

PROJECT: WORLD ENERGY RENEWABLES PROJECT

AIR PRODUCTS PROJECT NUMBER: EN-20-7120

FLOUR PROJECT NUMBER: A8KM

UNIT NAME: S21-13258-10, STRIPPER FEED / DEBUTANIZER
BOTTOMS EXCHANGER

CLIENT NAME: WORLD ENERGY PARAMOUNT

VOLUME TITLE: S21-13258-10 DATABOOK

CODE: ASME SECTION VIII, DIVISION 1, 2021 Ed.

FABSCO SHELL & TUBE, LLC.
STANDARD MANUFACTURING RECORD BOOK OUTLINE

SECTION “A” MANUFACTURER’S DATA REPORT

**SECTION “B” MILL/CERTIFIED MATERIAL TEST REPORTS
w/ MATERIAL MAP (*INCLUDING IMPACT TEST RECORDS IF APPLICABLE*)**

SECTION “C” CERTIFIED AS BUILT DRAWINGS (*INCLUDES WELD MAP & NDE MAP*)

SECTION “D” MECHANICAL DESIGN CALCULATIONS

**SECTION “E” QUALITY RELATED DOCUMENTS/ALL TESTING RECORDS, REPORTS
(*PAINT, PMI, HELIUM TEST, HYDRO, RT, PT, UT, MT, HT, PWHT TESTING
REPORTS/CHARTS/CERTS, ITP, TRAVELER*)**

SECTION “F” SPECIFICATION/THERMAL DATA SHEET

SECTION “G” CODE NAMEPLATE FACSIMILE

**SECTION “H” MISCELLANEOUS DOCUMENTS (*FLANGED JOINT ASSEMBLY RECORD FORM,
CERT OF COMPLIANCE, INSEPCION RELEASE*)**

SECTION “I” INSTALLATION, OPERATION AND MAINTENANCE MANUAL

A

FORM U-1 MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS

As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1 **Corrected Copy** Page 1 of 3

1. Manufactured and certified by **Fabsco Shell & Tube, LLC, Plant Two, 2410 Industrial Road, Sapulpa, Oklahoma, 74066, USA**
(Name and address of Manufacturer)

2. Manufactured for **AIR PRODUCTS MANUFACTURING, LLC., 1940 AIR PRODUCTS BLVD, ALLENTOWN, Pennsylvania, 18195, USA**
(Name and address of Purchaser)

3. Location of installation **WORLD ENERGY, PARAMOUNT, California, USA**
(Name and address)

4. Type **HORIZ.** **HEAT EXH.** **S21-13258-10**
(Horizontal, vertical, or sphere) (Tank, separator, jkt. vessel, heat exch., etc.) (Manufacturer's serial number)

N/A **S21-13258-10-1 REV 8** **11283** **2023**
(CRN) (Drawing number) (National Board number) (Year built)

5. ASME Code, Section VIII, Div. 1 **2021/ N/A** **N/A** **N/A**
[Edition and Addenda, if applicable (date)] (Code Case Number) [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 multichamber vessels.

6. Shell: (a) Number of course(s) **1** (b) Overall length **12' 10.8125"**

Course(s)			Material	Thickness		Long. Joint (Cat. A)			Circum. Joint (Cat. A, B, & C)			Heat Treatment	
No.	Diameter	Length	Spec./Grade or Type	Nom.	Corr.	Type	Full, Spot, None	Eff.	Type	Full, Spot, None	Eff.	Temp.	Time
1	16" OD	12' 10.8125"	SA-106B	3/8"	1/8"	S	NONE	1.00	1	SPOT	1.00	N/A	N/A

Body Flanges on Shells												
No.	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Location	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
1	N/A	15.2500"	21.1250"	4 3/16"	N/A	SA-350LF2CL1	WELDED	END	28 - 7/8"	SA-193-B7	7/8" O.D.	F-436-1

7. Heads: (a) **SA-234WPB** (b) **N/A**
(Material spec. number, grade or type) (H.T. - time and temp.) (Material spec. number, grade or type) (H.T. - time and temp.)

	Location (Top, Bottom, Ends)	Thickness		Radius		Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure		Category A		
		Min.	Corr.	Crown	Knuckle					Convex	Concave	Type	Full, Spot, None	Eff.
(a)	END	3/8"	1/8"	N/A	N/A	2:1	N/A	N/A	N/A		X	S	None	1.00
(b)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A

Body Flanges on Heads												
No.	Location	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
(a)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A	N/A	N/A

8. Type of jacket **N/A** Jacket closure **N/A**
(Describe as ogee & weld, bar, etc.)

If bar, give dimensions; if bolted, describe or sketch **N/A**

9. MAWP **405 psi** **15 psi** at max. temp. **300 °F** **300 °F** Min. design metal temp. **5 °F** at **405 psi**
(Internal) (External) (Internal) (External)

10. Impact test **NO, EXEMPT PER UG-20(f), UCS-66(a,c, g), FIG. UCS-66 GENERAL NOTE(c), UCS-67** at test temperature of **N/A**
[Indicate yes or no and the component(s) impact tested]

11. Hydro., pneu., or comb. test pressure **HYDRO at 631/527** Proof test **N/A**

Items 12 and 13 to be completed for tube sections.

12. Tubesheet **SA-516-70N** **17.7500"** **2"** **1/8"** **BOLTED**
[Stationary (material spec. no.)] [Diameter (subject to press.)] (Nominal thickness) (Corr. allow.) Attachment (welded or bolted)

N/A **N/A** **N/A** **N/A** **N/A**
[Floating (material spec. no.)] (Diameter) (Nominal thickness) (Corr. allow.) (Attachment)

13. Tubes **SA-179** **3/4"** **0.083"** **60** **U**
(Material spec. no., grade or type) (O. D.) (Nominal thickness) (Number) [Type (Straight or U)]

Manufactured by **Fabsco Shell & Tube, LLC, Plant Two, 2410 Industrial Road, Sapulpa, Oklahoma, 74066, USA**Manufacturer's Serial No. **S21-13258-10**CRN **N/A**National Board No. **11283***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 **1' 10"**

Course(s)			Material		Thickness		Long. Joint (Cat. A)			Circum. Joint (Cat. A, B, & C)			Heat Treatment	
No.	Diameter	Length	Spec./Grade or Type		Nom.	Corr.	Type	Full, Spot, None	Eff.	Type	Full, Spot, None	Eff.	Temp.	Time
1	16" OD	1' 10"	SA-106B		3/8"	1/8"	S	NONE	1.00	1	FULL	1.00	N/A	N/A

Body Flanges on Shells

No.	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Location	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
2	N/A	15.2500"	21.1250"	4 3/16"	N/A	SA-350LF2CL1	WELDED	ENDS	28 - 7/8"	SA-193-B7	7/8" O.D.	F-436-1

15. Heads: (a) **SA-516-70** (Material spec. number, grade or type) (H.T. - time and temp.) (b) **N/A** (Material spec. number, grade or type) (H.T. - time and temp.)

	Location (Top, Bottom, Ends)	Thickness		Radius		Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure		Category A		
		Min.	Corr.	Crown	Knuckle					Convex	Concave	Type	Full, Spot, None	Eff.
(a)	END	2 1/8"	1/8"	N/A	N/A	N/A	N/A	N/A	21 1/8"			S	None	1.00

Body Flanges on Heads

No.	Location	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

16. MAWP **405 psi** **15 psi** at max. temp. **330 °F** **300 °F** Min. design metal temp. **32 °F** at **405 psi**.
(Internal) (External) (Internal) (External)17. Impact test **NO, EXEMPT PER UG-20(f), UCS-66(a,c,g), FIG. UCS-66 GENERAL NOTE(c), UCS-67** at test temperature of **N/A**.
[Indicate yes or no and the component(s) impact tested]18. Hydro., pneu., or comb. test pressure **Hydro. at 631/527** Proof test **N/A**

19. Nozzles, inspection, and safety valve openings:

Purpose (Inlet, Outlet, Drain, etc.)	No.	Diameter or Size	Type	Material		Nozzle Thickness		Reinforcement Material	Attachment Details		Location (Insp. Open.)
				Nozzle	Flange	Nom.	Corr.		Nozzle	Flange	
INLET/OUTLET	1/1	6"-600#	RF WN	SA-106B	SA-350LF2CL1	XH	1/8"	SA-516-70	UW16.1	WELDED	SHELL
INLET/OUTLET	1/1	3"-600#	RF LWN		SA-350LF2CL1	0.88"	1/8"	SA-516-70	UW16.1	WELDED	CHANNEL
VENT/DRAIN	1/1	2"-300#	RF LWN		SA-350LF2CL1	0.63"	1/8"		UW16.1	WELDED	CHANNEL
AUX	3	2"-300#	RF LWN		SA-350LF2CL1	0.63"	1/8"		UW16.1	WELDED	SHELL NOZS.
AUX	2	2"-300#	RF LWN		SA-350LF2CL1	0.63"	1/8"		UW16.1	WELDED	CHANNEL NOZS.

20. Supports: Skirt **No** Lugs **NONE** Legs **NONE** Others **4 SADDLES** Attached **WELDED TO SHELL**
(Yes or no) (Number) (Number) (Describe) (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, Manufacturer's name, and identifying number):

N/A

22. Remarks

SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER ITEM: 18-X-372B

Manufactured by **Fabsco Shell & Tube, LLC, Plant Two, 2410 Industrial Road, Sapulpa, Oklahoma, 74066, USA**Manufacturer's Serial No. **S21-13258-10**CRN **N/A**National Board No. **11283****CERTIFICATE OF SHOP COMPLIANCE**

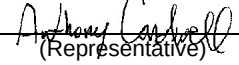
We certify that the statements in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. U Certificate of Authorization Number **30112** Expires **December 30, 2024**

Date **08/05/2024**

Name

Fabsco Shell & Tube, LLC, Plant Two

Signed


(Representative)

(Manufacturer)

CERTIFICATE OF SHOP INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by

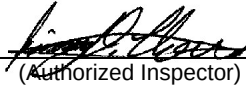
Bureau Veritas Inspection and Insurance Company, of Lynn, MA

have inspected the pressure vessel described in this Manufacturer's Data Report on **October 25, 2023**, and state that,

to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. By signing this certificate neither the Inspector nor his/her employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his/her 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 this inspection.

Date **08/05/2024**

Signed


(Authorized Inspector)

Commissions:

16613

(National Board Authorized Inspector Commission number)

CERTIFICATE OF FIELD ASSEMBLY COMPLIANCE

We certify that the statements made in this report are correct and that the field assembly construction of all parts of this vessel conforms with the requirements of ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. U Certificate of Authorization Number _____ Expires _____

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 employed by _____,

have compared the statements in this Manufacturer's Data Report with the described pressure vessel and state that parts referred to as data items _____, 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 the ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. The described vessel was inspected and subjected to a pressure test of _____. By signing this certificate neither the Inspector nor his/her employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his/her 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 this inspection.

Date _____

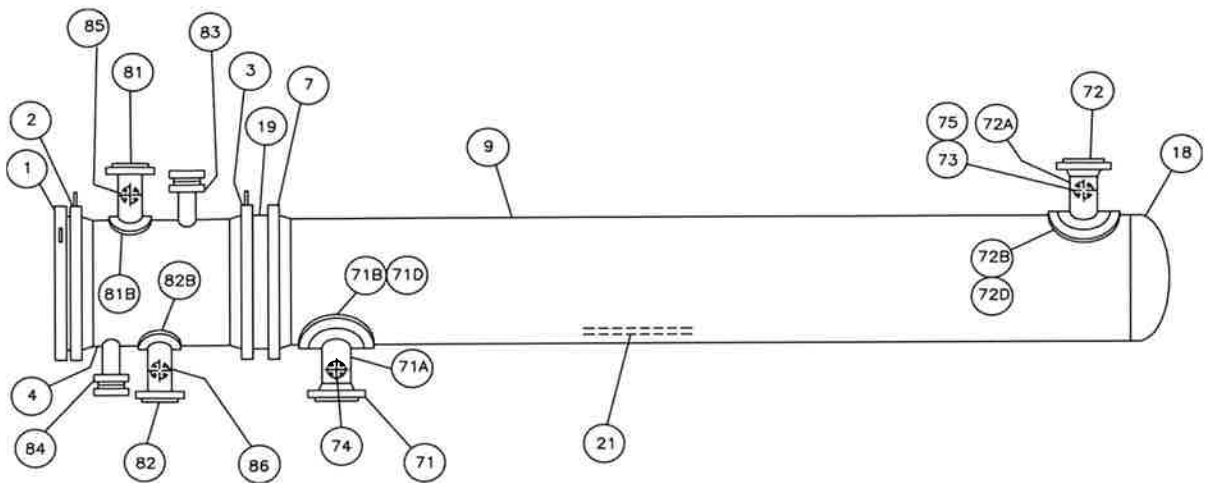
Signed _____

(Authorized Inspector)

Commission _____

(National Board Authorized Inspector Commission number)

B



Mark No	MATERIAL DESCRIPTION		
	SUPPLIERS	HEAT No.	MATERIAL
1	CLEVELAND-CLIFFS BURNS HARBOR	812W37820	SA-516-70
2	OKLAHOMA FORGE	408681-1	SA-350LF2CL1
3	OKLAHOMA FORGE	408681-1	SA-350LF2CL1
4	TENARIS	995775	SA-106B
7	OKLAHOMA FORGE	408681-1	SA-350LF2CL1
9	TENARIS	995775	SA-106B
18	WELDBEND	CXDS	SA-234WPB
19	CLEVELAND-CLIFFS BURNS HARBOR	611D98310	SA-516-70N
21	BENTELER	292235/293004	SA-179
71	ULMA	C12A5	SA-350LF2CL1
71A	VOESTALPINE	1022457977	SA-106B
71B	CLEVELAND-CLIFFS BURNS HARBOR	821T09150	SA-516-70
71D	SSAB	B2K599	SA-516-70
72	ULMA	C12A5	SA-350LF2CL1
72A	VOESTALPINE	1022457977	SA-106B
72B	CLEVELAND-CLIFFS BURNS HARBOR	821T09150	SA-516-70
72D	SSAB	B2K599	SA-516-70
73	AMERIFORGE	CR3-KD	SA-350LF2CL1
74	AMERIFORGE	CR3-KD	SA-350LF2CL1
75	FEDERAL FLANGE	21801292	SA-350LF2CL1
81	AMERIFORGE	C939AN	SA-350LF2CL1
81B	CLEVELAND-CLIFFS BURNS HARBOR	821T09150	SA-516-70
82	AMERIFORGE	C975AN	SA-350LF2CL1
82B	CLEVELAND-CLIFFS BURNS HARBOR	821T09150	SA-516-70
83	AMERIFORGE	284218	SA-350LF2CL1
84	AMERIFORGE	284218	SA-350LF2CL1
85	FEDERAL FLANGE	21202122	SA-350LF2CL1
86	FEDERAL FLANGE	21202122	SA-350LF2CL1

CUSTOMER: AIR PRODUCTS MANUFACTURING, LLC.

PO NO: 450560057/A8KM-4-402-PO-2

ITEM NO: 18-X-372B

DATE

AC



FABSCO
SHELL & TUBE, LLC

DWG No

S21-13258-10-HS'

REV

0

m/az

Cleveland-Cliffs Burns Harbor LLC
QUALITY ASSURANCE REPORT OF TEST AND ANALYSIS

23794

US HWY 12 Burns Harbor, Indiana

SHIPMENT NO. 803-86559		DATE SHIPPED 05-06-22		CAR OR VEHICLE NO. CSS-CHGO-BNSF ATW 317128	
C G MARTIN CO INC PO BOX 9345 TULSA OK 74157-0345		C G MARTIN CO INC OAKHURST OK			
S H I P T O N O T E	SERIAL NUMBER	PAT NO.	HEAT NUMBER	NO. PCS.	SIZE AND QUANTITY
	THICKNESS	WIDTH OR DIA.	LENGTH	WEIGHT	YIELD POINT
					TENSILE STRENGTH
					AF FRAC. ELONG.
					RED.

QUALITY STEEL MELTED & MANUFACTURED IN THE U. S. A.

PLATES - ASME SA516 GR 70 PVQ KLD FINE GRAIN

PRAC 2021 EDITION, ASME SA516 GR 65

2021 EDITION, ASME SA516 GR 60 2021

EDITION --- PLT NORMALIZED & COOLED

IN STILL AIR --- TEST CERTS PER EN

10204:2004 TYPE 3.1, PLT CHEM NI

<1.00%, NOT RE SULPHURIZED, BHN

<=200 PER NACE MR0175 & MR0103

NO WELD REPAIR WAS PERFORMED ON BELOW PLATE(S)

MFST - MFST PPI 0092648- 0001 MFST TEST CERTS PER EN

10204:2004 TYPE 3.1, PLT CHEM NI <1.00%, NOT RE

MFST SULPHURIZED, BHN <=200 PER NACE MR0175 &

MR0103

- LIFT MAX 10 TON

UNLDG MOBILE CRANE-PLATE CLAMP

CO# 7462 GH 376-0352 --SR# X030866 ALSO MEETS ASTM A516-70/65/60 (10 JUN 2022)

PLATES HEAT TREATED - TEST SPECIMENS ATTACHED & YIELD STRENGTH @ .5% EUL

X030866 812W37820 1 2.5 120 300 25524 48800 75800 2 33
N 1650 DEG F - 125 MIN

DUPLICATE ORIGINAL TEST REPORT FROM C.G. MARTIN CO., INC.				T-TEMPER TEMPERATURE				N-NORMALIZE TEMPERATURE			
CUST ID	770	WO#	102624								
CUST	FABSCO SHELL & TUBE, LLC										
P.O. #	R22-13258-9TS										
ITEM #	2										
DESC	(2) 21-1/8" OD(F) X 2-1/8" THK(F)										
	TAG: (1) 13258-10-1; (1) 13258-9-1										
DATE	08/22/22	BY:									

HEAT NUMBER	CHEMICAL ANALYSIS																MOQUAD GRAIN SIZE
	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Ti	Al	B	Cb	N	Sn	

812W37820 .18 1.04 .008 .002 .340.204 .18 .03.037.002.002.044.0002 .002.004.004

Farid Hassani

I certify that the above results are a true and correct copy of actual results contained in records maintained by Cleveland-Cliffs Burns Harbor LLC and are in full compliance with the requirements of the specification cited above. This test report cannot be altered and must be transmitted intact with any subsequent third party test reports, if required.

