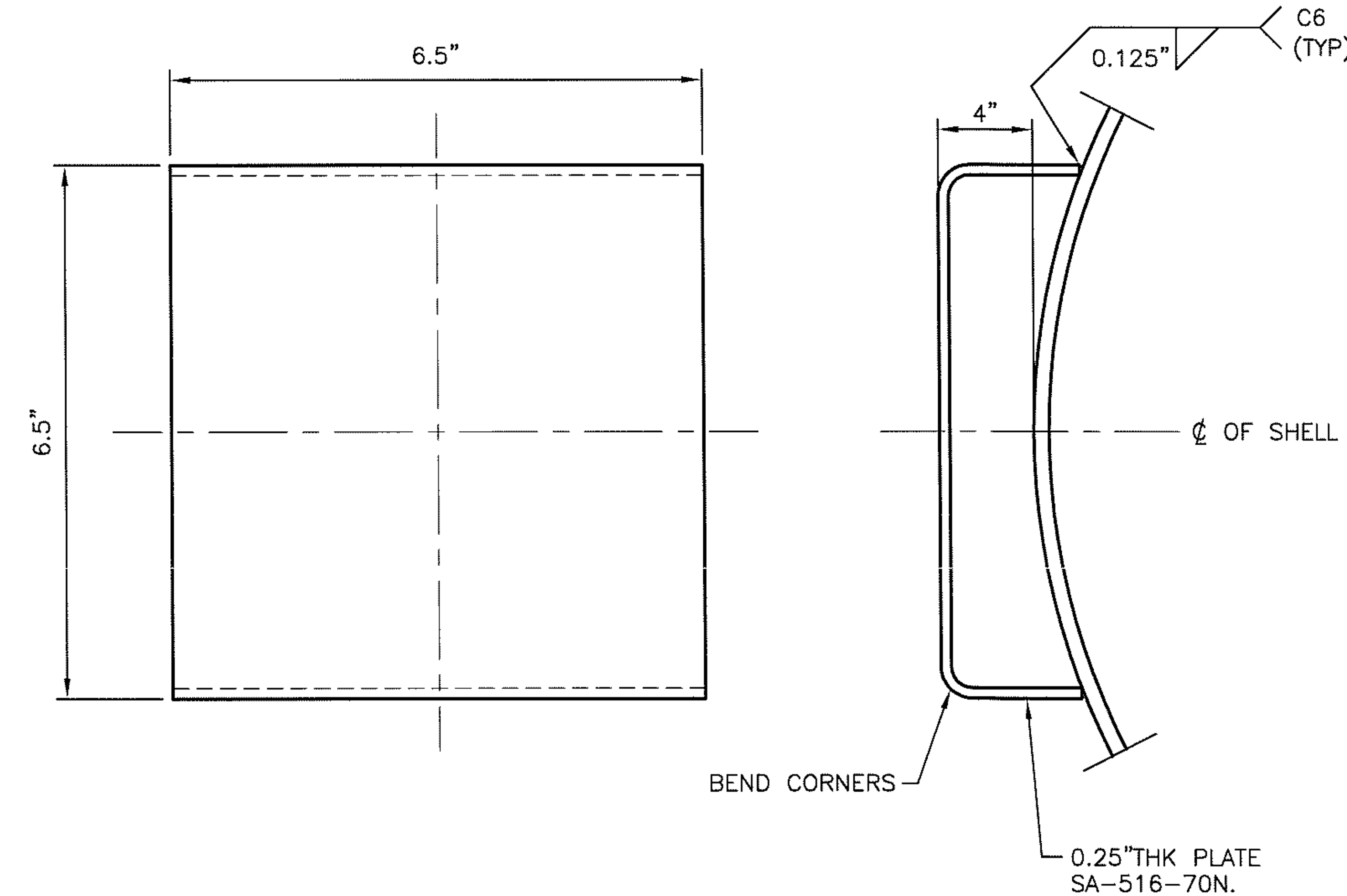
BUNDLE WEIGHT: 2440 LBS

DUTY: 6,974,418 BTU/HR SURFACE AREA: 346.7 SQ. FT

TEST PRESSURE: SHELL=2418 PSIG CHANNEL=2418 PSIG

PROV. REG. CRN –

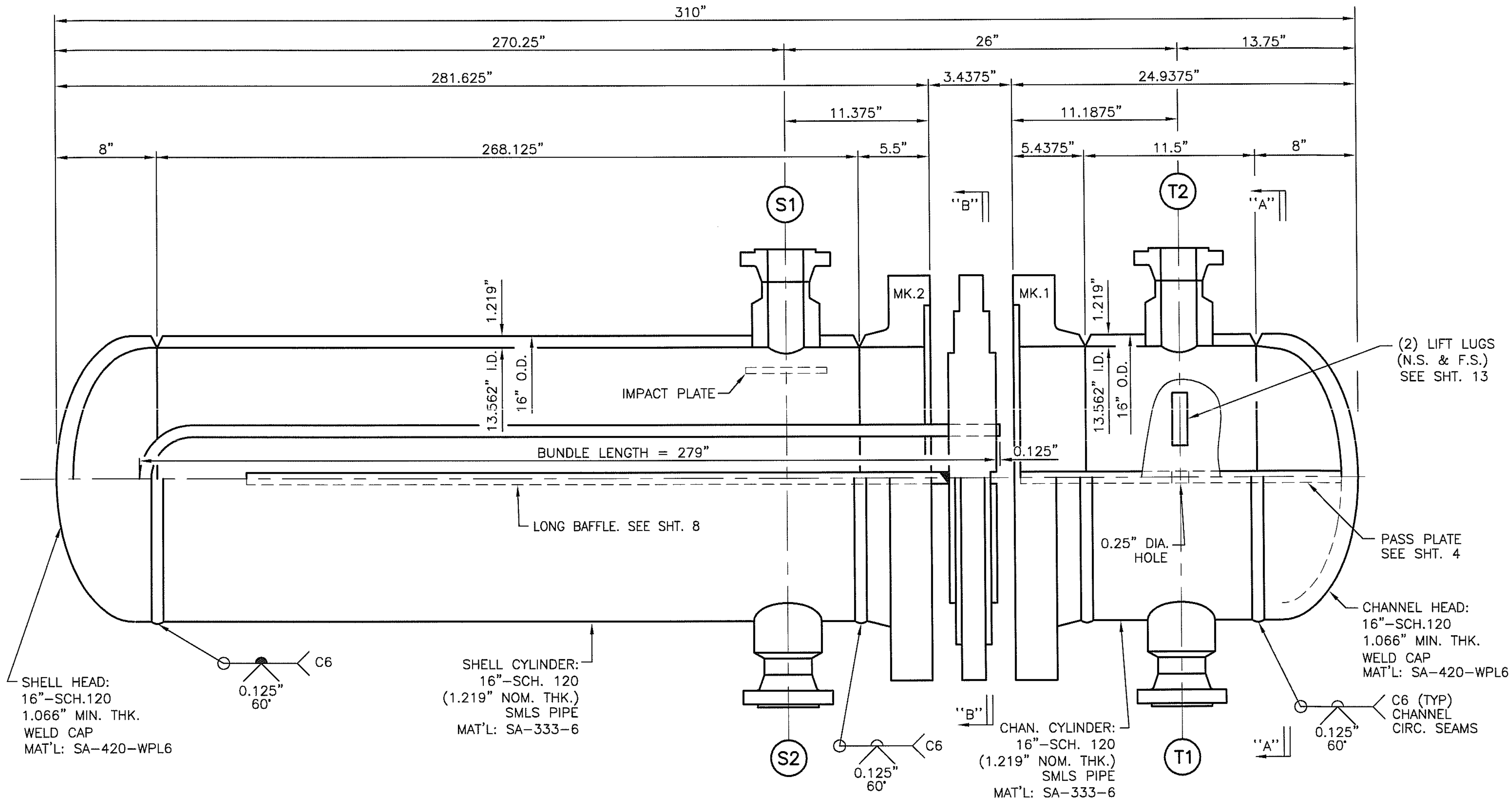
NO. REQ'D EACH EXCHANGER: ONE



NAMEPLATE BKT DETAIL
ONE REQ'D

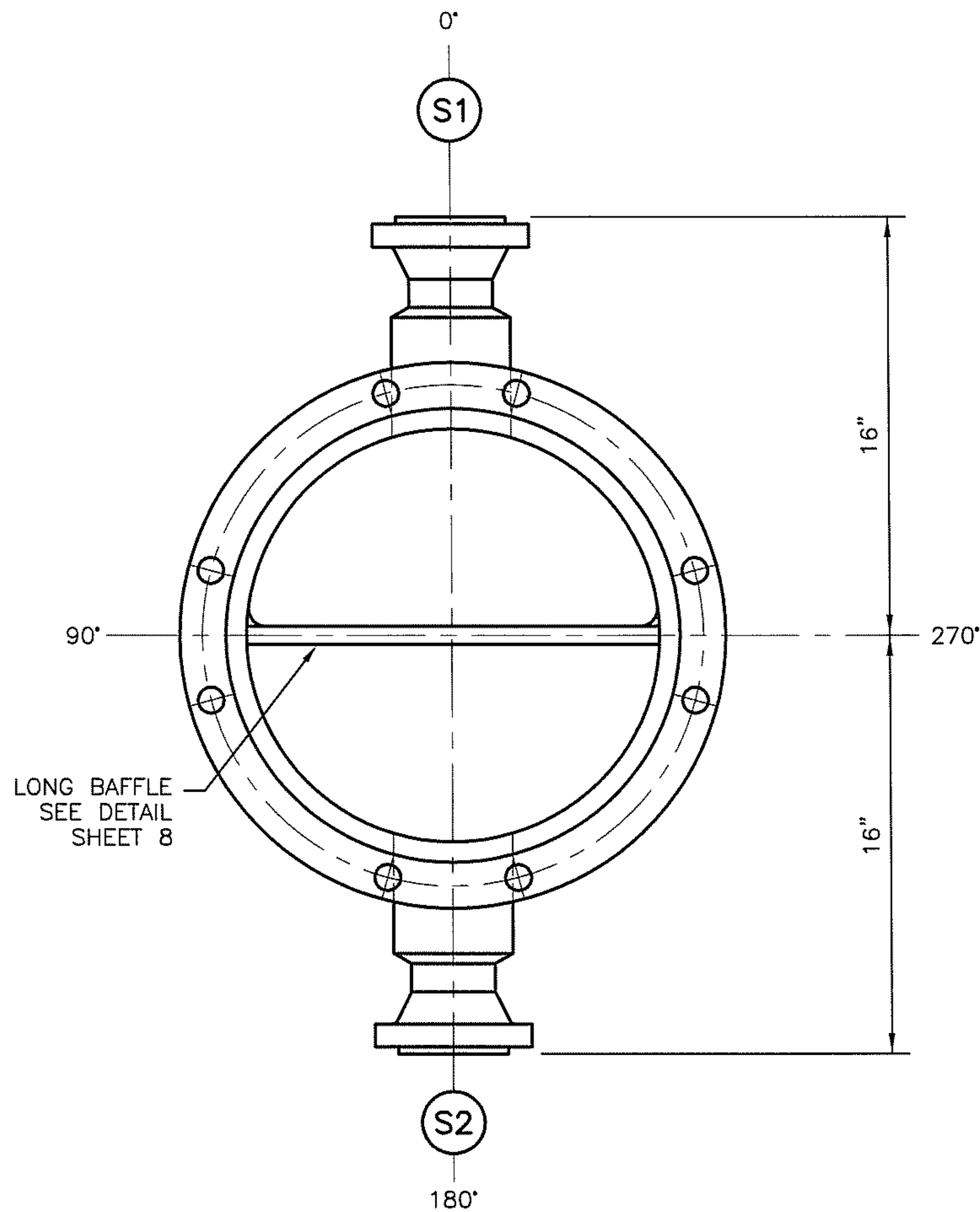
*
A
B

REVISIONS	NAME PLATE DETAIL NO. OF EXCHANGERS REQ'D: TWO	EXCHANGER INDUSTRIES CALGARY, ALBERTA