SUPV. QUALITY ASSURANCE
Form BHPLTRPT.TIF

FARID HASSANI PER MWT

ANTHONY CARDWELL
09/06/2022

GLOBE X-RAY SERVICES, INC.

8441 South Union Tulsa, OK 74132

Certification 159609

Report of Ultrasonic Examination

Customer: CG Martin P. O.
Address: Job # Stock

Ultrasonic Examination

Test Instrument: Sonatest D-20+ S/N: I013300
Surface Condition: Smooth Procedure #: GXS-II-D & B Rev: 1-22
Couplant: Sonix Search Unit Cable: RG-174 Co-Axial, 6FT. Long with BNC to BNC Connectors
Beam Angle: 0 Degrees Search Unit 1" x 2.25 MHz S/N: 66159
Scanning Pattern: 100% Reference Level: 43-48 Db
Calibration Reference: Backwall Technique: Contact, Manual Scan
Scanning Surface: One Major Surface

Reference Standard:

The plates listed below have been ultrasonically examined and comply with the acceptance criteria of the indicated specifications. In addition to the requirements of SA-578, paragraph 5 and 6, all indications with amplitudes equal to or greater than 50% of the initial back reflection and accompanied by a 50% loss of back reflection shall be recorded regardless of plate thickness. Unless otherwise noted by an * following the plate number, there were no recordable indications observed. UT per A-435 entire surface in accordance with ASME BPVC section V & applicable standards of Article 23.

✓ ASTM/ASME A-578/SA-578 LEVEL A(1) w/S1 ✓ ASTM/ASME A-435/SA-435 w/S1
✓ ASTM/ASME A-578/SA-578 LEVEL B(2) w/S1 ✓ Wheatley-Gasso Sep 6.6.2 Rev. D
✓ ASTM/ASME A-578/SA-578 LEVEL C(3) w/S1 ✓ Other: AM203.2

✓ In addition to the above ultrasonic examination, the material has been hardness tested and meets the requirements of ANSI/NACE Standard MR0175. Hardness value does not exceed 22 HRC

Plate #	Mat'l Spec.	Thickness	Dimensions	Heat #	Slab #	Hardness
23797	516-70 MT	3-1/4"	96" x 280"	821V07130	X030882	172
23798	516-70 MT	3-1/4"	120" x 240"	812W37820	X030865	169
23793	516-70 MT	2-1/8"	96" x 480"	812W37820	X030883	170
23795	516-70 MT	2-3/4"	120" x 280"	812W37820	X030867	166
23796	516-70 MT	3"	96" x 300"	812W37820	X030884	168
23794	516-70 MT	2-1/2"	120" x 300"	812W37820	X030866	171
23792	516-70 MT	4-1/2"	120" x 280"	D68388	35298	173
23791	516-70 MT	5-3/4"	120" x 220"	E66972	35296	168
23497	516-70 MT	2"	25-3/4" OD	1601583	01	164

Unless otherwise noted by an * following the item number, there were no recordable indications observed.

Examination By: Colter Moyer Qualification Level: II
Date: April 15, 2022 Time: NA AM/PM

GLOBE XRAY ASSUMES NO RESPONSIBILITY FOR THE INTEGRITY OF THE STRUCTURE OR ANY LOSSES OF ANY KIND DUE TO ANY KIND OF INTERPRETATION

no
1/16



CLEVELAND-CLIFFS INC.
Cleveland-Cliffs Plate LLC
139 Modena Rd., Coatesville, PA 19320
P 610.383.2000 clevelandcliffs.com

August 25, 2021

To Whom it May Concern,

Regarding the required steelmaking practice for all grades of ASTM A516 and ASME SA516, the steel is killed.

As shown in ASTM A516 Year 17, current as of the date of this letter:

4. Materials and Manufacture

4.1 Steelmaking Practice—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

Best regards,

Deborah L. Fialkowski

Deborah L. Fialkowski
Senior Metallurgical Engineer
Eastern Plate QA Product Metallurgy

mf
2/26



OKLAHOMA FORGE

Certification of Analysis and Tests

INVOICE NUMBER
122-26825

Date: 8/08/22

Toll Free (866)909-5553
Local(918)446-5553 FAX (918)446-4150

e:Mail ~ sales@oklahomaforge.com
Web Site ~ www.oklahomaforge.com

5259 S. 49TH West Ave
Tulsa, OK 74107

Sold To	Your Purchase Order	Sales Order
FABSCO INC P. O. BOX 988 SAPULPA, OK 74066 USA	Number R22-13258-9FO By RUSTY KNAPP Dated 6/29/2022	Number 122-98893 Shipped Via DELIVERY Ship Date 8/08/2022

Item#	PART DESCRIPTION				Quantity
	Your Part Number	Shop Order Number	Shape	Dimensions	
		Supplier	Heat Number	Material Specifications	
	Chemical Analysis				
	Physical Properties			Charpy Impact (Ft.Lbs.)	

1	13258-9-2				122-98893-01			RING		21.125"OD x 15.250"ID x 4.188"TH						1
					NUCOR			408681-1		ASME SA350 LF2 CL1 2019 NORM						
	C	Mn	P	S	Si	Ni	Cr	Cu	Mo	V	Cb	Al	Ti	Ce	Other	
	.18	1.19	.006	.002	.193	.05	.09	.16	.02	.022	.004	.020	.002	.42	B-.0002;Sn-.004	
	Yield Lb/SqIn	Tensile Strength Lb/SqIn			Elong%in 2In		Red of Area%	Brinell	Rckwl	Bend Tes	Grain Siz	Type	Temp	Average	#1 #2 #3	
	47,000	73,000			35		71	146			FINE	CVN	-50F	58	64 44 65	

2	13258-9-3				122-98893-02			RING		21.125"OD x 15.250"ID x 4.188"TH					1		
				NUCOR			408681-1		ASME SA350 LF2 CL1 2019 NORM								
C		Mn	P	S	Si	Ni	Cr	Cu	Mo	V	Cb	Al	Ti	Ce	Other		
.18		1.19	.006	.002	.193	.05	.09	.16	.02	.022	.004	.020	.002	.42	B-.0002;Sn-.004		
Yield Lb/SqIn		Tensile Strength Lb/SqIn			Elong%in 2In		Red of Area%		Brinell	Rckwl	Bend Tes	Grain Siz	Type	Temp	Average	#1 #2 #3	
47,000		73,000			35		71		146			FINE	CVN	-50F	58	64 44 65	

3	13258-9-7				122-98893-03			RING		21.125"OD x 15.250"ID x 4.188"TH						1		
					NUCOR			408681-1		ASME SA350 LF2 CL1 2019 NORM								
	C	Mn	P	S	Si	Ni	Cr	Cu	Mo	V	Cb	Al	Ti	Ce	Other			
	.18	1.19	.006	.002	.193	.05	.09	.16	.02	.022	.004	.020	.002	.42	B-.0002;Sn-.004			
Yield Lb/SqIn		Tensile Strength Lb/SqIn			Elong%in 2In		Red of Area%		Brinell	Rckwl	Bend Tes	Grain Siz	Type	Temp	Average	#1	#2	#3
47,000		73,000			35		71		146			FINE	CVN	-50F	58	64	44	65

ANTHONY CARDWELL
08/16/2020

Notes: NORM. @ 1675F FOR 4.5 HOURS. AIR COOLED
FULLY KILLED, EFVD, FINE GRAIN PRACTICE
BHN- 146/156
PER NACE MR0175/ MR0103/ ISO15156
UT INSPECTION REPORT ATTACHED

Page 1
F040-4/2014

m
1/16

I CERTIFY THAT THERE IS A TRUE COPY OF THE ORIGINAL TEST SHEET NOW ON FILE AT THE OFFICE OF
OKLAHOMA FORGE, INC. AND THAT THIS MATERIAL WAS MELTED AND MANUFACTURED IN THE USA.
MATERIAL CONTAINS NO MERCURY OR RADIOACTIVE CONTAMINATION. BS EN 10204 3.1.

Ryan Umbarger



**NON DESTRUCTIVE TESTING
AND INSPECTION**

17110 East Pine St, Tulsa, OK 74116

Tele: (918) 234-6300 Fax: (918) 234-6301

ULTRASONIC INSPECTION AND CALIBRATION REPORT

CUSTOMER DATA

NAME OKLAHOMA FORGE
ADDRESS TULSA
PURCHASE ORDER # RU-00167
ATTENTION
DAY THURSDAY DATE 8/4/2022

JOB NUMBER:

APPLICABLE CODE: ASME SEC V ART 23/ ASTM SA-388

PROCEDURE # UT1

REVISION # 15

REV. DATE: 10/5/2020

EQUIPMENT DATA

EQUIPMENT MANUFACTURER: OLYMPUS MODEL# EPOCH 650 S/N 150133512
SEARCH UNIT CABLES: #1 TYPE LENGTH S/N
SEARCH UNIT CABLES: #2 TYPE LENGTH S/N
LONGITUDINAL SEARCH UNIT MFG. #1 TECHNISONIC ANGLE 0 FREQ. 2.25 MHz SIZE 1" S/N 1073849
LONGITUDINAL SEARCH UNIT MFG. #2 ANGLE FREQ. MHz SIZE S/N
SHEAR WAVE SEARCH UNIT MFG #1 TECHNISONIC ANGLE 45 FREQ. 2.25 MHz SIZE 1" S/N 14030
SHEAR WAVE SEARCH UNIT MFG #2 ANGLE FREQ. MHz SIZE S/N
SHEAR WAVE SEARCH UNIT MFG #3 ANGLE FREQ. MHz SIZE S/N
COUPLANT BRAND NAME: SONATECH TYPE: ULTRA GEL 2
SPECIAL EQUIPMENT: (IF USED) N/A
CALIBRATION BLOCK TYPE: IIW TYPE 1
SIMULATION BLOCK TYPE: N/A

CALIBRATION DATA

LONGITUDINAL - #1 REFERENCE LEVEL 44 (db) SCANNING LEVEL 50 (db)
LONGITUDINAL - #2 REFERENCE LEVEL (db) SCANNING LEVEL (db)
SHEAR WAVE - ANGLE #1 REFERENCE LEVEL 58 (db) SCANNING LEVEL 64 (db)
SHEAR WAVE - ANGLE #2 REFERENCE LEVEL (db) SCANNING LEVEL (db)
SHEAR WAVE - ANGLE #3 REFERENCE LEVEL (db) SCANNING LEVEL (db)
Initial Cal. Time Cal. Check Ending Cal. Time

TEST CONDITIONS

PART CONDITION: CLEAN AND SMOOTH
SIMULATION BLOCK TEMP: AMBIENT F PART TEMP. AMBIENT F
SCANNING TYPE: CONTACT X IMMERSION MANUAL X AUTOMATIC
SCANNING SPEED:
SCANNING SURFACE: INSIDE OUTSIDE X VERTICLE HORIZONTAL X
SCANNING DIRECTIONS: PARALLEL X PERPENDICULAR OPPOSING

PART IDENTIFICATION:

SO# 98893-01

SO# 98893-02

SO# 98893-03

1-21.125 X 15.250 X 4.188

1- 21.125 X 15.250 X 4.188

1-21.125 X 15.250 X 4.188

MATERIAL: LF2

HEAT# 408681-1

RESULTS: No relevant indications found of rejectable size. UT is performed

PER ASTM SA388 & ASME SEC VIII DIV 2 PARA 3.3.4

TECHNICIAN HRS. ASST. HRS. TRAVEL HRS. MILEAGE PERDIEM

TECHNICIAN: SHANE BUSBY S Busby LEVEL II Cert. Type SNT-TC-1A

ASSISTANT: LEVEL Page OF

CUSTOMER REPRESENTATIVE: TOTAL TIME 3 PCS

11/1/22



INSPECTION CERTIFICATE
CERTIFICATO DI COLLAUDO
(UNI EN 10204 3.1 / ISO 10474 3.1)

Customer / Cliente: INDUSTRIAL PIPING SPECIALISTS, INC.
Manufacture Process / Processo di fabbricazione:
Product Type / Tipo di prodotto:
SEAMLESS LINE PIPES (WITH EXTRA REQUIREMENTS)
TUBI S.S. LINE PIPE (CON RICHIESTE SUPPLEMENTARI)
Steel Grade / Grado dell'Acciaio:
See note nr.2
Vedi nota nr.2
Dimensions / Dimensioni:
Ø 16.000" O.D. x 0.375" W.T.
Ø 408.40mm O.D. x 9.53mm W.T.
Schedule / Scheda:
Length / Lunghezza:
37.999 ft ÷ 43.999 ft
11582 mm ÷ 13411 mm
Quantity / Quantità: 28Pcs/Pz
75223,8 lb
34121 kg
Nominal Weight / Peso nominale
62.68 lb/ft
93.28 Kg/m

Customer's Order Item / Rifer. Ordine Cliente - I	Customer's Reference / Posizione Cliente	Manufacturer's Works Order N° / Conferma-Posizione:
HR104731		1212556/001
Surface / Superficie:		See note nr.1 Vedi nota nr.1
Ends / Estremità:		BEVEL API 5L / ISO 3183 CT4-8825 SMUSSATI SECONDO API 5L / ISO 3183 CT4-8825
Nominal Weight / Peso nominale		62.68 lb/ft
		93.28 Kg/m

DELIVERY NOTES / AVVISI DI SPEDIZIONE

Delivery Notes Avvisi di spedizione	Delivery Notes Avvisi di spedizione
Job Number: 0031253412 / 000010	Town: 74158 TULSA
Shipping note: 0101510857 - 03/12/2019	Country: USA
Address: PO BOX 581270	

TENSILE TEST / PROVA DI TRAZIONE

Heat N° Cottale N°	Sample N° Prova N°	Specimen condition Condizioni della provetta	Test Temp Temp. di prova	Y.S. EUL 0.6%	U.T.S. Req.	Y.S./U.T.S. Req. Max.	Bongation / Allungamento Lo Min.	Min.	Max.	Oht
995774	00002	B AM	365.90	+20	475.00	765.00	2"	50.8	28.0%	36.5%
995775	00005/C	B AM	358.70	+20	471.00	796.00	2"	50.8	27.0%	34.5%
995928	00814	B AM	369.40	+20	484.00	768.00	2"	50.8	28.0%	36.5%

AM As manufactured / Come laminato	LS: Location of sample / Ubicazione provetta	Oht: Orientation / Orientamento
B: Body / Corpo	Max: Maximum / Massimo	Req. Max: Required maximum / Massimo richiesto
L: Longitudinal / Longitudinale	Min: Minimum / Minimo	Req. Required / Richiesto
Lo: Initial length / Lunghezza iniziale	Oht: Orientation / Orientamento	SC: Specimen condition / Condizioni Provetta
		YS: Yield Strength / Snervamento
		U.T.S: Ultimate Tensile Strength / Rottura

This certificate is issued by a computerized system and it is valid with electronic signature. On the original certificate the trademark price is marked "Tenaris" is stamped. In case the owner of the original certificate would release a copy of it, he must attest its conformity to the original one taking upon himself the responsibility for any use of it or not allowed use. Any alteration and/or falsification will be subject to legal action.

Questo certificato è emesso da un sistema computerizzato ed è valido con firma elettronica. Il certificato originale riporta il marchio "Tenaris" in colore verde. In caso l'originale, qualora rilasci copia, deve attestare la sua conformità all'originale, assumendosi ogni responsabilità per un illecito o non autorizzato utilizzo e/o falsificazione sarà perseguita a norma di legge.

11/16/20

ANTHONY CARDWELL
08/03/2022



INSPECTION CERTIFICATE
CERTIFICATO DI COLLAUDO
(UNI EN 10204 3.1 / ISO 10474 3.1)

Number / Numero:
01-19-16603

Page / Pagina:
2 / 8

Customer / Cliente: INDUSTRIAL PIPING SPECIALISTS, INC.		Customer's Order Item / Rifer. Ordine Cliente: HR104731		Manufacturer's Works Order N° / Conferma-Posizione: 12125567001	
Manufacture Process / Processo di fabbricazione:		Product Type / Tipo di prodotto: SEAMLESS LINE PIPES (WITH EXTRA REQUIREMENTS)		Surface / Superficie See note nr.1	
Standard or Specification / Norme o specifica: See note nr.2		SEAMLESS LINE PIPES (CON RICHIESTE SUPPLEMENTARI)		Ends / Estremità: See note nr.1	
Dimensions / Dimensioni: Ø 406.40mm O.D. x 9.53mm W.T.		Schedule / Scheda:		Steel Grade / Grado dell'Acciaio: See note nr.3	
Vedi nota nr.2		Length / Lunghezza: 37.999 ft ÷ 43.999 ft		Quantity / Quantità: 28Pcs/Pz	
		11592 mm ÷ 13411 mm		Vedi nota nr.3	
				Nominal Weight / Peso nominale 82.68 lb/ft	
				93.28 Kg/m	

CHEMICAL COMPOSITION / COMPOSIZIONE CHIMICA

Heat N° Colata N°	Sample N° Prova N°	Composition % / Composizione %															X 1000	X 10000
		C	Mn	Si	Ni	Cr	Mo	Cu	Ce	LF	F1	F2	F3	P	S	Ti	Nb	V
995774	H	23	120	40	30	30	15	40	43	100	15	8	25	15	40	60	10	
995774	P	23	120	40	30	30	15	40	43	100	15	8	25	15	40	60	10	
995774	H	20	83	22	11	13	5	15	41	44.4	0.8	0.5	12	2	1	1	4	2
995774	P	19	83	22	11	14	5	15	40	45.4	0.8	0.5	12	2	1	1	4	2
995775	H	18	83	23	12	13	5	16	38	49.4	0.8	0.5	14	2	1	1	4	2
995775	P	18	83	23	12	14	5	17	40	48.1	0.4	0.3	12	1	1	1	4	2
995775	H	20	94	23	12	14	5	16	41	47.4	0.6	0.5	13	2	1	1	4	2
995775	P	19	94	22	10	12	4	20	40	49.4	0.8	0.5	13	1	3	1	4	2
995775	H	20	85	21	12	14	5	22	40	53.4	0.7	0.5	10	2	2	1	4	1
995775	P	20	85	21	12	14	5	22	42	53.3	0.6	0.4	10	2	2	1	3	1

Ca: LF: C+Mn+V(Cr+Mo+V)S+(Ni+Cu)75	F2: (Nb+V) ÷ 77	H: Heat / Colata	Min: Minimum / Minimo
Fe: (V+Ni+Cr+Mo+Cu)	F3: (Nb+V)	Max: Maximum / Massimo	P: Product / Prodotto

This certificate is valid only if accompanied by the original signature. On the original certificate, the "Tenaris" logo is stamped. In case the owner of the original certificate would release a copy of it, he must also release a copy of the original one having upon himself the responsibility for any alteration or not allowed use. Any alteration under falsification will be subjected to the law.

Handwritten signature

ANTHONY CARDWELL
08/03/2022



INSPECTION CERTIFICATE
CERTIFICATO DI COLLAUDO
(UNI EN 10204 3.1 / ISO 10474 3.1)

Page / Pagina:
3 / 8

Number / Numero:
01-19-16603

Date / Data: December 06, 2019

Customer / Cliente: INDUSTRIAL PIPING SPECIALISTS, INC.		Customer's Order Item / Rifer. Ordine Cliente: HR104731		Customer's Reference / Posizione Cliente: 1212556/001		Manufacturer's Works Order N° / Conferma-Posizione: 1212556/001	
Manufacture Process / Processo di fabbricazione:				Product Type / Tipo di prodotto: SEAMLESS LINE PIPES (WITH EXTRA REQUIREMENTS) TUBI S.S. LINE PIPE (CON RICHIESTE SUPPLEMENTARI)			
Standard or Specification / Norme o specifica: See note nr.2 Vedi nota nr.2				Steel Grade / Grado dell'Acciaio: See note nr.3 Vedi nota nr.3			
Dimensions / Dimensioni: Ø 16.000" O.D. x 0.375" W.T. Ø 406.40mm O.D. x 9.53mm W.T.				Length / Lunghezza: 37.999 ft ÷ 43.999 ft 11582 mm ÷ 13411 mm			
Schedule / Scheda				Quantity / Quantità: 28PCS/PZ 75223.8 lb 34121 kg			

THROUGH WALL HARDNESS / DUREZZA ATTRAVERSO LO SPESSORE

Heat N° Colata N°	Sample N° Prova N°	Individuals / Individuali		Average / Media		Hardness type / Tipo di durezza		Formula applied / Formula Applicata	
		Min	Max	Min	Max	Minimum mantensile / mantensile minima	(%)		
995774	Q0002	B	AM	1	2	140.0	148.0	1	2
995775	Q0005/C	B	AM	1	2	150.0	155.0	1	2
995928	Q0814	B	AM	1	2	154.0	150.0	1	2

AM: As manufactured / Come laminato	diametro esterno	Min: Minimum / Minimo
AV: Average / Media	ID: Internal Diameter / Diametro interno	MM: Middle Wall / Centro da spessore
B: Body / Corpo	LS: Location of sample / Ubicazione provetta	OD: Outside Diameter / Diametro esterno
Dist: Distance from outer diameter / Distanza dal	Max: Maximum / Massimo	Quad: Quadrant / Quadrante

IMPACT TEST / PROVA DI RESILIENZA

Type/Type: KCV	Position/Posizione:	Orientation/Dirizione: T		Unit/Unità: FT-LB		Shear area / Area di taglio	
		Temp: 32	Unit/Unità: °F	Ind. Min. Req: 11	Req. Min. Avg: 16	Ind. Min. Req: 11	Req. Min. Avg: 16
Colata N°	Sample N°	Zone	Size / Dimensione	Results / Risultato	Results / Risultato	Results / Risultato	Results / Risultato
995774	Q0002	B	AM	10 x 7.50	76.0	1	2
995775	Q0005/C	B	AM	10 x 7.50	87.0	1	2
995928	Q0814	B	AM	10 x 7.50	77.0	1	2

AM: As manufactured / Come laminato	Ind. Min. Req: Individual Minimum Required /	Req. Min. Avg: Required minimum average / Minimo	%: Transversal / Trasversale

This certificate is issued by a computerized system and it is valid with electronic signature. On the original certificate the mark "Tenaris" is stamped. In case the owner of the original certificate would release a copy of it, he must attest its conformity to the original one taking upon himself the responsibility for any unlawful or not allowed use. Any alteration and/or falsification will be subjected to the law.

AM
1/16h

ANTHONY CARDWELL
08/03/2022



Tenaris

INSPECTION CERTIFICATE
CERTIFICATO DI COLLAUDO
(UNEN 10204 3.1 / ISO 10474 3.1)

Servizio S.p.A. - Customer Service
Piazza Carlo Cattaneo 10448
24044 CANTÙ (BS) - Italy
Tel: +39 030 510 111 100
Fax: +39 030 510 111 101

Customer / Cliente: INDUSTRIAL PIPING SPECIALISTS, INC.		Customer's Order Item / Rifer. Ordine Cliente: HR104731		Customer's Reference / Posizione Cliente: 1212556/001	
Manufacturer Process / Processo di fabbricazione		Product Type / Tipo di prodotto:		Surface / Superficie:	
		SEAMLESS LINE PIPES (WITH EXTRA REQUIREMENTS)		See note nr.1	
		TUBI S.S. LINE PIPE (CON RICHIESTE SUPPLEMENTARI)		Vedi nota nr.1	
Standard or Specification / Norme o specifica:		Steel Grade / Grado dell'Acciaio:		Ends / Estremità:	
See note nr.2		See note nr.3		BEVEL API 6L / ISO 3183 CT4:8825	
Vedi nota nr.2		Vedi nota nr.3		SMUSSATI SECONDO API 5L / ISO 3183 CT4:8825	
Dimensions / Dimensioni:		Length / Lunghezza:		Nominal Weight / Peso nominale:	
ø 16.000" O.D. x 0.375" W.T.		37.999 ft ÷ 43.999 ft		82.68 lb/ft	
ø 406.40mm O.D. x 9.53mm W.T.		11582 mm ÷ 13411 mm		93.28 Kg/m	

IMPACT TEST / PROVA DI RESILIENZA

Avg. Average / Media	Minimo singolo richiesto	media richiesta	Temp. Temperature / Temperatura
B. Body / Corpo	Ls. Location of sample / Ubicazione provetta	Sc. Specimen condition / Condizioni Provetta	

FLATTENING TEST / PROVA DI SCHIACCIAMENTO

Standard / Norme:				Standard / Norme:			
Heat N° Colata N°	Sample N° Prova N°	Zone	Sc	Heat N° Colata N°	Sample N° Prova N°	Zone	Sc
995774	Q0001/C	E1	AM	995828	Q0013/C	E1	AM
995775	Q0004	E1	AM				
1 pipe of the lot				1 pipe of the lot			
1 pipe of the lot				1 pipe of the lot			
Result Esito				Result Esito			
Good / Buono				Good / Buono			

AM: As manufactured / Come laminato E1 / E2: Ends of Sampling / Estremità della provetta Sc: Specimen condition / Condizioni Provetta

This certificate is issued by a computerized system and it is valid with electronic signature. On the original certificate the track-mark given below "Tenaris" is stamped. In case the owner of the original certificate would release a copy of it, he must state its conformity to the original one taking upon himself the responsibility for any unlawful or not allowed use. Any alteration in this information will be subjected to the law.

Questo certificato è emesso da un sistema computerizzato ed è valido con firma elettronica. Il certificato originale riporta il marchio "Tenaris" in colore verde. In caso l'utente del certificato originale rilasciasse una copia di esso, deve attestare la sua conformità all'originale, assumendosi ogni responsabilità per usi illeciti o non autorizzati. Qualunque alterazione delle informazioni sarà punita a norma di legge.

ANTHONY CARDWELL
08/03/2022



INSPECTION CERTIFICATE
CERTIFICATO DI COLLAUDO
(UNI EN 10204 3.1 / ISO 10474 3.1)

Customer / Cliente: INDUSTRIAL PIPING SPECIALISTS, INC.
Manufacture Process / Processo di fabbricazione:
Product Type / Tipo di prodotto:
SEAMLESS LINE PIPES (WITH EXTRA REQUIREMENTS)
TUBI S.S. LINE PIPE (CON RICHIESTE SUPPLEMENTARI)
Steel Grade / Grado dell'Acciaio:
See note nr.3
Vedi nota nr.3
Ends / Estremità:
SMUSSATI SECONDO API 5L / ISO 3183 CT4:8825
Nominal Weight / Peso nominale:
62.68 lb/ft
93.28 Kg/m

Number / Numero:
01-19-16603
Date / Data: December 06, 2019

Page / Pagina:
5 / 8

Customer / Cliente: INDUSTRIAL PIPING SPECIALISTS, INC.	Customer's Order Item / Rifer. Ordine Cliente: HR104731	Manufacturer's Works Order N° / Conferma-Posizione: 1212556/001
Manufacture Process / Processo di fabbricazione:	Product Type / Tipo di prodotto: SEAMLESS LINE PIPES (WITH EXTRA REQUIREMENTS) TUBI S.S. LINE PIPE (CON RICHIESTE SUPPLEMENTARI)	Surface / Superficie: See note nr.1 Vedi nota nr.1
Standard or Specification / Norme o specifica: See note nr.2 Vedi nota nr.2	Schedule / Scheda: Length / Lunghezza: 37,999 ft ± 43,999 ft 11582 mm ± 13411 mm	Ends / Estremità: SMUSSATI SECONDO API 5L / ISO 3183 CT4:8825 Nominal Weight / Peso nominale: 62.68 lb/ft 93.28 Kg/m
Dimensions / Dimensioni: ø 406.40mm O.D. x 9.53mm W.T.	Schedule / Scheda: Length / Lunghezza: 37,999 ft ± 43,999 ft 11582 mm ± 13411 mm	Ends / Estremità: SMUSSATI SECONDO API 5L / ISO 3183 CT4:8825 Nominal Weight / Peso nominale: 62.68 lb/ft 93.28 Kg/m

HYDROSTATIC TEST / PROVA IDRAULICA

Pressure / Pressione	Time / Tempo	Results / Risultato
psi	5	Satisfactory / Soddisfacente

SUPPLEMENTARY INFORMATION / INFORMAZIONI SUPPLEMENTARI

STANDARD EDITIONS	EDIZIONI NORME
Standard: API 5L, Year: 2018, Revision: 46	Standard: API 5L, Year: 2018, Revision: 46
Standard: NFW N32/N106, Year: 2018, Revision: 101	Standard: NFW N32/N106, Year: 2018, Revision: 101
Standard: NFW N32/N106, Year: 2019, Revision: 101	Standard: NFW N32/N106, Year: 2019, Revision: 101
Standard: NFW N32/N106, Year: 2019, Revision: 101	Standard: NFW N32/N106, Year: 2019, Revision: 101
Standard: NFW N32/N106, Year: 2019, Revision: 101	Standard: NFW N32/N106, Year: 2019, Revision: 101

PRODUCT DESCRIPTION NOTES	NOTE DI DESCRIZIONE DEL PRODOTTO
NOTE 1: The full description of the "Surface".	La nota 1 è la descrizione completa della "Superficie".
NOTE 2: The full description of the "Surface".	La nota 2 è la descrizione completa della "Superficie".
NOTE 3: The full description of the "Surface".	La nota 3 è la descrizione completa della "Superficie".
NOTE 4: The full description of the "Surface".	La nota 4 è la descrizione completa della "Superficie".
NOTE 5: The full description of the "Surface".	La nota 5 è la descrizione completa della "Superficie".

This certificate is issued by a computerized system and is valid with electronic signature. On the original certificate the Tenaris logo is visible. In case of any discrepancy, the original certificate shall prevail. Any alteration and/or falsification will be subject to legal action.

ANTHONY CARDWELL
08/03/2022



INSPECTION CERTIFICATE
CERTIFICATO DI COLLAUDO
(UNI EN 10204 3.1 / ISO 10474 3.1)

Edizione 5.0.1 - 01/01/2019
Tenaris Cardwell Italia S.p.A.
24044 Oleggio (VC) - Italy
+39 011 5011110
+39 011 5011111

Number / Numero:
01-19-16603
Page / Pagina:
6 / 8

Date / Data: **December 06, 2019**

Customer / Cliente: INDUSTRIAL PIPING SPECIALISTS, INC.		Customer's Order Item / Rifer. Ordine Cliente: HR104731		Manufacturer's Works Order N° / Conferma-Posizione: 1212556/001	
Manufacture Process / Processo di fabbricazione:		Product Type / Tipo di prodotto:		Surface / Superficie:	
		SEAMLESS LINE PIPES (WITH EXTRA REQUIREMENTS)		See note nr.1	
Standard or Specification / Norme o specifica:		TUBI S.S. LINE PIPE (CON RICHIESTE SUPPLEMENTARI)		Ends / Estremità:	
See note nr.2		See note nr.3		See note nr.1	
Dimensions / Dimensioni:		Length / Lunghezza:		Ends / Estremità:	
Ø 16.000" O.D. x 0.375" W.T.		37.999 ft + 43.999 ft		SMUSSATI SECONDO API 5L / ISO 3183 CT4:8825	
Ø 406.40mm O.D. x 9.53mm W.T.		11582 mm + 13411 mm		Nominal Weight / Peso nominale:	
				62.68 lb/ft	
				93.28 Kg/m	

SUPPLEMENTARY INFORMATION / INFORMAZIONI SUPPLEMENTARI

Country of origin / Paese di origine: ITALY		Supplementary Information / Informazioni supplementari:	
Continents casting and fully killed		Faesce di colaggio acciaio ITALIA Colaggio continuo ed acciaio d. tipo ordinario	

Supplementary Information / Informazioni supplementari:		Supplementary Information / Informazioni supplementari:	
AFTER INSPECTION OPERATION, THE MATERIAL HAS NOT A RESIDUAL MAGNETIC INDUCTION MORE THAN 20 GAUSS.		DOPO LE OPERAZIONI DI CONTROLLO, IL MATERIALE NON PRESENTA UN VALENZIMISMO RESIDUO SUPERIORE A 20 GAUSS.	
BENDING HRC 22 MAX, ACCORDING TO NACE MR0175/ISO 15156		DUREZZA HRC 22 MAX, IN ACCORDO ALLA SPEC. NACE MR0175/ISO 15156	
WELDING HRC 248 MAX, ACCORDING TO NACE MR0175/ISO 17945		DUREZZA HRC 248 MAX, IN ACCORDO ALLA SPEC. NACE MR0175/ISO 17945	
ALL TUBES HAVE BEEN TESTED BY ELECTROMAGNETIC TEST		TUBI SONO STATI SOTTOPOSTI AL CONTROLLO ELETTROMAGNETICO	
LONG. INTEREST 12.5% ISO 10893-3 F4, WITH SATISFACTORY RESULT		LONG. INTEREST 12.5% ISO 10893-3 F4 CON RISULTATO SODDISFACENTE	
END FULL LENGTH		FINE SU TUTTA LA LUNGHEZZA	
HYPERMIL ACCORDING TO ASME B 36.10		VANTAGGIO IN ACCORDO ALLA ASME B 36.10	
STRESSING HOT FINISHED STEPS		TUBI SONO STATI FINITI A CALDO	
VIBRATION AND CHIMNEY CONTROL. HAS BEEN CARTRIDGED OUT WITH SATISFACTORY RESULT		IL CONTROLLO VIBRAZIONALE E DIMENSIONALE HA DATO RISULTATO SODDISFACENTE	
STRESS IS FULLY MET AND PROVIDED BY ELECTRIC FURNACE TO A FINE GRAIN PRACTICE		IL TRATTAMENTO E' DI TIPO CALZATO, A GRANO FINO, PRODOTTO AL FORNO ELETTRICO	
THE PRODUCT SUPPLIED IS IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER.		IL MATERIALE FORNITO E' IN ACCORDO AI REQUISITI DELL'ORDINE.	
MANUFACTURED BY TENARIS ITALY		PRODOTTO DA TENARIS ITALIA	
NO FIELD REPAIR, WELDING AND RADIATION FREE		NON RIPARATO MEDIANTE SALDATURE, ESISTE UN RICORSO E RADIAZIONI	
AS PER STANDARD, PIPES CAN BE RE-GRIND. MANUFACTURER SHOULD DECIDE TO GRIND THE		COME DA PROCEDURA STANDARD, I TUBI POSSONO ESSERE RISPACATI; IL CONTRUTTORE DOVRANNE	
AGE DETERMINED. THE RESULTED SURFACE AREAS, AFTER GRINDING, HAS DIFFERENT		STADUE VORRANO RILEVARE DELLE DEFECTUOSITA'. DOPO LA RETTIFICA, LE AREE SUPERFICIALI	
COLORATION COMPARED WITH USUAL ONE, AS MANUFACTURED. THE RESIDUAL WALL THICKNESS		INTERESSANTE PRESENTANO UNA COLORAZIONE DIVERSA RISPETTO A QUELLA ORIGINALE. DO	
AFTER GRINDING HAS BEEN CHECKED RESULTING IN TOLERANCE WITH STANDARD.		SPESORE RESIDUO DELLE PARETI RIENTRA NELLA SOGGIA DI TOLLERANZA.	