	DWN FX · CKD KW · ITEM E–200A/B	DWG NO. 10–3155A/B SHEET 2 OF 14



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

REVISIONS	SHELL & CHANNEL DETAIL	EXCHANGER INDUSTRIES CALGARY, ALBERTA
	NO. OF EXCHANGERS REQ'D: TWO	DWG NO. 10-3155A/B
	DWN FX / CKD KW / ITEM E-200A/B	SHEET 3 OF 14

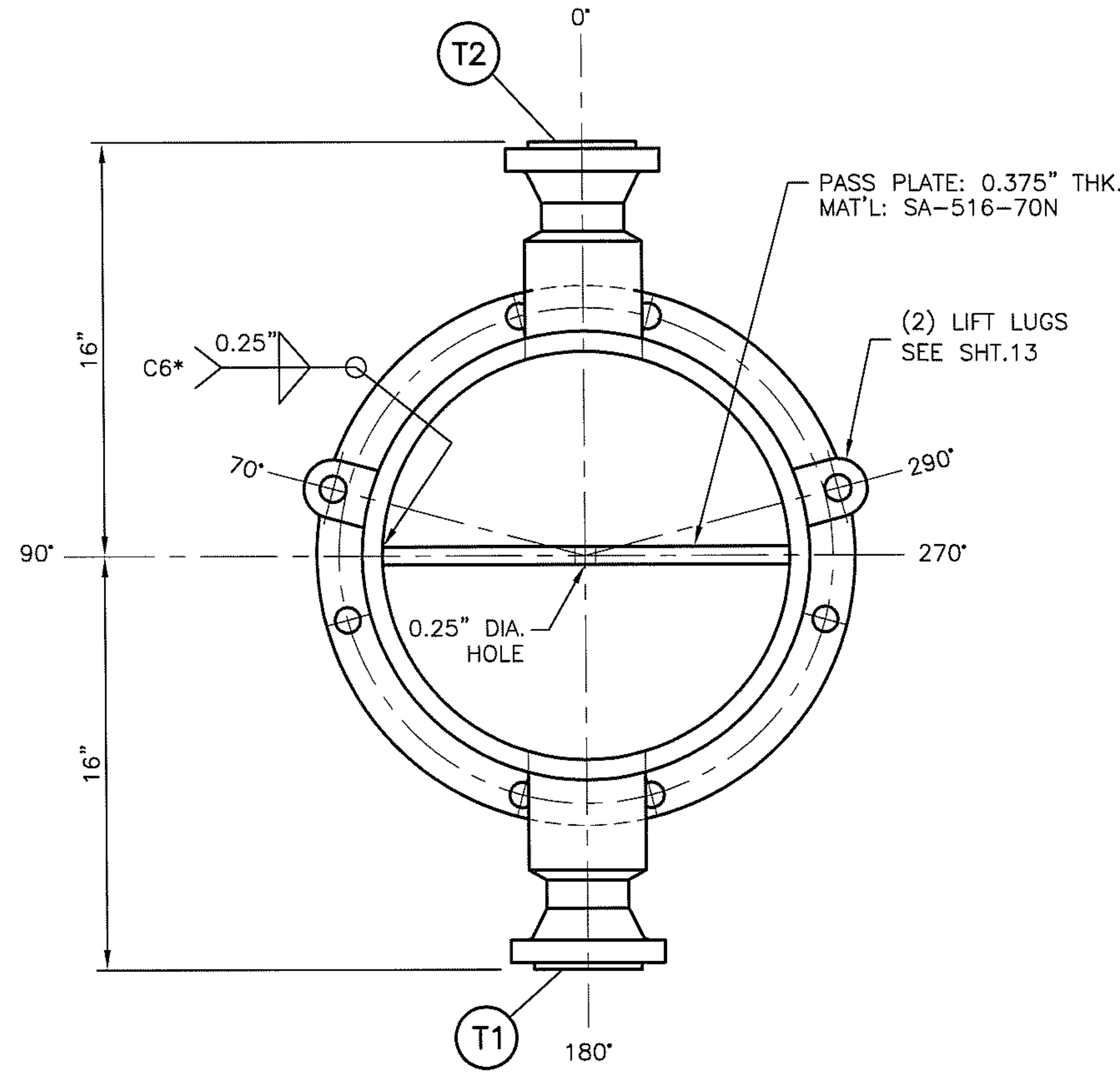


SECTION "B-B"

PREHEAT WELDS: 50 °F

RADIOGRAPHY: RT1 100% ALL BUTT WELDS

POST HEAT TREAT: YES



SECTION "A-A"

PREHEAT WELDS: 50 °F

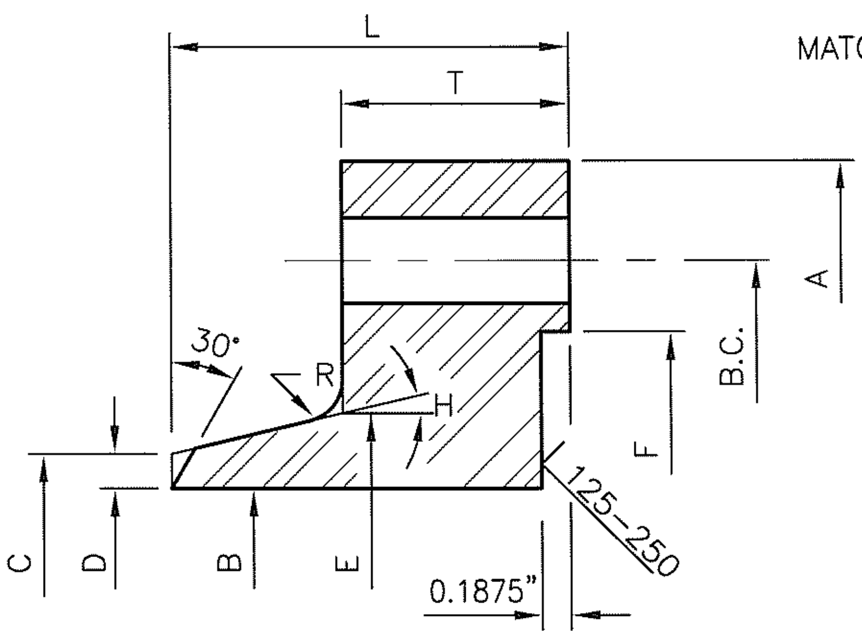
RADIOGRAPHY: RT1 100% ALL BUTT WELDS

POST HEAT TREAT: YES

* PASS PLATE TO HAVE FULL PEN.
WELDS 2" IN FROM TSHT END.
FILLET WELD REMAINDER.

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

REVISIONS	SHELL & CHANNEL SECTIONS NO. OF EXCHANGERS REQ'D: TWO	EXCHANGER INDUSTRIES CALGARY, ALBERTA
	DWN FX · CKD KW · ITEM E-200A/B	DWG NO. 10-3155A/B SHEET 4 OF 14



FLG. STYLE I

MATCH MARK @ 0°

STAMP ITEM# ON
TOP OF FLANGES

LOCATE (2) 0.5" DIA. JACKSCREWS
ON B.C. @ 90°, & 270°. DRILL & TAP
0.75" DEEP & COUNTERBORE REMAINDER
TO 0.625" DIA. ON MK.1&2

MATERIAL: SA-350-LF2 CL.1

250 OVERALL FINISH EXCEPT AS NOTED.

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

LINE NO.	MK. NO.	NO. REQ'D	FLG. STYLE	A	B	C	D	E	F	H	R	T	L	B.C.	BOLT HOLES NO.	BOLT HOLES DIA.
1	1	ONE	I	24"	13.562"	16"	1.219"	16.5"	16.375"	8.13°	0.625"	3.6875"	5.4375"	20.75"	16	1.75"
2	2	ONE	I	↓	↓	↓	↓	↓	↓	8.43°	↓	3.8125"	5.5"	↓	↓	↓

REVISIONS

FLANGE DETAIL

MK.1 13.562" – 1860 PSIG
MK.2 13.562" – 1860 PSIG

DESIGN TEMA "R"