This certificate is issued by a computerized system and is valid with electronic signature. On the original certificate the red mark green colored "Tenaris" is stamped. In case the owner of the original certificate would release a copy of it, he must attach the original one taking upon himself the responsibility for any unlawful use. Any alteration and/or falsification will be subject to the law.

Questo certificato è emesso da un sistema computerizzato ed è valido con firma elettronica. Il certificato originale riporta il marchio "Tenaris" in colore verde. In caso l'utente dell'originale, qualora rilasci copie, deve ritenersi a sua volta responsabile per qualsiasi uso non autorizzato. Qualsiasi alterazione o falsificazione sarà perseguita a norma di legge.

mm
-1/16"

ANTHONY CARDWELL
08/03/2022



INSPECTION CERTIFICATE
CERTIFICATO DI COLLAUDO
(UNEN 10204 3.1 / ISO 10474 3.1)

Number / Numero: **01-19-16603**
Page / Pagina: **7 / 8**
Date / Data: **December 06, 2019**

INDUSTRIAL PIPING SPECIALISTS, INC.
Customer's Order Item / Rifer. Ordine Cliente: **HR104731**
Product Type / Tipo di prodotto:
SEAMLESS LINE PIPES (WITH EXTRA REQUIREMENTS)
TUBI S.S. LINE PIPE (CON RICHIESTE SUPPLEMENTARI)

Customer / Cliente: INDUSTRIAL PIPING SPECIALISTS, INC.	Manufacturer Process / Processo di fabbricazione:	Manufacturer's Works Order N° / Conferma-Posizione: 1212556/001
Standard or Specification / Norme o Specifica: See note nr.2 Vedi nota nr.2	Dimensions / Dimensioni: ø 406.40mm O.D. x 9.53mm W.T.	Surface / Superficie: See note nr.1 Vedi nota nr.1
Schedule / Scheda: 11562 mm ÷ 13411 mm	Length / Lunghezza: 37.999 ft ÷ 43.999 ft	Ends / Estremità: BEVEL API 5L / ISO 3183 CT4-8825 SMUSSATI SECONDO API 5L / ISO 3183 CT4-8825
Quantity / Quantità: 28Pcs/Pz	Weight / Peso: 75223,8 lb	Nominal Weight / Peso nominale: 62.68 lb/ft
		93.28 Kg/m

SUPPLEMENTARY INFORMATION / INFORMAZIONI SUPPLEMENTARI

Supplementary Information Informazioni supplementari
Tenaris IT identification number (ot MTC): 56709, 9A
Numero Identificativo Tenaris IT per MTC: 56709, 9A

MARKING / MARCATURA

STENCILING	VERNICIATURA
T API Spec 5L 0038.1 API DATA 16 0.375 BRX42R PSL 2 SMLS AST M/ASME A/SA	T API Spec 5L 0038.1 API DATA 16 0.375 BRX42R PSL 2 SMLS AST M/ASME A/SA
100 BIC PSI: 1600NDE ASTM ASME A SA 53 B S HEAT COLATA F T FT LBS LBS NR	100 BIC PSI: 1600NDE ASTM ASME A SA 53 B S HEAT COLATA F T FT LBS LBS NR
NR	NR
LEGENDA	LEGENDA
T = TENARIS Logo	T = Logo TENARIS
API = API Logo	API = Logo API
DATA = Marking Data	DATA = Data di marcatura
COLATA = Heat Number	COLATA = Numero di colata
FT = Pipe/Tube Length in feet	FT = Lunghezza del tubo in piedi
LBS = Pipe/Tube Weight in pounds	LBS = Peso del tubo in libbre
NR = Pipe/Tube Identifier	NR = Identificativo numero del tubo

This certificate is issued by a computerized system and it is valid with electronic signature. On the original certificate, the trade-mark green colored "Tenaris" is stamped. In case the owner of the original certificate would release a copy of it, he must attest its conformity to the original one taking upon himself the responsibility for any unlawful use. Any alteration and/or falsification will be subjected to the law.

Questo certificato è emesso da un sistema computerizzato ed è valido con firma elettronica. Il certificato originale porta il marchio "Tenaris" in colore verde. In caso l'utente del certificato originale rilasciasse una copia di esso, deve attestare la sua conformità all'originale, assumendosi ogni responsabilità per usi illeciti e non autorizzati. Qualsiasi alterazione e falsificazione sarà punita a norma di legge.

Handwritten signature

ANTHONY CARDWELL
08/03/2022



Stazione S.p.A. - Direzione Area
Via S. Maria, 10 - 40138 Bologna (BO) - Italy
Tel. +39 051 2611111 - Fax +39 051 2611112
E-mail: info@tenaris.com

INSPECTION CERTIFICATE CERTIFICATO DI COLLAUDO (UNI EN 10204 3.1 / ISO 10474 3.1)

Number / Numero:
01-19-16603

Page / Pagina:
8 / 8

Date / Data: **December 06, 2019**

Customer / Cliente: **INDUSTRIAL PIPING SPECIALISTS, INC.** Customer's Order Item / Rifer. Ordine Cliente: **HR104731** Manufacturer's Works Order N° / Conferma Posizione: **1212556/001**

Manufacture Process / Processo di fabbricazione: SEAMLESS LINE PIPES (WITH EXTRA REQUIREMENTS) TUBI S.S. LINE PIPE (CON RICHIESTE SUPPLEMENTARI)		Product Type / Tipo di prodotto: SEAMLESS LINE PIPES (WITH EXTRA REQUIREMENTS) TUBI S.S. LINE PIPE (CON RICHIESTE SUPPLEMENTARI)	Surface / Superficie: See note nr.1 Vedi nota nr.1
Standard or Specification / Norme o specifica: See note nr.2 Vedi nota nr.2	Steel Grade / Grado dell'Acciaio: See note nr.3 Vedi nota nr.3	Ends / Estremità: BEVEL API 5L / ISO 3183 CT4-8825 SMUSSATI SECONDO API 5L / ISO 3183 CT4-8825	Nominal Weight / Peso nominale: 62.68 lb/ft 93.28 Kg/m
Dimensions / Dimensioni: ø 406.40mm O.D. x 9.53mm W.T.	Length / Lunghezza: 37.999 ft ÷ 43.999 ft 1174.41 ft 357.96 mt	Quantity / Quantità: 28Pcs/Pz	

This is to certify that the product described here has been manufactured, sampled, tested, and inspected in accordance with the purchaser order requirements. This certificate is not a declaration of origin nor may it be used as a declaration of origin.

Si certifica che il prodotto descritto è stato prodotto, provato, testato e controllato in conformità ai requisiti dell'ordine del cliente. Questo certificato non è una dichiarazione d'origine e non può essere usato come tale.

CUSTOMER THIRD PARTY		TENARIS QUALITY DEPARTMENT SIGNATURE	
INSPECTION COMPANY COMPAGNIA DISPEZIONE		QUALITY CERTIFICATION DEPT. UFFICIO CERTIFICAZIONE QUALITÀ LATTANZI Sabrina	CHIEF OF QUALITY CERTIFICATION DEPT. RESPONSABILE DELL'UFFICIO CERTIFICAZIONE QUALITÀ FERRARI Donatello

This certificate is issued by a computerized system and it is valid with electronic signature. On the original certificate, the red mark green colored "Tenaris" is stamped. In case the owner of the original certificate would release a copy of it, he must attach his conformity to the original one taking upon himself the responsibility for any misuse or not allowed use. Any alteration and/or falsification will be subjected to the law.

Questo certificato è emesso da un sistema computerizzato ed è valido con firma elettronica. Il certificato originale porta il marchio "Tenaris" in colore verde. In caso l'utente dell'originale, qualora rilasci copia, deve apporre e far firmare a conferma al sistema, assumendosi ogni responsabilità per un eventuale abuso. Qualunque falsificazione sarà perseguita a norma di legge.

no
11/06

ANTHONY CARDWELL
08/03/2022

23840

06/24/2022 From: AMERICAN ALLOY STEEL, INC. To: METALS USA
 P.O.#: MUS-261394 S.O.#: 715470 AA PL#: 5258811
 Item: 1 (1 PC) 2-1/4" X 96" X 480"

Cleveland-Cliffs Burns Harbor LLC
 QUALITY ASSURANCE REPORT OF TEST AND ANALYSIS

US HWY 12 Burns Harbor, Indiana

SHIPMENT NO. 803-86415		DATE SHIPPED 05-04-22		CAR OR VEHICLE NO. CSS-CHEGO-BNSF		LMIC 200028		
AMERICAN ALLOY STEEL INC PO BOX 40469 HOUSTON TX 77240-0469				AMERICAN ALLOY STEEL INC BNSF TR# 7226 MILE 66.4 LN SEG 492 6230 N HOUSTON ROSSLYN RD HOUSTON TX 77091-3410				
S H I P T O	S E R I A L N O.	P A T N O.	H E A T N O.	N O. P C S.	SIZE AND QUANTITY			
					THICKNESS	WIDTH OR DIA	LENGTH	WEIGHT
					INCHES	INCHES	INCHES	POUNDS

QUALITY STEEL MELTED & MANUFACTURED IN THE U. S. A.

PLATES - ASTM A516-17 GR 70 PVQ KLD FINE GRAIN PRAC, ASTM A516-17 GR 65 PVQ, ASTM A516-17 GR 60 PVQ, ASME SA516 GR 70 PVQ 2021 EDITION, ASME SA516 GR 65 PVQ 2021 EDITION, ASME SA516 GR 60 PVQ 2021 EDITION, CH-V SA2085 PLT L 15/12 FT LBS AT -50F, VACUUM DEGASSED --- PLT NORMALIZED & COOLED IN STILL AIR --- IN ACCORDANCE WITH EN 10204:2004 TYPE 3.1 10204:2004 TYPE 3.1
 NO WELD REPAIR WAS PERFORMED ON BELOW PLATE(S)

CO# 129966 GH 391-0414D

PLATES HEAT TREATED - TEST SPECIMENS ATTACHED & YIELD STRENGTH @ .5% EUL MERCURY IN ANY FORM HAS NOT BEEN USED IN THE PRODUCTION OF THIS ORDER

X030860 611D98310 1 2 1/4 96 480 29404 49000 75300 2 33
 N 1650 DEG F - 112 MIN

(M55)MFST REF#:5

CERTIFIED TRUE COPY TEST REPORT FROM
C.G. MARTIN CO., INC.

CUST ID	770	WO#	102624
CUST	FABSCO SHELL & TUBE, LLC		
P.O. #	R22-13258-9TS		
ITEM #	1		
DESC	(2) 17-3/4" OD(F) X 2" THK(F)		
	TAG: (1) 13258-10-19; (1) 13258-9-19		
DATE	08/22/22	BY:	<i>[Signature]</i>

RATURE

N-NORMALIZE TEMPERATURE

S E R I A L N O.	P A T N O.	H E A T N O.	H A R D B H N	B E N D	T H I C K N E S S	T Y P E	S I Z E	D I R	T E S T T E M P	E N E R G Y	CHARBY IMPACT					
											FT LBS			MILS		
X030860		611D98310			2.250	V	FULL	L	-50	91	92	88				

Certified a true copy of the original, retained in our file.
 AMERICAN ALLOY STEEL

JP 6/24/2022

H E A T N O.	C H E M I C A L A N A L Y S I S															M O D U L E G R A I N S I Z E
	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Ti	Al	B	Co	N	

611D98310 .18 1.11 .011 .001 .310.190 .11 .11.030.003.004.038.0004 .001.010.006

CEQ=0.41

I certify that the above results are a true and correct copy of actual results contained in records maintained by Cleveland-Cliffs Burns Harbor LLC and are in full compliance with the requirements of the specification cited above. This test report cannot be altered and must be transmitted intact with any subsequent test results. SUPV. QUALITY ASSURANCE

AMERICAN
 ALLOY STEEL
 PLATE #10

ANTHONY CARDWELL
 09/06/2022

GLOBE X-RAY SERVICES, INC.

8441 South Union Tulsa, OK 74132

Certification: 161611

Report of Ultrasonic Examination

Customer: CG Martin P. O.
Address: Job # Stock Plate

Ultrasonic Examination

Test Instrument: Sonatest D-20+ S/N: 1011920
Surface Condition: Smooth Procedure #: GXS-II-D/B Rev: 1-22
Couplant: Water Search Unit Cable: RG-174 Co-Axial, 6FT. Long with BNC to BNC Connectors
Beam Angle: 0 Degrees Search Unit: 1" x 2.25 MHz S/N: 61156
Scanning Pattern: 100% Reference Level: 49 Db
Calibration Reference: Backwall Technique: Contact, Manual Scan
Scanning Surface: One Major Surface.

Reference Standard:

The plates listed below have been ultrasonically examined and comply with the acceptance criteria of the indicated specifications. In addition to the requirements of SA-578, paragraph 5 and 6, all indications with amplitudes equal to or greater than 50% of the initial back reflection and accompanied by a 50% loss of back reflection shall be recorded regardless of plate thickness. Unless otherwise noted by an * following the plate number, there were no recordable indications observed.

<u>X</u>	ASTM/ASME A-578/SA-578 LEVEL A(1) W/SI	<u>X</u>	ASTM/ASME A-435/SA-435
<u>X</u>	ASTM/ASME A-578/SA-578 LEVEL B(2) W/SI	<u>X</u>	Wheatley-Gasso Sep 6.6.2 Rev. D
<u>X</u>	ASTM/ASME A-578/SA-578 LEVEL C(3) W/SI	<u>X</u>	Other: AM203.2

X In addition to the above ultrasonic examination, the mat'l has been hardness tested and meets the requirements of ANSI/NACE Standard MR0175. Hardness value does not exceed 22 HRC

Plate #	Mat'l Spec.	Thickness	Dimensions	Heat #	Slab #	Hardness
23839	516-70MT	4"	120" x 301"	E67303	36168	179
→ 23840	516-70MT	2.25"	96" x 144"	611D98310	X030860	184

Unless otherwise noted by an * following the item number, there were no recordable indications observed.

Examination By: W. Kellough W.Kellough Qualification Level: II
Date: January 16, 2020 Time: NA AM/PM

GLOBE XRAY ASSUMES NO RESPONSIBILITY FOR THE INTEGRITY OF THE STRUCTURE OR ANY LOSSES OF ANY KIND DUE TO ANY KIND OF INTERPRETATION

Handwritten initials

Benteler Steel/Tube GmbH
Postfach 13 40
33043 Paderborn
Deutschland
Tel.: + 49.5254.81-0 Fax: + 49.5254.13666



ABNAHMEPRÜFZEUGNIS EN 10204-3.1
INSPECTION CERTIFICATE EN 10204-3.1
CERTIFICAT DE RECEPTION EN 10204-3.1
EN 10204:2005-01

Benteler Steel/Tube GmbH - Postfach 1340 - 33043 Paderborn - Deutschland

Tubes Inc.
900 E. Pecan
SAND SPRINGS OK 74063
USA

Dokument-Nr.: 41-1281463/001/E

Document No.:
No. du document:

Kunden-Bestell-Nr.:
Purchase Order No.:
No. de commande du client:

Benteler Auftrags-Nr.:
Benteler Order No.:
No. de commande Benteler:

Versandanzeigen-Nr.:
Dispatch Note No.:
No. d'avis d'expédition:

Produkt: NAHTLOSE STAHLROHRE
Product: SEAMLESS STEEL TUBES
Produit: TUBES D'ACIER SANS SOUDURE

Herstellerzeichen:
Manufacturer's brand:
Marque du producteur:

Stempel des Abnahmebeauftragten:
Stamp of the inspection representative:
Poinçon du contrôleur:

Stahlschmelzungsverfahren:
STEELMAKING PROCESS:
Procédé d'élaboration de l'acier:

Lieferbedingungen: ASTM-A 334-2004a-CD, ASTM-A 179-2019, ASME SA-334-CD, ASME BPVC.II.A-2019, ASME SA-179, ASME
Terms of delivery: BPVC.II.A-2019, NACE Standard MR0103-2010, ANSI/NACE MR0175/ISO 15156-1: 2015, ANSI/NACE MR0175/ISO
Conditions de livraison: 15156-2: 2015

Maße - Toleranzen: ASME SA-450-CFS, ASME BPVC.II.A-2019, ASME SA-1016-CFS ASME BPVC.II.A-2019, ASTM-A 450-2018a-CD, ASTM-A
Dimensions-tolerances: 1016-2018a-CF

Stahlsorte: A 179, GRADE 1, SA 179

Steel grade:

Nuance d'acier:

Lieferzustand: Normalized

Delivery condition:

État de livraison:

Produktkennzeichnung: FSD: BENTELER A334-CD-A179-SA334-CD-SA179 A/SA 179/1 46008119 / Tubes Inc. 2523T-21

Product marking: HEAT-NO. DIMENSIONS MW WEEK/YEAR MADE IN GERMANY WA

Marquage du produit:

AEZ = Alzintinbeschichtung, Etching ink marking, gravure à l'encre . RK = Farbkennzeichnung, color marking, marquage par couleur . FS = Farbschablonierung, paint stenciling, marquage par peinture . FSD = Farbschablonierung, color jet printer, imprimante à jet d'encre de couleur . FSI = Farbschablonierung innen, Color jet printer inside, imprimante à jet d'encre de couleur int . LK = Laserkennzeichnung, Laser marking, Marquage laser . RKE = Etikettenkennzeichnung, Tag marking, marquage sur étiquette . PS = Prägestempel, die stamp, marquage par poinçonnage . TS = Titelnstrahlkennzeichnung, ink jet spray marking, imprimante à jet d'encre .