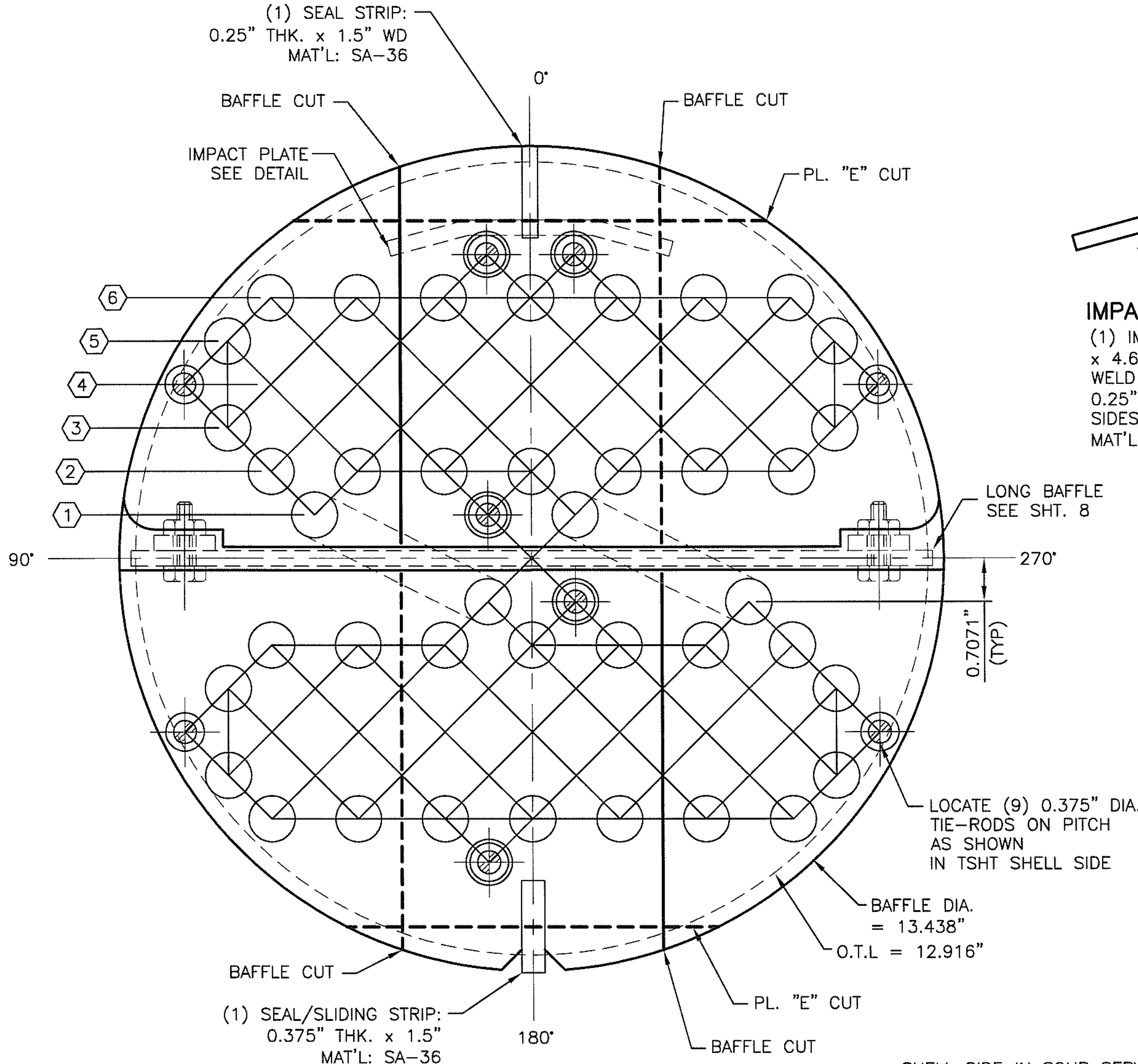
NO. OF EXCHANGERS REQ'D: TWO

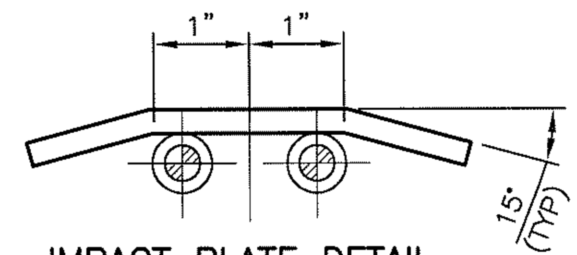
DWN FX | CKD KW | ITEM E-200A/B

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWG NO. 10-3155A/B

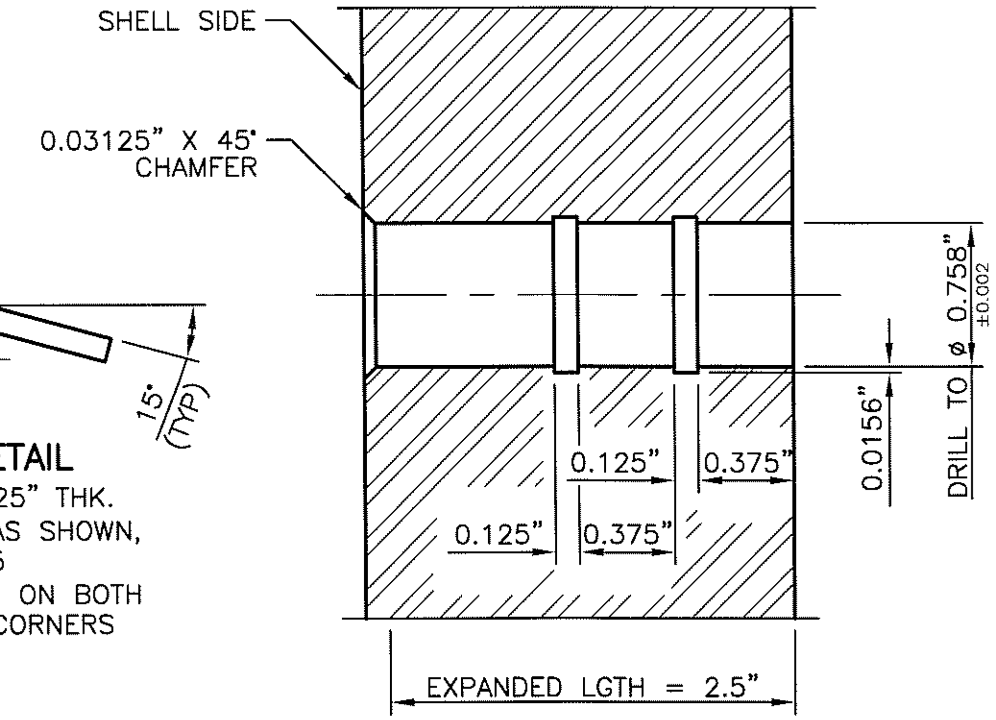
SHEET 5 OF 14



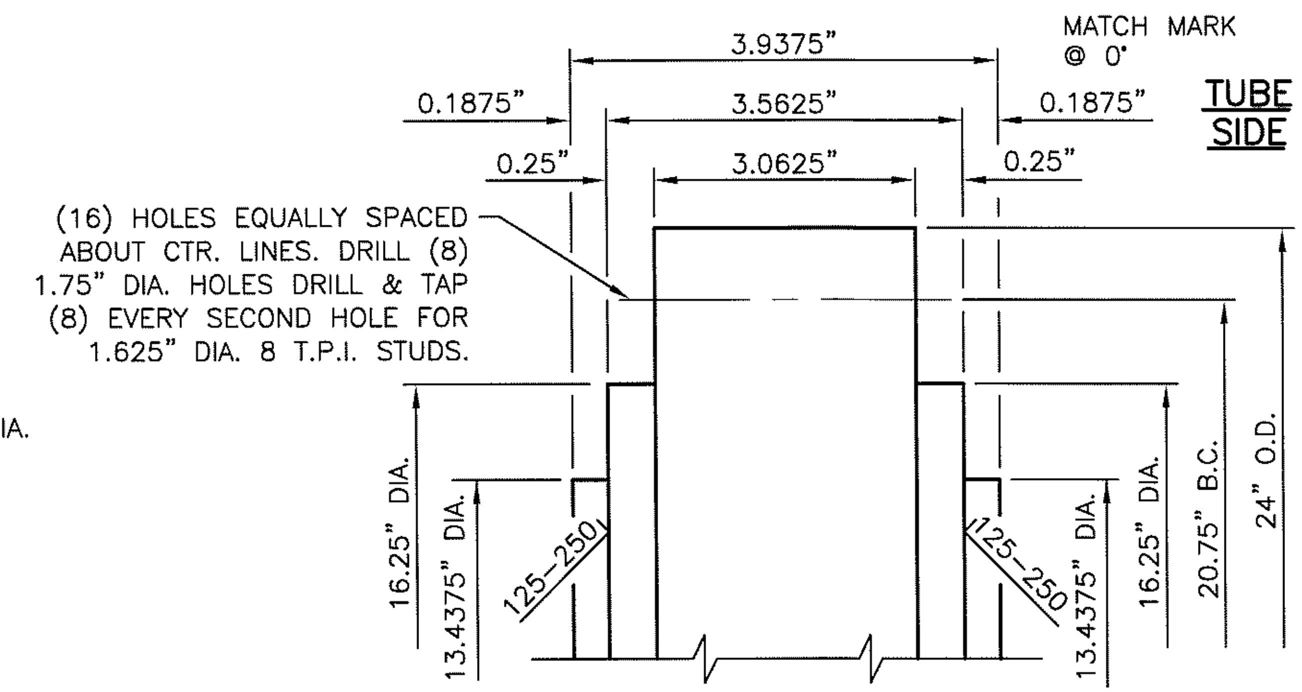


IMPACT PLATE DETAIL

(1) IMPACT PLATE: 0.25" THK.
x 4.625" DIA. BEND AS SHOWN,
WELD TO SPACERS C5
0.25" FILLET 2" LONG ON BOTH
SIDES AT THE FOUR CORNERS
MAT'L: SA-36