Pos.	Stück	Maße	Gesamtlänge	Gewicht	Schmelzen-Nr.	Prüfdruck	Rohr-Nr.-Gruppe	Vierfachlängen
Item	Number	Dimensions	Length total	Weight	Heat No.	Test pressure	Tube number group	Multiple lengths
Poste	Nombre	Dimensions	Longueur totale	Poids	No. de coulée	Pression d'épreuve	Série de no. des tubes	Longueurs multiples
		feet	feet	lbs				
0001	660	0.750" O.D. * 0.083" MW 30 FT	19800,00	12467	292235			

ANTHONY CARDWELL
03/04/2022

TUBES, INC.
1-888-537-8880

THESE MILL TESTS REPORTS APPLY TO:

YOUR P.O. NO. T-21-13258-T

JOB NUMBER 13258-9-21

Benteler Steel/Tube GmbH
Postfach 13 40
33043 Paderborn
Deutschland
Tel.: + 49.5254.81-0 Fax: + 49.5254.13666



Steel/Tube

ABNAHMEPRÜFZEUGNIS EN 10204-3.1
INSPECTION CERTIFICATE EN 10204-3.1
CERTIFICAT DE RECEPTION EN 10204-3.1

Dokument-Nr.: 41-1281463/001/E
Document No.:
No. du document:

Blatt: 3 / 3
Page:

Zugversuch längs bei RT, Vollprobe / Tensile test longitudinal at RT, Full section test specimen / Essai de traction longitudinale à TA, Eprouvette a section complete

Pos.	Proben-Nr.	Schmelzen-Nr.	Probenabmessung	Streckgrenze	Zugfestigkeit	Dehnung
Item	Specimen No.	Heat No.	Specimen dimensions	Yield strength	Tensile strength	Elongation
Poste	No. de l'éprouv.	No. de coulée	Dimensions de l'éprouv.	Limite élastique	Résistance à la traction	Allongement
Anforderungen						
			mm	ReH	Rm	A2"
				KSI	KSI	%
				MIN 30	MIN 55	MIN 35.00
			19,05 X	2,23	60	40,00
			19,05 X	2,23	60	42,00
						1. Formel
						1. Formula
						1. Formule

Härteprüfung / Hardness test / Essai de dureté

Pos.	Proben-Nr.	Schmelzen-Nr.	HRC	HB	HV	HRB	HBW	HRA	HRBW
Item	Specimen No.	Heat No.							
Poste	No. de l'éprouv.	No. de coulée							
Härte									
Hardness									
Dureté									
			MAX 72						
			00001	292235		68			
			00002	292235		68			

Vermerk / Remark / Remarque

Pos. / Item / Poste: 0001
NACE Standard: Hardness acc. to ANSI/NACE MR0175/ISO 15156: HRC max 22., Hardness acc. to Standard MR0103 HRC max. 22.
Certificate remarks: fully killed fine grained steel, Hardness values in HRB correspond to values in HRBW., Country of origin of the material and heat: Germany

Verkäufer(in) / Sales Personnel / Personne chargée: Mr Dicke, Tel.: + 49 2064 623-2260

Werk 41, Marienloher Str., 33104 Paderborn, 30.09.2021, TEL.: 05254.81-201767

Abnahmebeauftragter
Inspection representative

Contrôleur

i. A. THOMAS GOLLAN / TEM

Es wird bestätigt, dass die gelieferten Erzeugnisse den techn. Lieferbedingungen des Auftrages entsprechen. Dieses Dokument wurde mittels EDV erstellt und ist ohne Unterschrift rechtsgültig.
We certify that the supplied products comply with the order specifications. This document was prepared by means of electronic data processing and is valid without signature.

Nous ANTHONY CARDWELL informons aux stipulations de la commande. Ce document a été établi par traitement électronique de l'information et est valide sans signature.

03/04/2022

Handwritten signature



Steel/Tube

Benteler Steel/Tube GmbH
Postfach 13 40
33043 Paderborn
Deutschland
Tel.: + 49.5254.81-0 Fax: + 49.5254.13666

ABNAHMEPRÜFZEUGNIS EN 10204-3.1
INSPECTION CERTIFICATE EN 10204-3.1
CERTIFICAT DE RECEPTION EN 10204-3.1
EN 10204:2005-01

Benteler Steel/Tube GmbH - Postfach 1340 - 33043 Paderborn - Deutschland

Tubes Inc.
900 E. Pecan
SAND SPRINGS OK 74063
USA

Blatt: 1 / 3
Page:

41-1286382/001/E

Dokument-Nr.:
Document No.:
No. du document:

Kunden-Bestell-Nr.:
Purchase Order No.:
No. de commande du client:

Benteler Auftrags-Nr.:
Benteler Order No.:
No. de commande Benteler:

Versandanzeigen-Nr.:
Dispatch Note No.:
No. d'avis d'expédition:

Produkt: NAHTLOSE STAHLROHRE
Product: SEAMLESS STEEL TUBES
Product: TUBES D'ACIER SANS SOUDURE

WarmrohrwerkZieherei
[DIN EN ISO 9001, IATF 16949 CERTIFIED BY TÜV NORD CERT]
[PED 2014/68/EU CERTIFIED BY TÜV NORD SYSTEMS]



Herstellerzeichen:
Manufacturer's brand:
Marque du producteur:

Stempel des Abnahmebeauftragten: WA
Poignon du contrôleur:

Stahlschmelzungsverfahren: ELEKTROSTAHL
Steelmaking process: ELECTRIC FURNACE
Procédé d'élaboration de l'acier: FOUR ELECTRIQUE

Lieferbedingungen: ASTM-A 179-2019, ASME SA-179, ASME BPVC.II.A-2019, ANSI/NACE MR0175/ISO 15156-1: 2015, ANSI/NACE MR0175/ISO 15156-2: 2015, ANSI/NACE MR0103/ISO 17945-2015

Conditions de livraison:

Maße - Toleranzen:

Dimensions-tolerances:

Dimensions-tolerances:

Stahlsorte:

Steel grade:

Nuance d'acier:

Lieferzustand:

Delivery condition:

État de livraison:

Produktkennzeichnung:

Product marking:

Marquage du produit:

AEZ = Alziminbeschichtung, Eching ink marking, gravure à l'encre, FK = Farbkennzeichnung, color marking, marquage par couleur, FS = Farbschablonierung, paint stenciling, marquage par peinture, FSD = Farbschablonierung, Color jet printer, imprimante à jet d'encre de couleur, FSI = Farbschablonierung, Color jet printer inside, imprimante à jet d'encre de couleur intr, LX = Laserkennzeichnung, Laser marking, marquage laser, PKE = Elketkenzeichnung, tag marking, marquage sur étiquette, PS = Prägestempel, die stamp, marquage par poinçonnage, TS = Tintenstrahlkennzeichnung, Ink jet spray marking, imprimante à jet d'encre

TUBES, INC.
1-888-537-8880

THESE MILL TESTS REPORTS APPLY TO:

YOUR P.O. NO. T-21-13258-T

JOB NUMBER 13258-11-21

FSD: BENTELER A179-SA179 A 179/SA 179 WA 46008196 / Tubes Inc. T-63900-26 HEAT-NO.

DIMENSIONS MW WEEK/YEAR MADE IN GERMANY

Marquage du produit:

AEZ = Alziminbeschichtung, Eching ink marking, gravure à l'encre, FK = Farbkennzeichnung, color marking, marquage par couleur, FS = Farbschablonierung, paint stenciling, marquage par peinture, FSD = Farbschablonierung, Color jet printer, imprimante à jet d'encre de couleur, FSI = Farbschablonierung, Color jet printer inside, imprimante à jet d'encre de couleur intr, LX = Laserkennzeichnung, Laser marking, marquage laser, PKE = Elketkenzeichnung, tag marking, marquage sur étiquette, PS = Prägestempel, die stamp, marquage par poinçonnage, TS = Tintenstrahlkennzeichnung, Ink jet spray marking, imprimante à jet d'encre

Pos.	Stück	Maße	Gesamtlänge	Gewicht	Schmelzen-Nr.	Prüfdruck	Rohr-Nr.-Gruppe	Vielfachlängen
Item	Number	Dimensions	Length total	Weight	Heat No.	Test pressure	Tube number group	Multiple lengths
Poste	Nombre	Dimensions	Longueur totale	Poids	No. de coulée	Pression d'épreuve	Série de no. des tubes	Longueurs multiples
		feet	feet	lbs				
0001	500	0.750" O.D. * 0.083" MW 32 FT 1 "	16041,67	10075	293004			

ANTHONY CARDWELL
03/04/2022

nr
1/1/21

Benteler Steel/Tube GmbH
Postfach 13 40
33043 Paderborn
Deutschland
Tel.: + 49.5254.81-0 Fax: + 49.5254.13666

BENTELER
Steel/Tube

ABNAHMEPRÜFZEUGNIS EN 10204-3.1

INSPECTION CERTIFICATE EN 10204-3.1
CERTIFICAT DE RECEPTION EN 10204-3.1

Ort der Stahlherstellung / Country of melt and pour / Lieu de l'élaboration de l'acier

BENTELER Steel/Tube GmbH, Lingen, Germany

41-1286382/001/E

Prüf-Nr.:
Inspection No.:
No. du certificat:

Blatt: 2 / 3

Page:

Schmelzenanalyse [%] / Heat analysis [%] / Analyse sur coulée [%]

Pos.	Schmelzen-Nr.	C	SI	MN	P	S	CR	MO
Item	Heat No.	> = 0,0600		> = 0,2700				
Poste	No. de coulée	< = 0,1800		< = 0,6300	< = 0,0350	< = 0,0350		
0001	293004	0,095	0,145	0,45	0,013	0,002	0,14	0,06

Prüfergebnisse / Test results / Résultats des essais

Die Rohre sind auf Dichtheit geprüft durch:

The tubes have been submitted to a leak tightness test by:

Les tubes ont passé un contrôle d'étanchéité par:

Die Rohre wurden zerstörungsfrei geprüft:

The tubes are non destructive tested:

Les tubes ont passé un essai non destructif:

Augensichtkontrolle:

Visual inspection:

Examen visuel:

Ringfaltversuch:

Flattening test:

Essai d'aplatissement:

PASSED

PASSED

Aufweitversuch:

Drift expanding/flare test:

Essai d'évasement:

PASSED

Maßkontrolle:

Dimensions examination:

Vérification des dimensions:

PASSED

Hydrostatic test: eddy current testing instead of hydrostatic test

ET-test: acc. to ASME SA-450, ASTM-A 450, ET - Test method: acc. to ASTM-E 309; for imperfections

PASSED

Ergebnisse der mechanischen Prüfung / Results of mechanical testing / Résultats des essais mécaniques

Die Probenahme erfolgte an Vielfachlängen.

The sampling was carried out on multiple lengths.

L'échantillonnage était réalisé aux longueurs multiples.

Härteprüfung / Hardness test / Essai de dureté

Pos. Proben-Nr. Schmelzen-Nr.

Item Specimen No. Heat No.

Poste No. de l'éprouv. No. de coulée

Härte

Hardness

Dureté

HRC

HB

HV

HRB

HBW

HRA

HRBW

ANTHONY CARDWELL

03/04/2022

MAX 72

72

Benteler Steel/Tube GmbH
Postfach 13 40
33043 Paderborn
Deutschland
Tel.: + 49.5254.81-0 Fax: + 49.5254.13666



Steel/Tube

ABNAHMEPRÜFZEUGNIS EN 10204-3.1

INSPECTION CERTIFICATE EN 10204-3.1
CERTIFICAT DE RECEPTION EN 10204-3.1

41-1286382/001/E

Dokument-Nr.:
Document No.:
No. du document:

Prüf-Nr.:
Inspection No.:
No. du certificat:

Blatt: 3 / 3
Page:
Page:

Härteprüfung / Hardness test / Essai de dureté

Pos.	Proben-Nr.	Schmelzen-Nr.	HRC	HB	HV	HRB	HBW	HRA	HRBW
Item	Specimen No.	Heat No.							
Poste	No. de l'éprouv.	No. de coulée							
Härte									
Hardness									
Dureté									
0001	000002	293004							
0001	000003	293004							

Vermerk / Remark / Remarque

NACE Standard: Hardness acc. to ANSI/NACE MR0175/ISO 15156: HRC max 22., Hardness acc. to ANSI/NACE MR0103/ISO 17945: HRC max. 22.; Certificate remarks: fully killed fine grained steel, Hardness values in HRB correspond to values in HRBW., Country of origin of the material and heat: Germany

Wärmebehandlung / Heat treatment / Traitement thermique

Pos.	Schmelzen-Nr.	Temp. 1	Haltezeit 1	Abkühlmedium 1	Temp. 2	Haltezeit 2	Abkühlmedium 2
Item	Heat No.	Temp. 1	Holding time 1	Cooling 1	Temp. 2	Holding time 2	Cooling 2
Poste	No. de coulée	Temp. 1	Temps maintien 1	Refrondissement 1	Temp. 2	Temps maintien 2	Refrondissement 2
0001	293004	920 °C	5 min	Air			

Verkäufer(in) / Sales Personnel / Personne chargée : Mr Dicke, Tel.: + 49 2064 623-2260

Werk 41, Marienloher Str., 33104 Paderborn, 26.10.2021, TEL.: 05254.81-201768

Abnahmebeauftragter
Inspection representative

Contrôleur

i. A. THOMAS GOLLAN / TAT

Es wird bestätigt, dass die gelieferten Erzeugnisse den techn. Lieferbedingungen des Auftrages entsprechen. Dieses Dokument wurde mittels EDV erstellt und ist ohne Unterschrift rechtsgültig.
It is confirmed that the delivered products comply with the order specifications. This document was prepared by means of electronic data processing and is valid without signature.

ANTHONY CARDWELL ont conformes aux stipulations de la commande. Ce document a été établi par traitement électronique de l'information et est valide sans signature.

03/04/2022

Handwritten signature

voestalpine Tubulars GmbH & Co KG

Alpinestrasse 17
8652 Kindberg-Aumuehl
T: +43/050304/23-0
F: +43/050304/63-532
www.voestalpine.com/tubulars

Legal Structure: Limited Partnership
Location: Kindberg/Austria
Company Registry Number 165400k
Commercial Court of Leoben
DPR 0592684, VAT Nr. ATU 43630406

General Partner: voestalpine Tubulars
GmbH
Legal Structure: Limited Liability Company
Location: Linz, Company Registry Number
106933f
Commercial Court of Linz

MILL TEST CERTIFICATE 3.1

(according to EN 10204)

ABNAHMEPRUEFZEUGNIS 3.1

(gem. EN 10204)

CERTIFICAT DE CONTROLE DES PRODUITS PAR L'USINE 3.1

(selon EN 10204)

Hersteller:
Manufacturer:
Producteur:

voestalpine Tubulars GmbH & Co KG, Austria

Besteller:
Purchaser:
Archeteur:

VOEST-ALPINE TUBULAR CORPORATION
HOUSTON, TEXAS 77077, USA
INDUSTRIAL PIPING SPECIALISTS, INC
P. O. BOX 581270
TULSA OK 74158-1270, USA

Pruefgegenstand:
Object of tests:
Eprouvette:

Seamless hot rolled carbon steel tubes
Line Pipe LP-USA-STD-2-PSL-2
LINEPIPE-04.0
LP-USA-STD-2-PSL-2-1 Rev. 1
non upset ends (API-5-L) - non upset
UV coating
A/SA 106 - GRADE-B
A/SA 53 - GRADE-B
API-5-L - GRADE-BN - PSL2
API-5-L - GRADE X42N - PSL2
API-5-L-46.edt.
NACE MR 0175 / ISO 15156
NACE MR 0103 / ISO 17945
Mechanical properties A/SA 106 GRADE-C (if applicable)
GRADE-C - no marking on pipes

Werkstoff:
Material:
Matières:

GRADE B / GRADE BN/X42N / GRADE C

Anforderungen:
Requirements:
Exigence:

GRADE-B acc. to ASTM A 106 / A 106 M-2019
ASME SA 106-2019
GRADE-B acc. to ASTM A 53 / A 53 M-2020
ASME SA 53-2019
GRADE BN / X42N acc. to API-5-L, 46.edt., Edition/Errata 1, May 2018 (PSL-2)
NACE MR 0175 / ISO 15156-2015; NACE MR 0103 / ISO 17945-2016
LINEPIPE-04.0; LP-USA-STD-2-PSL-2-1 Rev.1

Ausführung:
Condition:
Cond. de livraison:

NU, PLAIN END, PE, BEB-API/ASTM (30°)

Wärmebehandlung:
Heat treatment:
Traitement de chaleur:

NORMALIZED ROLLED

Kindberg, 13.05.2022

Page 1 of 9

Abnahmeprüfzeugnis wurde digital signiert und ist ohne
Originalunterschrift gültig/
Inspection certificate has been signed digitally and is
valid without an original signature

No. 183512**No. 183512 Rev.: 0**

Auftrags-Nr.: 46580 / 23
Our works order No.:
No usine:

Bestellnr./Pos.: HR134513/2203036
Your order No.:
No de la commande:

Zeichen des Lieferanten: **va**
Marking of producer:
Marque du fabricant:

Erschmelzungsart: **BOF**
Melting process: fully killed, produced to
Procédé d'élaboration: fine grain practice

voestalpine Tubulars GmbH & Co KG
Qualitätsstelle / Quality Department
WETZER

Abnahmebeauftragter
Authorized inspection representative
Représentant autorisé du contrôle

voestalpine

10010101000000000000

*m
1/11/22*

voestalpine Tubulars GmbH & Co KG

Coupl. die stamped:

Coupl. paint stencilling:

Coupl. colour coding: Fully painted: Bands:

Tube die stamped:

Tube paint stencilling: va API Spec 5L-0033 "API" 05-22 6,625 x 0,432 BN/X42N PSL2 SMLS 2970 PSI Length FT Weight LB Heat No. Lot No.A/SA
53 Grade B S A/SA 106 Grade B Sched 80 LP-USA-STD-2-PSL-2-1 PO# HR134513 Made in Austria

Tube colour coding: Fully painted: Bands: purple

Label: PO# HR134513 DAT Quay Port of Houston, TX

Measurement Notes: Product was tested and verified against requirements using the International System of units (SI).
Reported data were converted and rounded from SI units into United States customary units (USC).