TUBE HOLE GROOVING DETAIL



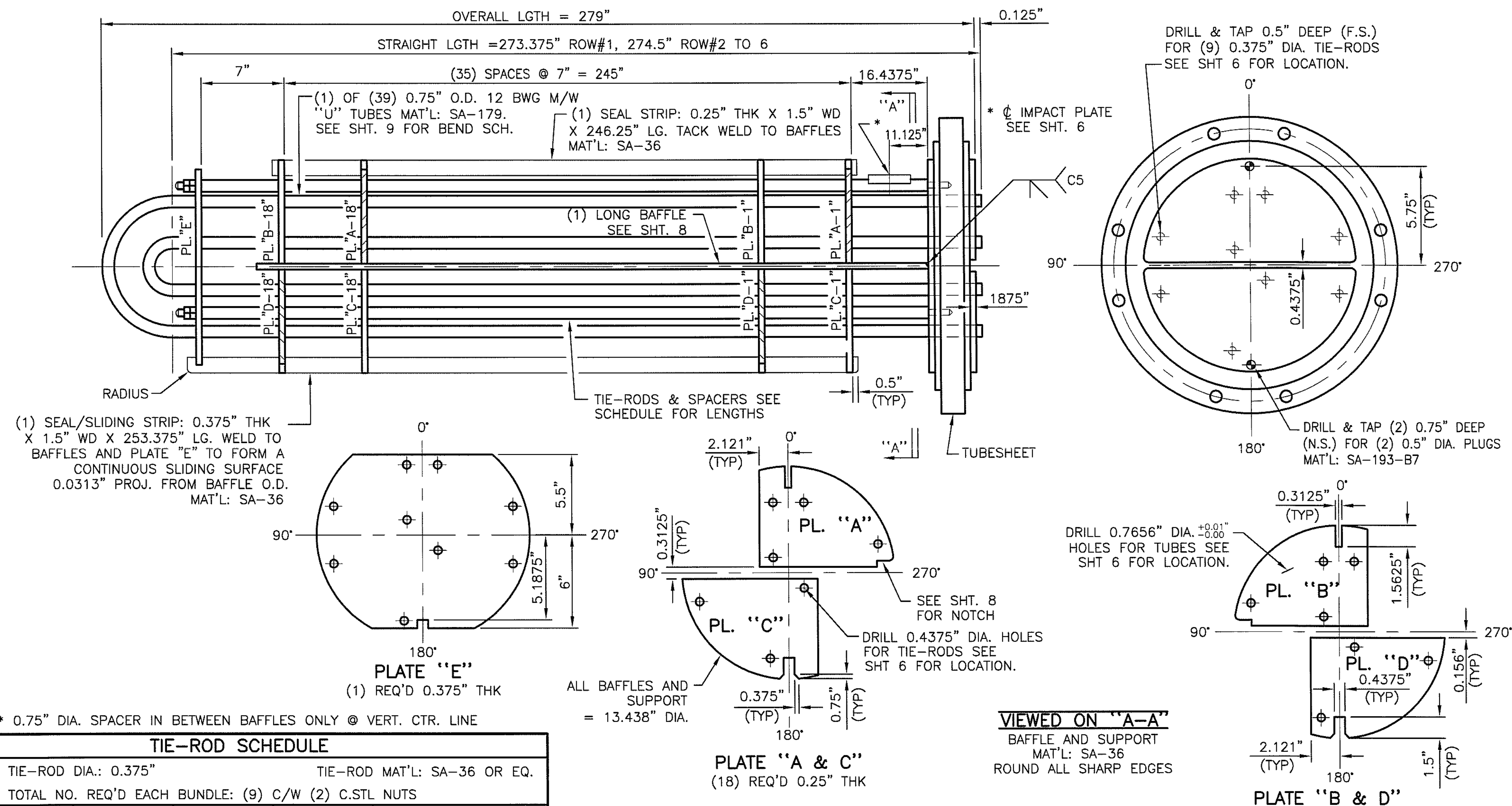
TUBESHEET DETAIL

ONE REQ'D EACH EXCHANGER
MAT'L: SA-516-70N

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

TUBE O.D. = 0.75"
TUBE PITCH = 1" 45° ◇
NO. OF TUBES = (39) "U"
NO. OF PASSES = TWO

REVISIONS	TUBE HOLE LAYOUT	EXCHANGER INDUSTRIES CALGARY, ALBERTA
	NO. OF EXCHANGERS REQ'D: TWO	DWG NO. 10-3155A/B
	DWN FX — CKD KW — ITEM E-200A/B	SHEET 6 OF 14



* 0.75" DIA. SPACER IN BETWEEN BAFFLES ONLY @ VERT. CTR. LINE

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

TIE-ROD SCHEDULE

TIE-ROD DIA.: 0.375" TIE-ROD MAT'L: SA-36 OR EQ.

TOTAL NO. REQ'D EACH BUNDLE: (9) C/W (2) C.STL NUTS

NO.:	(9)			
LGTH:	270.625"			

SPACER SCHEDULE

SPACER O.D.: 0.625"/0.75"* SPACER MAT'L: SA-214

TOTAL NO. REQ'D EACH BUNDLE: (86)/(175*)

NO.:	(7)	(2)	(175)*	(70)	(7)			
LGTH:	16.4375"	23.4375"	6.75"	13.75"	6.75"			