Remarks: *) Grade C without marking on tubes

Steelmaking & Casting:

voestalpine Stahl Donawitz GmbH, Kerpelystraße 199, 8700 Leoben-Donawitz, Austria

Kindberg, 13.05.2022

Page 2 of 9

No. 183512

Abnahmeprüfzeugnis wurde digital signiert und ist ohne
Originalunterschrift gültig/
Inspection certificate has been signed digitally and is
valid without an original signature

voestalpine Tubulars GmbH & Co KG
Qualitätsstelle / Quality Department

WEITZER

Abnahmebeauftragter
Authorized inspection representative
Représentant autorisé du contrôle

voestalpine

0910 4334 88 0000

me
vltz

ANTHONY CARDWELL
09/06/2022

R22-13258-9AN | | 1022457977 | LN: 17 | T0515182-1 | FSVAT6XHP8L2 |

voestalpine Tubulars GmbH & Co KG

Umfang der Lieferung / Volume of delivery / Contenu de la livraison:

Versandanzeige:	Pos.:	Abmessung:	Bundnr.:	Stückzahl:	Länge:	Gewicht:	Los:
Dispatch advice No.	Pos.:	Dimension:	Bundle No.:	Number of pieces:	Length:	Weight:	Lot:
Avis d'expédition:	Pos.:	Dimension:	Numéro de lot:	Pièces:	Longueur:	Poids:	Lot:
	23	6,825 in x 0,432 in 28,57 lb/ft Sched 80	1-16	102	4267,111 ft	55365,40 kg	

Heat	Lot	Remark
1022356901	280237	-- 01
1022457977	280238	-- 01

Kindberg, 13.05.2022

Page 3 of 9

No. 183512

Abnahmeprüfzeugnis wurde digital signiert und ist ohne
Originalunterschrift gültig/
Inspection certificate has been signed digitally and is
valid without an original signature

voestalpine Tubulars GmbH & Co KG
Qualitätsstelle / Quality Department

WEITZER

Abnahmebeauftragter
Authorized inspection representative
Représentant autorisé du contrôle

voestalpine

010113182-002

m
1/10/2

ANTHONY CARDWELL
09/06/2022

voestalpine Tubulars GmbH & Co KG

Additional tests and inspections performed on pipe

- 1 Dimensionskontrolle/ Dimensional inspection: bestanden/passed
- 2 Magnetpulverprüfung der Rohrenden nass fluoreszierend nach ASTM E 709 (304,8mm) / Magnetic particle inspection acc. ASTM E 709 (wet MPI) 12" each pipe end: bestanden/passed Reference indicator: Type Castrol Strip ELY1; location: OD & ID; orientation: longitudinal and transverse
- 3 Ringfaltversuch/Flattening test: bestanden/passed
- 4 Streifflussprüfung ASTM E 570; Laengs- und Querfehler/ Flux Leakage testing acc. ASTM E 570; longitudinal and transversal: bestanden/passed / Reference indicator: acceptance level 5%nWT; location OD; orientation: long & trans; type: Notch; size length 1 in.; width 0,012 in.. Acceptance Level 10%nWT; location ID; orientation: long & trans; type: Notch; size length 1 in.; width 0,020 in..
- 5 Streifflussprüfung nach API 5L EN ISO 10893-3; Laengs- und Querfehler/ Flux Leakage testing acc. API 5L EN ISO 10893-3; longitudinal and transversal: bestanden/passed / Reference indicator: acceptance level F2 5%nWT; location OD; orientation: long & trans; type: Notch; size length 1 in.; width 0,012 in.. Acceptance Level F3 10%nWT; location ID; orientation: long & trans; type: Notch; size length 1 in.; width 0,020 in..
- 6 Ultraschallprüfung gem. EN ISO 10893-12 (Wanddicke - 100 % Umfang)/Ultrasonic inspection acc. EN ISO 10893-12 (wall thickness - 100 % circumference): bestanden/passed
- 7 Visuelle Inspektion / Visual inspection: bestanden / passed (Wo es die Norm und die Bestellung zulässt erfolgte entweder eine visuelle Inspektion oder eine diese VT ersetzende geeignete zerstörungsfreie Prüfung nach Wahl des Herstellers / Where allowed by the applicable specification and the order a visual inspection or a suitable VT replacing nondestructive test was performed by the option of the manufacturer)
- 8 Wasserinnendruckversuch/Hydrostatic test: bestanden/passed, Mindestprüfdruck/min test pressure: 205 bar / 20.5 MPa / 2970 psi, min. Haltezeit/min duration: 5 sec
- 9 Restmagnetfeld gemäß API 5L max. 3,0mT (30Gs) / Residual magnetism according API 5L max. 3,0 mT (30Gs): bestanden/passed

Test remarks

Wir bestätigen, dass die gelieferten Erzeugnisse den Anforderungen der Bestellung entsprechen.
We hereby certify that the goods delivered are in compliance with the requirements of the order.

Kindberg, 13.05.2022

Page 4 of 9

No. 183512

Abnahmeprüfzeugnis wurde digital signiert und ist ohne
Originalunterschrift gültig/
Inspection certificate has been signed digitally and is
valid without an original signature

voestalpine Tubulars GmbH & Co KG
Qualitätsstelle / Quality Department
WEITZER

Abnahmebeauftragter
Authorized inspection representative
Représentant autorisé du contrôle

voestalpine

0010 1111 1111

m
2/16/22

ANTHONY CARDWELL
09/06/2022

voestalpine Tubulars GmbH & Co KG

Tensile testing

Lot No Test type Heat treatment Loc. Temp Specimen Yield strength Tensile strength Elong. length Gage length in area Reduct. of area R_m/R_e

		[°F]	No.	Type	Pipe	Dimension[inch]	[psi]	[psi]	[%]	[inch]	[%]
						Req. from	42100	60200	30.0		
						Req. to	71800	95000			
280237	-- 01 Standard	normalized rolled	Rear	68	1 Strip-long	1.000 x .445 R10.5	47000	72500	38.4	2.0	0.65
280237	-- 01 Standard	normalized rolled	Rear	68	2 Strip-long	1.000 x .442 R10.5	47400	73100	36.2	2.0	0.65
280238	-- 01 Standard	normalized rolled	Front	68	1 Strip-long	1.000 x .434 R10.5	48000	72800	38.3	2.0	0.66
280238	-- 01 Standard	normalized rolled	Rear	68	2 Strip-long	1.000 x .431 R10.5	46100	72500	36.9	2.0	0.64
280238	-- 01 Standard	normalized rolled	Front	68	3 Strip-long	1.001 x .443 R10.5	49600	73000	38.6	2.0	0.68
280238	-- 01 Standard	normalized rolled	Rear	68	4 Strip-long	1.002 x .440 R10.5	47700	73800	39.3	2.0	0.65

Yield strength:
Gr B: min. 35000 PSI
BN - PSL-2: 35500 - 71800 PSI
X42N - PSL-2: 42100 - 71800 PSI
Gr C (if applicable): min. 40000 PSI
Tensile strength:
Gr B: min. 60000 PSI
BN - PSL-2: 60200 - 95000 PSI
X42N - PSL-2: 60200 - 95000 PSI
Gr C (if applicable): min. 70000 PSI

Kindberg, 13.05.2022

Page 5 of 9

No. 183512

Abnahmeprüfzeugnis wurde digital signiert und ist ohne Originalunterschrift gültig/
Inspection certificate has been signed digitally and is valid without an original signature

voestalpine Tubulars GmbH & Co KG
Qualitätsstelle / Quality Department

WEITZER

Abnahmebeauftragter
Authorized inspection representative
Représentant autorisé du contrôle

voestalpine

0100 0000 0000

ms
11/10/22

voestalpine Tubulars GmbH & Co KG

Hardness testing

Lot No	Test type	Heat treatment				Specimen			Test	Hardness		Number		Mean	Hardness		Number	Variation	
						Loc.	No.	location	Pipe	method	from	to	from	to	from	to	to		
Req.:																			99.50
280237	-- 01 Standard	normalized rolled				Rear	1	Body	-	HRB	79.00	80.60	79.80	80.10	0.30				
Quadrant	1_Outer	2_Outer	3_Outer	AVG_Outer	1_Mid	2_Mid	3_Mid	AVG_Mid	1_Inner	2_Inner	3_Inner	AVG_Inner	AVG_Variation						
1	79.80	79.00	80.60	79.80	80.00	79.60	80.20	79.93	80.20	80.00	80.10	80.10	0.30						
280238	-- 01 Standard	normalized rolled				Front	1	Body	-	HRB	77.40	78.90	77.47	78.50	1.03				
Quadrant	1_Outer	2_Outer	3_Outer	AVG_Outer	1_Mid	2_Mid	3_Mid	AVG_Mid	1_Inner	2_Inner	3_Inner	AVG_Inner	AVG_Variation						
1	77.40	77.50	77.50	77.47	78.10	77.90	77.90	77.97	78.90	78.30	78.30	78.50	1.03						

Kindberg, 13.05.2022

Page 6 of 9

No. 183512

Abnahmeprüfzeugnis wurde digital signiert und ist ohne
Originalunterschrift gültig/
Inspection certificate has been signed digitally and is
valid without an original signature

voestalpine Tubulars GmbH & Co KG
Qualitätsstelle / Quality Department
WEITZER

Abnahmebeauftragter
Authorized inspection representative
Représentant autorisé du contrôle

voestalpine

09/06/2022

*mw
1/16/22*

ANTHONY CARDWELL
09/06/2022

voestalpine Tubulars GmbH & Co KG

Impact testing

Requirement:		Length [Inch] 2.165	Width [Inch] .394	Thickness [Inch] .295	Specimen orientation transv.		Type CH+V Req.	Temp. [°F] - 20	Single [ft-lbs] 15	Average [ft-lbs] 20	Factor 0.80		
Lot No	Test type			Loc.	No.	Pipe		Single1	Single2	Single3	Average	Unit	
280237 -- 01	Standard			Rear	1	-	transv.	Imp. values :	41	38	44	41	ft-lbs
	Heat treatment							Including factor:	51	47	55	51	
	normalized rolled							Shear area [%]:	100	100	100		
SHEAR AREA for information!						Lateral expansion (un-/broken):							
						Lateral expansion: [inch]							H: 0.295 [inch]

Requirement:		Length [Inch] 2.165	Width [Inch] .394	Thickness [Inch] .394	Specimen orientation long.		Type CH+V Req.	Temp. [°F] - 51	Single [ft-lbs] 10	Average [ft-lbs] 13	Factor		
Lot No	Test type			Loc.	No.	Pipe		Single1	Single2	Single3	Average	Unit	
280237 -- 01	Standard			Rear	2	-	long.	Imp. values :	108	109	105	107	ft-lbs
	Heat treatment							Including factor:					
	normalized rolled							Shear area [%]:	100	100	100		
SHEAR AREA for information!						Lateral expansion (un-/broken):							
						Lateral expansion: [inch]							H: 0.394 [inch]

Requirement:		Length [Inch] 2.165	Width [Inch] .394	Thickness [Inch] .295	Specimen orientation transv.		Type CH+V Req.	Temp. [°F] - 20	Single [ft-lbs] 15	Average [ft-lbs] 20	Factor 0.80		
Lot No	Test type			Loc.	No.	Pipe		Single1	Single2	Single3	Average	Unit	
280238 -- 01	Standard			Front	1	-	transv.	Imp. values :	43	44	41	42	ft-lbs
	Heat treatment							Including factor:	53	54	50	53	
	normalized rolled							Shear area [%]:	100	100	100		
SHEAR AREA for information!						Lateral expansion (un-/broken):							
						Lateral expansion: [inch]							H: 0.295 [inch]

Requirement:		Length [Inch] 2.165	Width [Inch] .394	Thickness [Inch] .394	Specimen orientation long.		Type CH+V Req.	Temp. [°F] - 51	Single [ft-lbs] 10	Average [ft-lbs] 13	Factor		
Lot No	Test type			Loc.	No.	Pipe		Single1	Single2	Single3	Average	Unit	
280238 -- 01	Standard			Rear	2	-	long.	Imp. values :	108	103	105	105	ft-lbs
	Heat treatment							Including factor:					
	normalized rolled							Shear area [%]:	100	100	100		
SHEAR AREA for information!						Lateral expansion (un-/broken):							
						Lateral expansion: [inch]							H: 0.394 [inch]

Kindberg, 13.05.2022

Page 7 of 9

No. 183512

Abnahmeprüfzeugnis wurde digital signiert und ist ohne
Originalunterschrift gültig/
Inspection certificate has been signed digitally and is
valid without an original signature

voestalpine Tubulars GmbH & Co KG
Qualitätsstelle / Quality Department

WEITZER

Abnahmebeauftragter
Authorized inspection representative
Représentant autorisé du contrôle

voestalpine

ONE CITY ONE BRAND

m. h. h.

ANTHONY CARDWELL
09/06/2022

voestalpine Tubulars GmbH & Co KG

Chemical testing

Heat analysis

C	Si	Mn	P	S	Cr	Ni	Cu	Al	Ti	Mo	V	Sn	B	N2	Nb	Ca	CEQ
Min. Req.																	
0.1000	0.2900																
Max. Req.																	
0.2300	0.4000	1.2000	0.0250	0.0150	0.3000	0.3000	0.4000		0.0400	0.1200	0.0600		0.0010		0.0200		0.4200
1022356901																	
0.1600	0.2313	1.0752	0.0128	0.0095	0.0257	0.0156	0.0187	0.0363	0.0010	0.0034	0.0020	0.0006	0.0001	0.0046	0.0010	0.0018	0.3676
1022457977																	
0.1663	0.2130	1.0913	0.0145	0.0077	0.0255	0.0139	0.0170	0.0474	0.0014	0.0022	0.0017	0.0007	0.0002	0.0052	0.0016	0.0019	0.3781

Kindberg, 13.05.2022

Page 8 of 9

No. 183512

Abnahmeprüfzeugnis wurde digital signiert und ist ohne
Originalunterschrift gültig/
Inspection certificate has been signed digitally and is
valid without an original signature

voestalpine Tubulars GmbH & Co KG
Qualitätsstelle / Quality Department
WEITZER

Abnahmebeauftragter
Authorized inspection representative
Représentant autorisé du contrôle

voestalpine

ONE STEP AHEAD

1/16/22

voestalpine Tubulars GmbH & Co KG

Chemical testing

Product analysis

C	Si	Mn	P	S	Cr	Ni	Cu	Al	Ti	Mo	V	Sn	B	N2	Nb	CEQ
Lot No. 280237 - 01 1 Standard Heat No 1022356901																
0.1828	0.2332	1.0658	0.0121	0.0111	0.0262	0.0154	0.0188	0.0349	0.0017	0.0034	0.0039	0.0013	0.0004	0.0050	0.0009	0.3692
Lot No. 280237 - 01 2 Standard Heat No 1022356901																
0.1862	0.2293	1.0657	0.0120	0.0115	0.0261	0.0155	0.0189	0.0343	0.0016	0.0034	0.0037	0.0012	0.0004	0.0055	0.0009	0.3728
Lot No. 280238 - 01 1 Standard Heat No 1022457977																
0.1854	0.1876	1.0950	0.0119	0.0066	0.0231	0.0138	0.0163	0.0453	0.0018	0.0013	0.0032	0.0012	0.0004	0.0050	0.0008	0.3755
Lot No. 280238 - 01 2 Standard Heat No 1022457977																
0.1868	0.1874	1.0950	0.0116	0.0081	0.0231	0.0139	0.0164	0.0442	0.0018	0.0019	0.0031	0.0014	0.0004	0.0055	0.0008	0.3769