REVISIONS

BUNDLE DETAIL

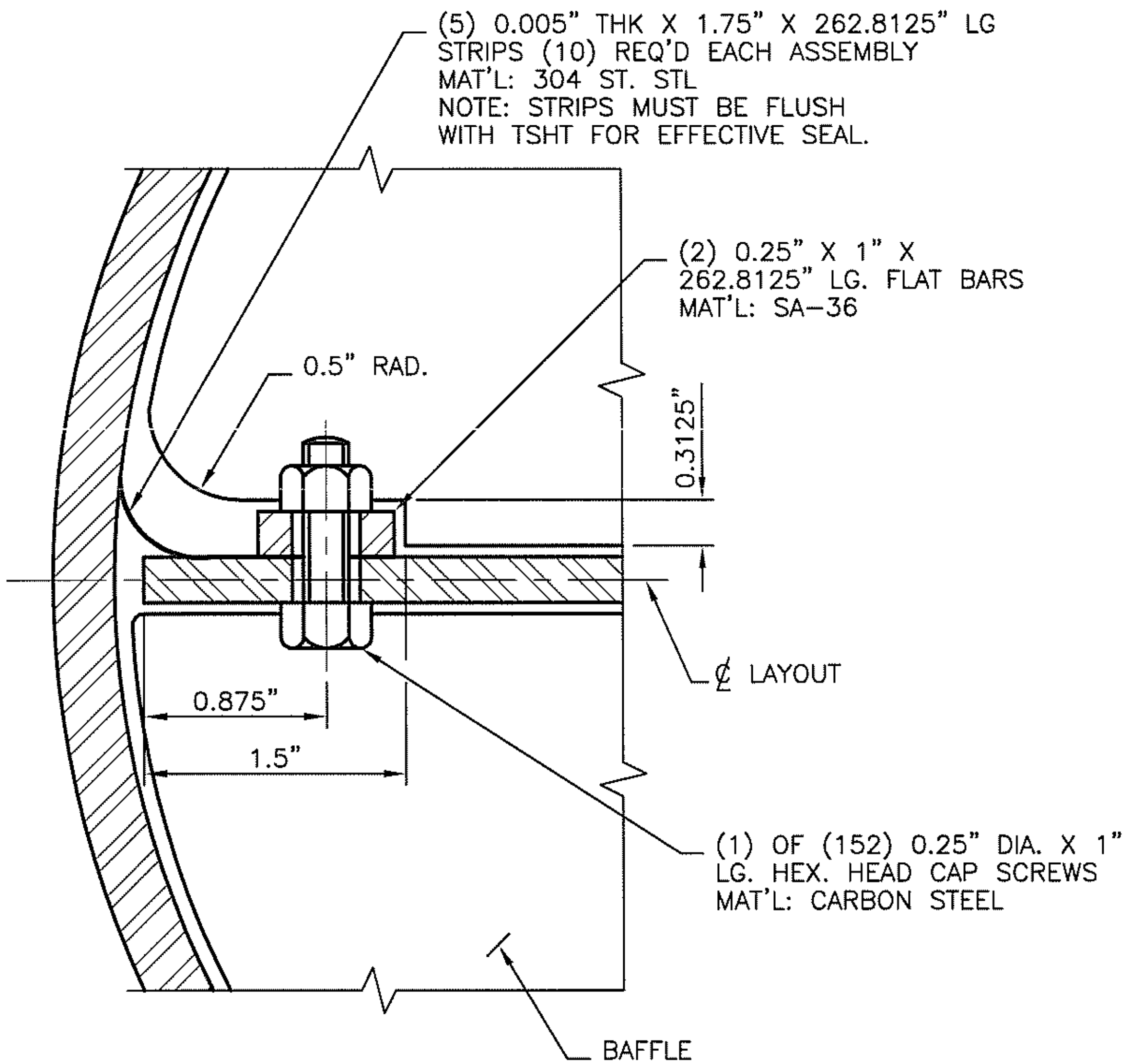
NO. OF EXCHANGERS REQ'D: TWO

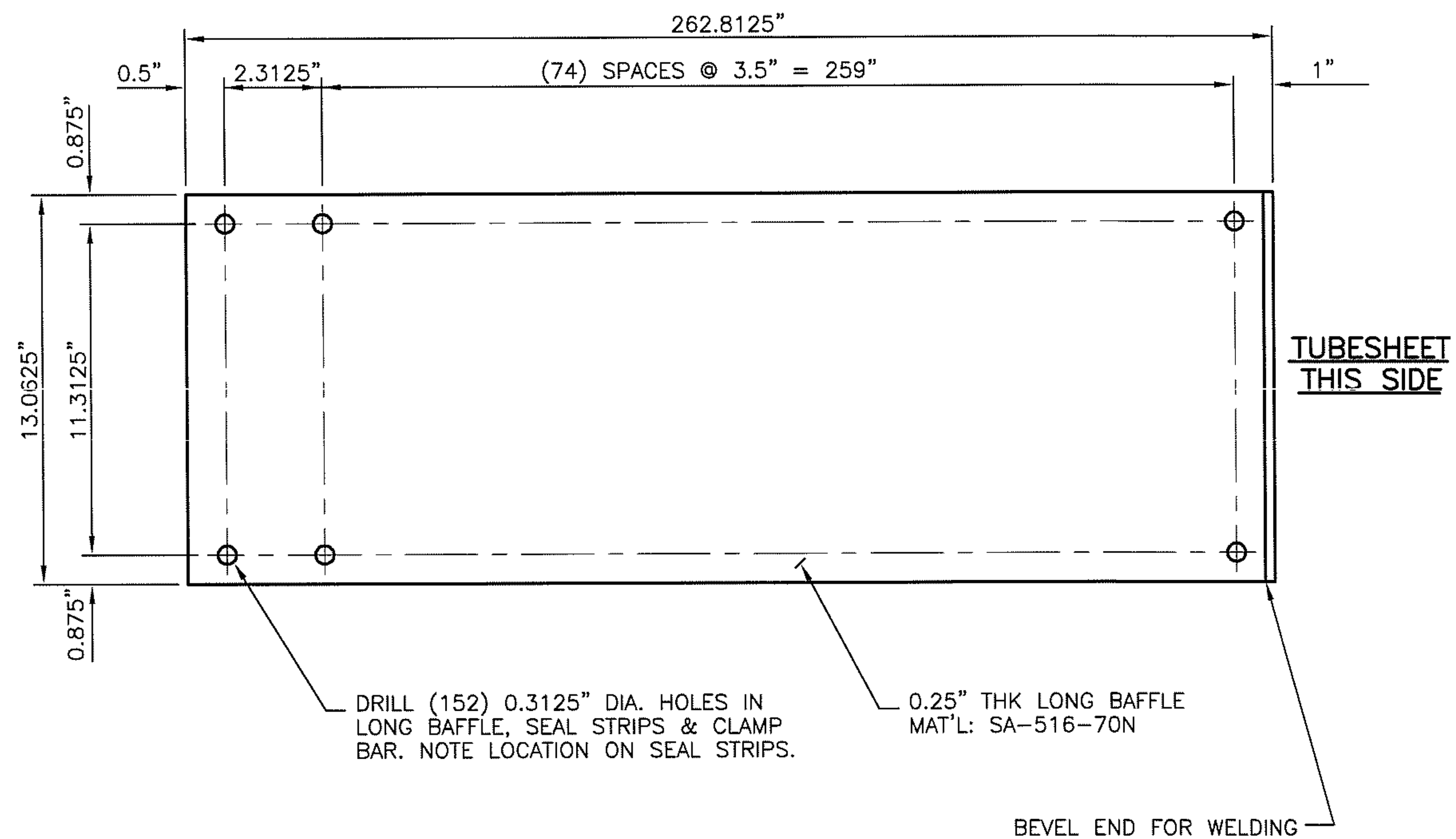
DWN FX | CKD KW | ITEM E-200A/B

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWG NO. 10-3155A/B

SHEET 7 OF 14





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

REVISIONS

LONG BAFFLE DETAIL

NO. REQ'D EACH BUNDLE: ONE
NO. OF BUNDLES REQ'D: TWO

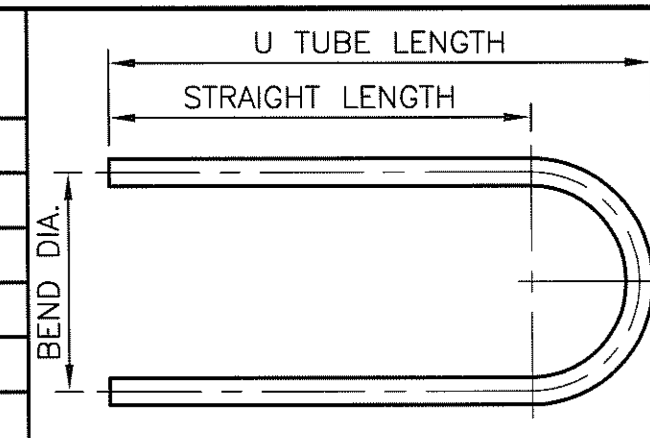
DWN FX | CKD KW | ITEM E-200A/B

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWG NO. 10-3155A/B

SHEET 8 OF 14

ROW NO.	NO. OF TUBES	BEND DIA.	STRAIGHT LENGTH	U TUBE LENGTH	OVERALL TUBE LENGTH
1	2	3.1875"	273.375"	275.375"	551.75"
2	7	2.8125"	274.5"	276.3125"	553.4375"
3	8	4.25"		277"	555.6875"
4	7	5.6875"		277.75"	557.9375"
5	8	7.0625"		278.4375"	560.125"
6	7	8.5"		279.125	562.375"
TOTAL (39) "U" TUBES					



NOTES:

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

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

(3) STRESS RELIEVE "U" BENDS AND 6" OF STRAIGHT LENGTH AT 1150°F $^{+25°F}_{-0°F}$ FOR ONE HOUR.

TUBE DETAILS:

TUBE O.D. = 0.75"

TUBE GAGE = 12 BWG M/W

TUBE MAT'L = SA-179 KILLED

MATERIAL NOTES:

1. UNIT IN SOUR SERVICE, MATERIAL MEET NACE MR 0175
2. MTR REQ'D.

REVISIONS

U BEND SCHEDULE

NO. OF EXCHANGERS REQ'D: TWO

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWN SF	CKD KW	ITEM E-200A/B	DWG NO. 10-3155A/B
			SHEET 9 OF 14

LOCATION	NO. REQ'D	SIZE	LENGTH	T.P.I.
CHANNEL TO SHELL*	16	1.625" DIA.	15"	8
JACKSCREWS**	4	0.5" DIA.	5"	13

* 0.25" THK. HARDENED WASHERS REQ'D UNDER EACH NUTS

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 COPPER COAT.