Kindberg, 13.05.2022

Page 9 of 9

No. 183512

Abnahmeprüfzeugnis wurde digital signiert und ist ohne
Originalunterschrift gültig/
Inspection certificate has been signed digitally and is
valid without an original signature

voestalpine Tubulars GmbH & Co KG

Qualitätsstelle / Quality Department

WEITZER

Abnahmebeauftragter

Authorized inspection representative
Représentant autorisé du contrôle

voestalpine

ONE LIFE AHEAD

M
1/1/1

TO: ACS STEEL CO., LLC

P.O.#: 5542

S.O.#: 693382

AA PL#: 5243742

Item: 1 (1 PC) 1/2" X 120" X 480" EXISTING

TAG: 211.668/669/670/STOCK

MTR 8214

Cleveland-Cliffs Burns Harbor LLC

QUALITY ASSURANCE REPORT OF TEST AND ANALYSIS

US HWY 12 Burns Harbor, Indiana

SHIPMENT NO. 803-75047		DATE SHIPPED 06-29-21				CAR OR VEHICLE NO. CSS-CHGO-BNSF		LMIC 200059		US HWY 12 Burns Harbor, Indiana	
S O L D I E R	AMERICAN ALLOY STEEL INC PO BOX 40469 HOUSTON TX 77240-0469			S H I P T O	AMERICAN ALLOY STEEL INC C/O SKOL TRUCK #21 6350 N ERIE AVE OWASSO OK						
SERIAL NUMBER		PAY NO.	HEAT NUMBER	NO. PCS.	SIZE AND QUANTITY			YIELD POINT	TENSILE STRENGTH	AF FRACT ELONG	RED.
					THICKNESS	WIDTH OR DIA.	LENGTH	WEIGHT			

QUALITY STEEL	MELTED & MANUFACTURED IN THE U S A	INCHES	INCHES	INCHES	POUNDS	PSI	PSI	IN	4

PLATES --- ASTM A516-17 GR 70 FVQ MOD C.20 MAX KLD FINE GRAIN PRAC, ASTM A516-17 GR 65 FVQ, ASME SA516 GR 70 FVQ 2019 EDITION, ASME SA516 GR 65 FVQ 2019 EDITION, FIRST TST AS ROLLED-ADD'L TENSION PER TST PC HEAT TREATMENT --- MILL TEST PCS NORM 1650+/-25F FOR 30MIN/IN (30 MINUTES MIN), AIRCOOL --- IN ACCORDANCE WITH EN 10204:2004 TYPE 3.1 10204:2004 TYPE 3.1

NO WELD REPAIR WAS PERFORMED ON BELOW PLATE(S)

CO# 127108-OK GH 377-1790G

MERCURY IN ANY FORM HAS NOT BEEN USED IN THE PRODUCTION OF THIS ORDER

T077363	821T09120	2	1/2	120	480	16336	49700	75900	8	25
(WSE)WEST BETH.0							52700	76000	8	25

(K55)MFST REF#: 8

T077365	821T09120	2	1/2	120	480	16336	49700	75100	8	25
(M55)WEST BR4-A							53600	76000	8	25

(M55)MFST REF#:0

→ T077366	821T09150	2	1/2	120	480	16336	50300	76300	8	26
(455) (455) (455)							52600	75200	8	26

(H55)MGT RKF4:3

MATERIAL CONFORMS TO

NACE MR0175

BHN 146 TO 153

CERTIFIED BY

AMERICAN AI

BY VB DATE 9/16/21

SERIAL NUMBER	PAT NO.	HEAT NUMBER	HARD BHN	BEND	THICKNESS INCHES	TYPE	SIZE	D I R	TEST TEMP °F	CHARPY IMPACT									
										ENERGY		SPEED (M)		LAT. EXP		MILE			
										FT LBS									
										1 2 3		1 2 3		1 2 3		1 2 3			

Certified a true copy of the
original, retained in our file.

AMERICAN ALLOY STEEL

It follows

[illegible]

821T09120	.17	1.11	.016	.006	.347.218	.18	.03.004.002.002.030.0002	.002.003.002
821T09150	.17	1.05	.016	.003	.347.216	.18	.03.004.002.002.038.0002	.002.004.004

CEQ = 38

I certify that the above results are a true and correct copy of actual results contained in records maintained by Cleveland-City's Bureau of Public Health and are in full compliance with the requirements of the specifications cited above. This test report cannot be altered and must be transmitted intact with any subsequent third party test reports, if required.

SUPPLY QUALITY ASSURANCE
Form SHIP-THT-16

FARID HASSANI PER MMT

AMERICAN ALLOY
PLATE # 2248742

ANTHONY CARDWELL
09/06/2022

MTR 8737

SSAB

Test Certificate

1770 Bth Sharp Boulevard, Muncie, IN 47304-1412, US

⚠ WARNING: This product can expose you to chemicals including nickel and nickel compounds, which are known to the State of California to cause cancer. For more information go to www.P65Warnings.ca.gov

Form TC1 Revision 5, Date 22 Aug 2022

Customer: LEECO STEEL PRODUCTS, INC. 1011 WARRENVILLE ROAD SUITE 500 LISLE IL 60532	Customer P.O.No.: V28754-59346R	Mill Order No.: 41-689979-02	Shipping Manifest: MR475291
	Product Description: ASTM A516-70(17)/ASME SA516-70(21) AS-ROLLED, CEV 43% MAX. TEST COUPON NORM. 1650F MIN 25F 5 HR/INCH 5 HR MIN		Ship Date: 12 Nov 22 Cert Date: 12 Nov 22 (Page 1 of 1)
Size: 0.500 X 96.00 X 480.0 (IN)			

Tested Pieces:			Tensiles:							Charpy Impact Tests												BDWTT Tmp %Shr
Heat Id	Piece Id	Tested Thickness	Test Loc	YS (KSI)	UTS (KSI)	%RA	Elong % 2in 8in	Test Dir	Hardness	Abs. Energy(FTLB) 1 2 3 Avg				% Shear 1 2 3 Avg				Test Tmp	Test Dir	Test Size (mm)		
B2K599	A24	0.456 (DSCRT)	L 53	75			40	T														
B2K599	A24*	0.456 (DSCRT)	L 52	74			44	T														
B2K599	A25	0.456 (DSCRT)	L 51	75			38	T														
B2K599	A25*	0.456 (DSCRT)	L 54	74			37	T														

Heat																	Chemical Analysis											
Id		C	Mn	P	S	Si	Total Al	Sol Al	Cu	Ni	Cr	Mo	Cb	V	Ti	B	IIW	ORGN										
B2K599		19	1.07	0.09	0.02	25	0.30	0.29	27	0.08	1.13	0.3	0.01	0.04	0.09	0.002	42	JSA										

FILLED STEEL
MERCURY IS NOT A METALLURGICAL COMPONENT OF THE STEEL AND NO MERCURY WAS INTENTIONALLY ADDED DURING THE MANUFACTURE OF THIS PRODUCT.

KILLED STEEL, PRODUCED TO A FINE GRAIN PRACTICE
CEV (18N) = C + Mn/6 + (Cr-Mo-V)/5 = (0.11+0.07)/5

RESULTS OF TESTS PERFORMED ON NORMALIZED TEST COUPONS ARE LABELED ABOVE WITH *

FACE RESULTS 16015156-2.2015 ANNEX A2 1.2 COMPLIANT

PER EN 10204:2004 INSPECTION CERTIFICATE 3.1 COMPLIANT

100% MELTED, POURER, AND ROLLED IN THE USA

NO WELD REPAIR HAS BEEN PERFORMED ON THIS MATERIAL.

PRODUCTS SHIPPED

B2K599 A24 PCEB: 3, L25: 19000 RPS99 A25 PCEB: 4, L25: 26136

CEQ= .42

ANTHONY CARDWELL
02/02/2023

Cust Part # 050096480A516-70

WE HEREBY CERTIFY THAT THIS MATERIAL WAS
TESTED IN ACCORDANCE WITH, AND MEETS THE
REQUIREMENTS OF, THE APPROPRIATE SPECIFICATION

Brian Wales
PRINCIPAL METALLURGIST

no
iluk



An AFG Holdings Company

Material Test Report

Heat Code: CR3-KD

Forged Vessel Connections (FVC)

13770 Industrial Rd. Houston, TX 77015

ISO 9001:2015 Certified

Sales: (713) 393-4200

Industrial Piping	IPS0003	PO: TYP94135	Sales Order: 188254S	Line: 17
P. O. Box 581270		Item Code: LWN020300090A002A1	Qty Shipped: 25	
Tulsa, OK 74158		Item Desc: 2 X 300 X 9 LWN RF SA105N		
		Mill Heat: C206734		
Spec: ASTM A350 (18)/ASME SA350 (21) - LF2 CL1 & ASTM A105/A105M (21)/ASME SA105/SA105M (21)				

Element	(%wt)	Ladle	Product	EPCRA	CAS#	Element	(%wt)	Ladle	Product	EPCRA	CAS#
C	Carbon	0.17				Cr	Chromium	0.13		Y	7440-47-3
Mn	Manganese	1.13		Y	7439-96-5	Mo	Molybdenum	0.02			
Mn:C		6.6				V	Vanadium	0.03			
P	Phosphorous	0.013				Cb	Columbium	0.001			
S	Sulphur	0.004				B	Boron	0.0004			
Si	Silicon	0.24				Al	Aluminum	0.024			
Cu	Copper	0.16		Y	7440-50-8	C.E.		0.41			
Ni	Nickel	0.05		Y	7440-02-0						

Mechanical Testing		Heat Treat	
Test Lab	GOOLSBY GT:22-2403	Norm. Temp. (F)	1676
Test Bar Size	3x3x11	Norm. (Hrs)	4
HBW	156 - 156	Norm. Cooling Type	AIR
Elg (%)	36.5		
RA (%)	68		
Tensile Specimen Size (in)	.500	Country of Melt	USA
Tensile (ksi)	76.6	Country of Finish Machining	USA
Yield (ksi)	49.5	Country of Forging	USA
Gauge Length (in)	2	Gr.Sz	13.5
Charpy Orientation	LONGITUDINAL		
Charpy Temp(F)	-50		
Charpy Specimen Size (mm)	10x10		
Charpy (ft lbs)	68 - 50 - 55		
Avg Energy 3 Specimens (ft-lbs)	58		
Min Energy 1 Specimens (ft-lbs)	50		
% Shear	20 - 20 - 20		
Lat. Exp.(in)	.056 - .043 - .062		

The recording of false, fictitious, or fraudulent statement or entries on this document may be punishable as a felony under federal statute.

EPCRA Supplier Notification: This product may contain one or more toxic chemicals subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right-to-Know Act (Title III of the Superfund Amendments and Reauthorization Act of 1986) and 40 C.F.R. Part 372. Potentially reportable chemicals are indicated with a checkmark in the "EPCRA" column and a Chemical Abstract Services (CAS) registry number is provided for each such chemical in addition to the percent by weight of the chemical present in this product. It is your responsibility alone to determine whether your facility is required to submit a Toxic Release Inventory Report under EPCRA Section 313.

Certification No.: 1597370
 Certification Date: 6/29/2022
 Issued By: Maria Ramirez

This report is issued in compliance with the requirements of EN10204 3.1 / ISO 10474 3.1.b

Handwritten initials

Material Test Report

Heat Code: CR3-KD

Forged Vessel Connections (FVC)

13770 Industrial Rd. Houston, TX 77015

ISO 9001:2015 Certified

Sales: (713) 393-4200

Industrial Piping	IPS0003	PO: TYP94135	Sales Order: 188254S	Line: 17
P. O. Box 581270		Item Code: LWN020300090A002A1	Qty Shipped: 25	
Tulsa, OK 74158		Item Desc: 2 X 300 X 9 LWN RF SA105N		
		Mill Heat: C206734		
Spec: ASTM A350 (18)/ASME SA350 (21) - LF2 CL1 & ASTM A105/A105M (21)/ASME SA105/SA105M (21)				

Material is Fully Killed; Fine Grain Practice

Product compliant with NACE MR0175/ISO 15156-2:2015, Annex A (A.2.1.2, A2.1.3).
Product compliant with NACE MR0103/ISO 17945:2015, Section 13.1.1 and 13.1.3.

We hereby certify that the material represented by this document has been tested and is in conformance with the Purchase Order and Specification Requirements.

- * No Weld repair performed.
- * Ladle Chemical Analysis results are reported from the raw material suppliers MTR.
- * Tensile taken from a round specimen. Measurement of elongation after fracture.
- * Yield strength was determined using the .2% offset method, unless specified.
- * All material supplied under this order is certified to be free of mercury contamination and no mercury bearing equipment was used in manufacturing, fabrication or testing.
- * When reported on MTR: Tensile Testing Per ASTM E8; Brinell Hardness Per ASTM E10; Charpy Testing Per ASTM E23
- * AF Global manufactures materials according to a certified Quality Management System conforming to ISO 9001:2015 and PED certified to 2014/68/EU, Annex 1, Section 4.3.
- Unless otherwise noted on PO, Dimensions of all standard pipe flanges and flange fittings (NPS 1/2 to NPS 24) per ASME B16.5-2020, large diameter steel flanges (NPS 26 to 60) per ASME B16.47-2020, Orifice flanges per ASME B16.36-2020.
- * AFGlobal uses the latest edition of ASTM E29 (Standard practice for using significant digits in test data to determine conformance with specifications), to claim conformance or nonconformance to a specification. When a accept/reject determination is required AFGlobal uses a test uncertainty ratio (TUR) of 1:1 or higher as acceptable.
- * DNV-GL PED Certificate No 10000425664-PA-ACCREDIA-USA Valid thru December 03, 2023.

The recording of false, fictitious, or fraudulent statement or entries on this document may be punishable as a felony under federal statute.

EPCRA Supplier Notification: This product may contain one or more toxic chemicals subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right-to-Know Act (Title III of the Superfund Amendments and Reauthorization Act of 1986) and 40 C.F.R. Part 372. Potentially reportable chemicals are indicated with a checkmark in the "EPCRA" column and a Chemical Abstract Services (CAS) registry number is provided for each such chemical in addition to the percent by weight of the chemical present in this product. It is your responsibility alone to determine whether your facility is required to submit a Toxic Release Inventory Report under EPCRA Section 313.

Certification No.: 1597370
Certification Date: 6/29/2022
Issued By: Maria Ramirez


Dusty Bannon - Quality Analyst

This report is issued in compliance with the requirements of EN10204 3.1 / ISO 10474 3.1.b

R23-13258-9AX | 21801292 | LN: 1 | T0532984-1 | DF230RFLN9NL2 |



MATERIAL TEST REPORT

FFI-QACON-P0003

Revision: 08, 05/02/2017

Mill Test Report			
INDUSTRIAL PIPING SPECIALIST		Purchase Order:	HP405461X
PO BOX 581270		Sales Order:	167982
TULSA, OK 74158		Line Item:	3 Qty: 8

Item Code:	FF105AU010A	Material:	A/SA105N/A350 LF2 CL1
Description:	2 300# RF LONG W/N 9"		Manufactured in the U.S.A.
FID:	A7257	Heat Code:	21801292

Element	Ladle
C Carbon	0.1900
Mn Manganese	1.2200
P Phosphorous	0.0130
S Sulphur	0.0060
Si Silicon	0.2800
Cu Copper	0.0230
Ni Nickel	0.0160
Cr Chromium	0.0220

Element	Ladle
N Nitrogen	
Mo Molybdenum	0.0000
V Vanadium	0.0030
CbNb Columbium/Niobium	0.0010
Ti Titanium	
Al Aluminum	
B Boron	0.0000
Sn Tin	

Additional Chemicals			

Melting Practice	EFVR	Reduction Ratio	>3

Mechanical Test Results			
Tensile (PSI)	77,595		
Yield (PSI)	48,877		
Elong (%)	32.00		
Red (%)	75.00		
CE	0.4009		
PCM			
HBW	154	to	156
CVN Test Temperature	-50		*F
Ft/Lbs.	109	135	121
Shear (%)	60	75	70
MLE	0.60	0.80	0.70
Charpy Sample	10 X 10 X 55mm		
QTC Type & Size			

Heat Treatment Information	
Normalizing Temperature (*F)	1670
Normalizing Time (HRS)	3

Additional Comments	
MADE TO FINE GRAIN PRACTICE	

D. Maldonado

Guadalupe Maldonado - Quality Representative

10/18/2021

Date

Product is compliant with NACE MR0175/ISO 15156 / Product is compliant with NACE MR0103.
No weld repair is performed.
The product is free of Mercury contamination.
Tensile test is taken from round specimen.
Yield Strength is determined using 0.2% offset method, unless otherwise specified.
When reported on the MTR: Tensile testing per ASTM E 8, Charpy Impact testing per ASTM E 23 and Brinell Hardness Testing per ASTM E 10.
Federal Flange manufactures products according to a certified QMS conforming to ISO 9001:2015.
Products are manufactured in compliance to EN 10204 Type 2.1.

Physical Address: 4014 Pinement Dr | Houston, TX 77015

Telephone: (713) 681-0606 | Fax: (713) 681-3005

m
1/1/2024

Ameriforge

An AFG Holdings Company

Material Test Report

Heat Code: C939AN

Forged Vessel Connections (FVC)

13770 Industrial Rd. Houston, TX 77015

ISO 9001:2015 Certified

Sales: (713) 393-4200

Industrial Piping	IPS0003	PO: TP767608X	Sales Order: 189145	Line: 1
P. O. Box 581270		Item Code: LWN030600200A004A1	Qty Shipped: 1	
Tulsa, OK 74158		Item Desc: 3 X 600 X 20 LWN RF SA350-LF2-CL1		
		Mill Heat: A116181		
Spec: ASTM A350 (18) / ASME SA350 (21) Section II Part A, - LF2 CL1				

Element	(%wt)	Ladle	Product	EPCRA	CAS#	Element	(%wt)	Ladle	Product	EPCRA	CAS#
C	Carbon	0.18				V	Vanadium	0.03			
Mn	Manganese	1.16		Y	7439-96-5	Cb	Columbium	0.001			
P	Phosphorous	0.009				B	Boron	0.0005			
S	Sulphur	0.003				Ti	Titanium	0.001		Y	7440-02-0
Si	Silicon	0.25				Al	Aluminum	0.025			
Cu	Copper	0.18		Y	7440-50-8	Ca	Calcium	0.0013			
Ni	Nickel	0.06		Y	7440-02-0	C.E.		0.42			
Cr	Chromium	0.10		Y	7440-47-3	CuNiCrMoV		0.39			
Mo	Molybdenum	0.02				CrMo		0.12			

Mechanical Testing		Heat Treat	
Test Lab	AFG	Norm. Temp. (F)	1675
HBW	143 - 143	Norm. (Hrs)	5
Elg (%)	35	Norm. Cooling Type	AIR
RA (%)	70		
Tensile Specimen Size (in)	.495	Other	
Tensile (ksi)	74.5	Country of Melt	USA
Yield (ksi)	47.2	Country of Finish Machining	USA
Gauge Length (in)	2	Country of Forging	USA
Charpy Temp(F)	-50	Gr.Sz	7
Charpy (ft lbs)	79 - 74 - 88		
Avg Energy 3 Specimens (ft-lbs)	80		
Min Energy 1 Specimens (ft-lbs)	74		
% Shear	50 - 50 - 50		
Lat. Exp.(in)	.053 - .055 - .061		

The recording of false, fictitious, or fraudulent statement or entries on this document may be punishable as a felony under federal statute.