MATERIAL:
STUDBOLTS: SA-193-B7M
NUTS: SA-194-2HM
**JACKSCREWS: SA-193-B7

REVISIONS

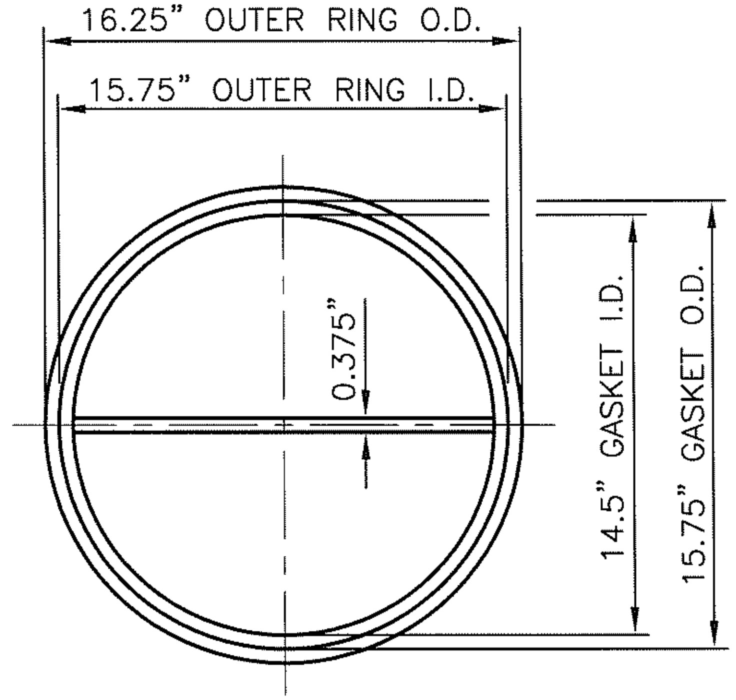
BOLT SCHEDULE

NO. OF EXCHANGERS REQ'D: TWO

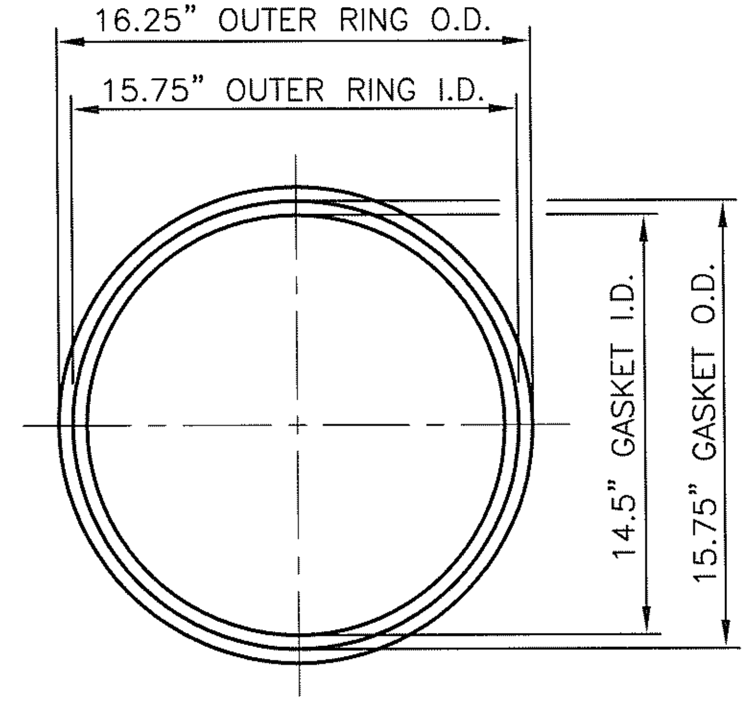
EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWG NO. 10-3155A/B

DWN FX | CKD KW | ITEM E-200A/B | SHEET 10 OF 14



CHANNEL TO TUBESHEET
DESIGN PRESSURE 1860 PSIG @ 428 °F



SHELL TO TUBESHEET
DESIGN PRESSURE 1860 PSIG @ 428 °F

NOTES:

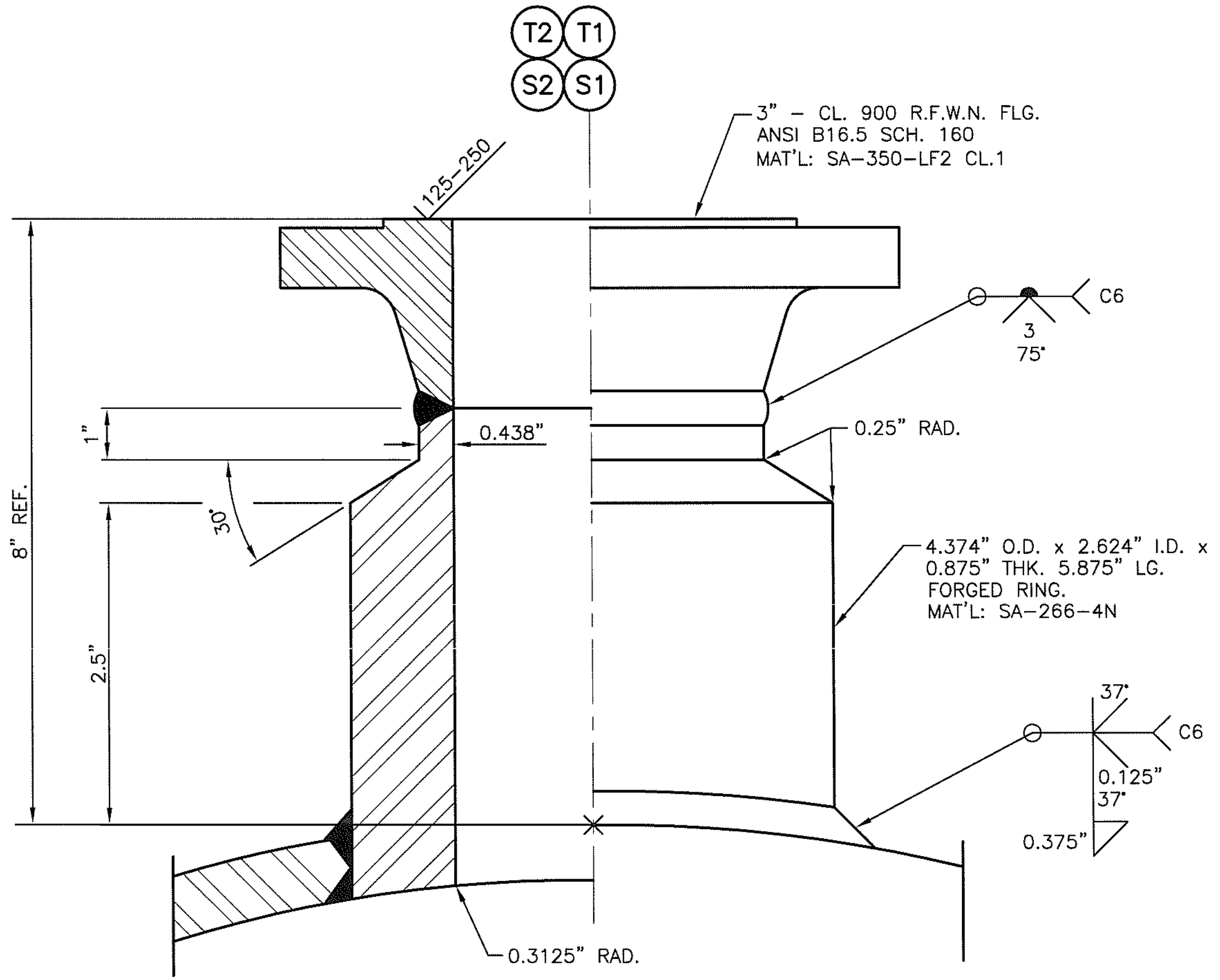
(1) UNLESS OTHERWISE NOTED ALL GASKETS ARE TO BE: 0.175" THK. 316 S.S. SPIRAL WOUND GRAPHOIL FILLED C/W CARBON STEEL OUTER COMPRESSION RING AND 0.125" THK. S.I.D.J. PASS PARTITION RIB.

(2) THICKNESS CALLED FOR IS THE TOTAL THICKNESS REQUIRED

(3) ALL GASKETS ARE TO BE ONE PIECE CONSTRUCTION

* INCLUDES TWO SPARE SETS

REVISIONS	GASKET DETAIL NO. OF SETS REQ'D EACH EXCHANGER: THREE* NO. OF EXCHANGERS REQ'D: TWO	EXCHANGER INDUSTRIES CALGARY, ALBERTA
	DWN FX | CKD KW | ITEM E-200A/B	DWG NO. 10-3155A/B
		SHEET 11 OF 14



TWO REQ'D ON CHANNEL
TWO REQ'D ON SHELL

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

NOZZLE ORIENTATION SEE SHT. 1

REVISIONS

NOZZLE DETAIL

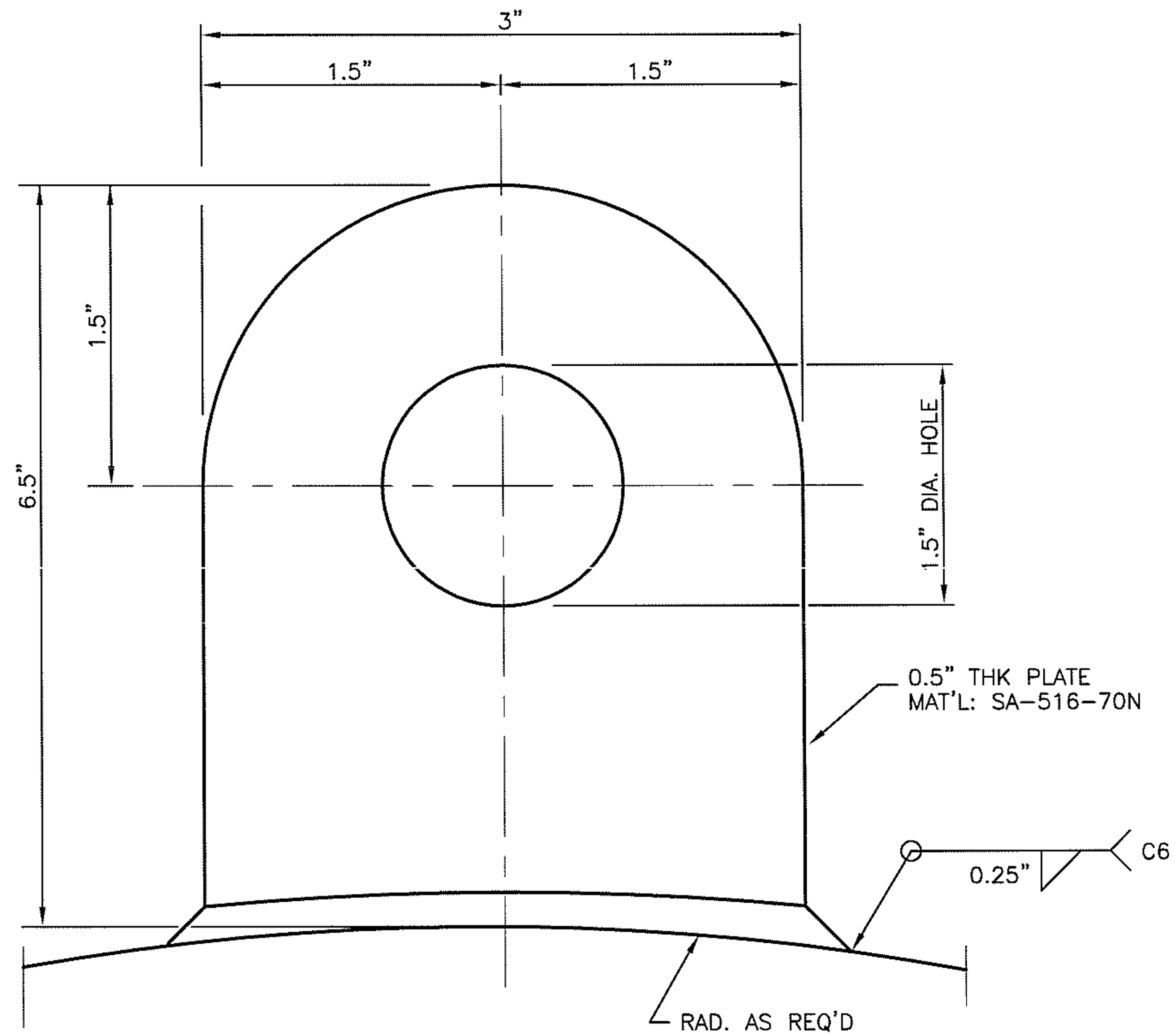
NO. OF EXCHANGERS REQ'D: TWO

DWN FX | CKD KW | ITEM E-200A/B

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWG NO. 10-3155A/B

SHEET 12 OF 14



TWO REQ'D ON CHANNEL CYLINDER

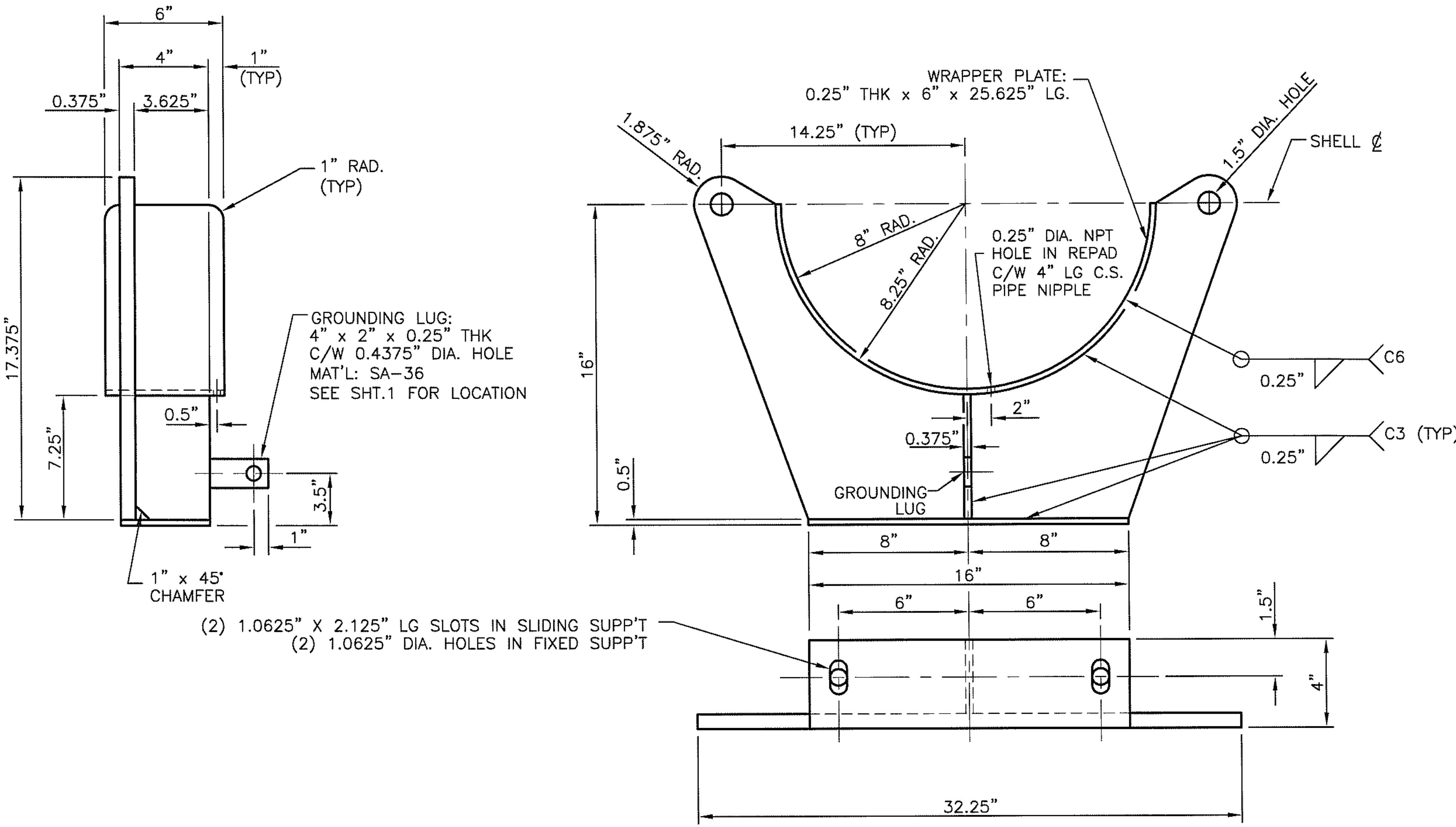
REVISIONS

LIFT LUG DETAIL

NO. OF EXCHANGERS REQ'D: TWO

EXCHANGER INDUSTRIES
CALGARY, ALBERTA

DWN FX	CKD KW	ITEM E-200A/B	DWG NO. 10-3155A/B
			SHEET 13 OF 14



NOTES:

1) ALL MATERIAL TO BE SA-516-70N EXCEPT FOR GROUNDING LUG

REVISIONS

SUPPORT DETAIL

NO. OF EXCHANGERS REQ'D: TWO

NO. REQ'D EACH EXCHANGER: TWO

DWN FX | CKD KW | ITEM E-200A/B

EXCHANGER INDUSTRIES

CALGARY, ALBERTA

DWG NO. 10-3155A/B

SHEET 14 OF 14