EPCRA Supplier Notification: This product may contain one or more toxic chemicals subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right-to-Know Act (Title III of the Superfund Amendments and Reauthorization Act of 1986) and 40 C.F.R. Part 372. Potentially reportable chemicals are indicated with a checkmark in the "EPCRA" column and a Chemical Abstract Services (CAS) registry number is provided for each such chemical in addition to the percent by weight of the chemical present in this product. It is your responsibility alone to determine whether your facility is required to submit a Toxic Release Inventory Report under EPCRA Section 313.

Certification No.: 1603122
 Certification Date: 8/15/2022
 Issued By: Jamie Granados

Page 1 of 2

This report is issued in compliance with the requirements of EN10204 3.1 / ISO 10474 3.1.b

ANTHONY CARDWELL
 09/19/2022

Material Test Report

Heat Code: C939AN

Forged Vessel Connections (FVC)

13770 Industrial Rd. Houston, TX 77015

ISO 9001:2015 Certified

Sales: (713) 393-4200

Industrial Piping	IPS0003	PO: TP767608X	Sales Order: 189145	Line: 1
P. O. Box 581270		Item Code: LWN030600200A004A1	Qty Shipped: 1	
Tulsa, OK 74158		Item Desc: 3 X 600 X 20 LWN RF SA350-LF2-CL1		
		Mill Heat: A116181		
Spec: ASTM A350 (18)/ASME SA350 (21) Section II Part A, - LF2 CL1				

Material is Fully Killed; Fine Grain Practice

Product compliant with NACE MR0175/ISO 15156-2:2015, Annex A (A.2.1.2, A2.1.3).

Product compliant with NACE MR0103/ISO 17945:2015, Section 13.1.1 and 13.1.3.

- * No Weld repair performed.
- * Ladle Chemical Analysis results are reported from the raw material suppliers MTR.
- * Tensile taken from a round specimen. Measurement of elongation after fracture.
- * Yield strength was determined using the .2% offset method, unless specified.
- * All material supplied under this order is certified to be free of mercury contamination and no mercury bearing equipment was used in manufacturing, fabrication or testing.
- * When reported on MTR: Tensile Testing Per ASTM E8; Brinell Hardness Per ASTM E10; Charpy Testing Per ASTM E23
- * AF Global manufactures materials according to a certified Quality Management System conforming to ISO 9001:2015 and PED certified to 2014/68/EU, Annex 1, Section 4.3.
- Unless otherwise noted on PO, Dimensions of all standard pipe flanges and flange fittings (NPS 1/2 to NPS 24) per ASME B16.5-2020, large diameter steel flanges (NPS 26 to 60) per ASME B16.47-2020, Orifice flanges per ASME B16.36-2020.
- * AFGlobal uses the latest edition of ASTM E29 (Standard practice for using significant digits in test data to determine conformance with specifications), to claim conformance or nonconformance to a specification. When a accept/reject determination is required AFGlobal uses a test uncertainty ratio (TUR) of 1:1 or higher as acceptable.
- * DNV-GL PED Certificate No 10000425664-PA-ACCREDIA-USA Valid thru December 03, 2023.

The recording of false, fictitious, or fraudulent statement or entries on this document may be punishable as a felony under federal statute.

EPCRA Supplier Notification: This product may contain one or more toxic chemicals subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right-to-Know Act (Title III of the Superfund Amendments and Reauthorization Act of 1986) and 40 C.F.R. Part 372. Potentially reportable chemicals are indicated with a checkmark in the "EPCRA" column and a Chemical Abstract Services (CAS) registry number is provided for each such chemical in addition to the percent by weight of the chemical present in this product. It is your responsibility alone to determine whether your facility is required to submit a Toxic Release Inventory Report under EPCRA Section 313.

Certification No.: 1603122
 Certification Date: 8/15/2022
 Issued By: Jamie Granados

Jamie Granados
 Jamie Granados - Met. Lab Machinist Supervisor

This report is issued in compliance with the requirements of EN10204 3.1 / ISO 10474 3.1.b

Page 2 of 2

ANTHONY CARDWELL
 09/19/2022

Ameriforge

An AFG Holdings Company

Material Test Report

Heat Code: C975AN

Forged Vessel Connections (FVC)

13770 Industrial Rd. Houston, TX 77015

Sales: (713) 393-4200

ISO 9001:2015 Certified

Industrial Piping	IPS0003	PO: TP767608X	Sales Order: 189145	Line: 1
P. O. Box 581270		Item Code: LWN030600200A004A1	Qty Shipped: 2	
Tulsa, OK 74158		Item Desc: 3 X 600 X 20 LWN RF SA350-LF2-CL1		
		Mill Heat: A131406		
Spec: ASTM A350 (18) / ASME SA350 (21) Section II Part A, - LF2 CL1				

Element	(%wt)	Ladle	Product	EPCRA	CAS#	Element	(%wt)	Ladle	Product	EPCRA	CAS#
C	Carbon	0.20				V	Vanadium	0.03			
Mn	Manganese	1.11		Y	7439-96-5	Cb	Columbium	0.00			
P	Phosphorous	0.008				B	Boron	0.00			
S	Sulphur	0.007				Ti	Titanium	0.001		Y	7440-02-0
Si	Silicon	0.25				Al	Aluminum	0.026			
Cu	Copper	0.15		Y	7440-50-8	Ca	Calcium	0.0023			
Ni	Nickel	0.06		Y	7440-02-0						
Cr	Chromium	0.08		Y	7440-47-3	CuNiCrMoV	0.35				
Mo	Molybdenum	0.03				CrMo	0.11				
CEQ = .42											

Mechanical Testing		Heat Treat	
Test Lab	AFG	Norm. Temp. (F)	1675
HBW	143 - 143	Norm. (Hrs)	6
Elg (%)	36	Norm. Cooling Type	AIR
RA (%)	69		
Tensile Specimen Size (in)	.495		Other
Tensile (ksi)	73.6	Country of Melt	USA
Yield (ksi)	40.0	Country of Finish Machining	USA
Gauge Length (in)	2	Country of Forging	USA
Charpy Temp(F)	-50	Vacuum Degassed	Y
Charpy (ft lbs)	44 - 31 - 62	Electric Furnace	Y
Avg Energy 3 Specimens (ft-lbs)	46		
Min Energy 1 Specimens (ft-lbs)	31		
% Shear	30 - 30 - 40		
Lat. Exp. (in)	.038 - .027 - .053		

The recording of false, fictitious, or fraudulent statement or entries on this document may be punishable as a felony under federal statute.

EPCRA Supplier Notification: This product may contain one or more toxic chemicals subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right-to-Know Act (Title III of the Superfund Amendments and Reauthorization Act of 1986) and 40 C.F.R. Part 372. Potentially reportable chemicals are indicated with a checkmark in the "EPCRA" column and a Chemical Abstract Services (CAS) registry number is provided for each such chemical in addition to the percent by weight of the chemical present in this product. It is your responsibility alone to determine whether your facility is required to submit a Toxic Release Inventory Report under EPCRA Section 313.

Certification No.: 1603123

Certification Date: 8/15/2022

Issued By: Jamie Granados

Page 1 of 2

This report is issued in compliance with the requirements of EN10204 3.1 / ISO 10474 3.1.b

ANTHONY CARDWELL
09/19/2022

MA
1-16-26

Material Test Report

Heat Code: C975AN

Forged Vessel Connections (FVC)

13770 Industrial Rd. Houston, TX 77015

Sales: (713) 393-4200

ISO 9001:2015 Certified

Industrial Piping	IPS0003	PO: TP767608X	Sales Order: 189145	Line: 1
P. O. Box 581270		Item Code: LWN030600200A004A1	Qty Shipped: 2	
Tulsa, OK 74158		Item Desc: 3 X 600 X 20 LWN RF SA350-LF2-CL1		
		Mill Heat: A131406		
Spec: ASTM A350 (18)/ASME SA350 (21) Section II Part A, - LF2 CL1				

Material is Fully Killed; Fine Grain Practice

Product compliant with NACE MR0175/ISO 15156-2:2015, Annex A (A.2.1.2, A2.1.3).
Product compliant with NACE MR0103/ISO 17945:2015, Section 13.1.1 and 13.1.3.

- * No Weld repair performed.
- * Ladle Chemical Analysis results are reported from the raw material suppliers MTR.
- * Tensile taken from a round specimen. Measurement of elongation after fracture.
- * Yield strength was determined using the .2% offset method, unless specified.
- * All material supplied under this order is certified to be free of mercury contamination and no mercury bearing equipment was used in manufacturing, fabrication or testing.
- * When reported on MTR: Tensile Testing Per ASTM E8; Brinell Hardness Per ASTM E10; Charpy Testing Per ASTM E23
- * AF Global manufactures materials according to a certified Quality Management System conforming to ISO 9001:2015 and PED certified to 2014/68/EU, Annex 1, Section 4.3.
- Unless otherwise noted on PO, Dimensions of all standard pipe flanges and flange fittings (NPS 1/2 to NPS 24) per ASME B16.5-2020, large diameter steel flanges (NPS 26 to 60) per ASME B16.47-2020, Orifice flanges per ASME B16.36-2020.
- * AFGlobal uses the latest edition of ASTM E29 (Standard practice for using significant digits in test data to determine conformance with specifications), to claim conformance or nonconformance to a specification. When a accept/reject determination is required AFGlobal uses a test uncertainty ratio (TUR) of 1:1 or higher as acceptable.
- * DNV-GL PED Certificate No 10000425664-PA-ACCREDIA-USA Valid thru December 03, 2023.

The recording of false, fictitious, or fraudulent statement or entries on this document may be punishable as a felony under federal statute.

EPCRA Supplier Notification: This product may contain one or more toxic chemicals subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right-to-Know Act (Title III of the Superfund Amendments and Reauthorization Act of 1986) and 40 C.F.R. Part 372. Potentially reportable chemicals are indicated with a checkmark in the "EPCRA" column and a Chemical Abstract Services (CAS) registry number is provided for each such chemical in addition to the percent by weight of the chemical present in this product. It is your responsibility alone to determine whether your facility is required to submit a Toxic Release Inventory Report under EPCRA Section 313.

Certification No.: 1603123

Certification Date: 8/15/2022

Issued By: Jaime Granados

Jaime Granados - Met. Lab Machinist Supervisor

This report is issued in compliance with the requirements of EN10204 3.1 / ISO 10474 3.1.b

Page 2 of 2

ANTHONY CARDWELL
09/19/2022

no check

Ameriforge

An AFG Holdings Company

Material Test Report

Heat Code: 284218

Forged Vessel Connections (FVC)

13770 Industrial Rd. Houston, TX 77016

Sales: (713) 393-4200

ISO 9001:2015 Certified

Industrial Piping	IPS0003	PO: TP749938	Sales Order: 187005S	Line: 39
P. O. Box 581270		Item Code: LWN020300120A002A1	Qty Shipped: 10	
Tulsa, OK 74158		Item Desc: 2 X 300 X 12 LWN RF SA105N		
		Mill Heat: 284218		
Spec: ASTM A350 (18) / ASME SA350 (21) - LF2 CL1 & ASTM A105/A105M (21) / ASME SA105/SA105M (21)				

Element	(%wt)	Ladle	Product	EPCRA	CAS#	Element	(%wt)	Ladle	Product	EPCRA	CAS#
C	Carbon	0.16				Cr	Chromium	0.13			
Mn	Manganese	1.23		Y	7439-96-5	Mo	Molybdenum	0.04		Y	7440-47-3
P	Phosphorous	0.017				V	Vanadium	0.01			
S	Sulphur	0.009				Cb	Columbium	0.014			
Si	Silicon	0.24				Al	Aluminum	0.022			
Cu	Copper	0.22		Y	7440-50-8	C.E.		0.42			
Ni	Nickel	0.15		Y	7440-02-0						

Mechanical Testing				Heat Treat			
Test Lab		SUPPLIER		Norm. Temp. (F)		1650	
HBW		158 - 169		Norm. (Hrs)		2.5	
Elg (%)		35.4		Norm. Cooling Type		AIR	
RA (%)		67.9					
Tensile Specimen Size (in)		.500			Other		
Tensile (ksi)		75.8		Country of Melt		USA	
Yield (ksi)		51.6		Country of Finish Machining		USA	
Gauge Length (in)		2		Country of Forging		USA	
Charpy Temp (F)		-50					
Charpy (ft lbs)		15 - 52 - 62					
Avg Energy 3 Specimens (ft-lbs)		43					
Min Energy 1 Specimens (ft-lbs)		15					

The recording of false, fictitious, or fraudulent statement or entries on this document may be punishable as a felony under federal statute.

EPCRA Supplier Notification: This product may contain one or more toxic chemicals subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right-to-Know Act (Title III of the Superfund Amendments and Reauthorization Act of 1986) and 40 C.F.R. Part 372. Potentially reportable chemicals are indicated with a checkmark in the "EPCRA" column and a Chemical Abstract Services (CAS) registry number is provided for each such chemical in addition to the percent by weight of the chemical present in this product. It is your responsibility alone to determine whether your facility is required to submit a Toxic Release Inventory Report under EPCRA Section 313.

Certification No.: 1595862

Certification Date: 6/20/2022

Issued By: Dusty Bannon

Page 1 of 2

This report is issued in compliance with the requirements of EN10204 3.1 / ISO 10474 3.1.b

m
vick

Material Test Report

Heat Code: 284218

Forged Vessel Connections (FVC)

13770 Industrial Rd. Houston, TX 77015

Sales: (713) 393-4200

ISO 9001:2015 Certified

Industrial Piping	IPS0003	PO: TP749938	Sales Order: 1870055	Line: 39
P. O. Box 581270		Item Code: LWN020300120A002A1	Qty Shipped: 10	
Tulsa, OK 74158		Item Desc: 2 X 300 X 12 LWN RF SA105N		
		Mill Heat: 284218		
Spec: ASTM A350 (18) / ASME SA350 (21) - LF2 CL1 & ASTM A105/A105M (21) / ASME SA105/SA105M (21)				

Material is Fully Killed; Fine Grain Practice

Product compliant with NACE MR0175/ISO 15156-2:2015, Annex A (A.2.1.2, A2.1.3).
Product compliant with NACE MR0103/ISO 17945:2015, Section 13.1.1 and 13.1.3.

We hereby certify that the material represented by this document has been tested and is in conformance with the Purchase Order and Specification Requirements.

- * No Weld repair performed.
- * Ladle Chemical Analysis results are reported from the raw material suppliers MTR.
- * Tensile taken from a round specimen. Measurement of elongation after fracture.
- * Yield strength was determined using the .2% offset method, unless specified.
- * All material supplied under this order is certified to be free of mercury contamination and no mercury bearing equipment was used in manufacturing, fabrication or testing.
- * When reported on MTR: Tensile Testing Per ASTM E8; Brinell Hardness Per ASTM E10; Charpy Testing Per ASTM E23
- * AF Global manufactures materials according to a certified Quality Management System conforming to ISO 9001:2015 and PED certified to 2014/68/EU, Annex 1, Section 4.3. Unless otherwise noted on PO, Dimensions of all standard pipe flanges and flange fittings (NPS 1/2 to NPS 24) per ASME B16.5-2020, large diameter steel flanges (NPS 26 to 60) per ASME B16.47-2020, Orifice flanges per ASME B16.36-2020.
- * AFGlobal uses the latest edition of ASTM E29 (Standard practice for using significant digits in test data to determine conformance with specifications), to claim conformance or nonconformance to a specification. When an accept/reject determination is required AFGlobal uses a test uncertainty ratio (TUR) of 1:1 or higher as acceptable.
- * DNV-GL PED Certificate No 10000425664-PA-ACCREDIA-USA Valid thru December 03, 2023.

The recording of false, fictitious, or fraudulent statement or entries on this document may be punishable as a felony under federal statute.

EPCRA Supplier Notification: This product may contain one or more toxic chemicals subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right-to-Know Act (Title III of the Superfund Amendments and Reauthorization Act of 1986) and 40 C.F.R. Part 372. Potentially reportable chemicals are indicated with a checkmark in the "EPCRA" column and a Chemical Abstract Services (CAS) registry number is provided for each such chemical in addition to the percent by weight of the chemical present in this product. It is your responsibility alone to determine whether your facility is required to submit a Toxic Release Inventory Report under EPCRA Section 313.

Certification No.: 1595862
Certification Date: 6/20/2022
Issued By: Dusty Bannon


Dusty Bannon - Quality Analyst

This report is issued in compliance with the requirements of EN10204 3.1 / ISO 10474 3.1.b

Page 2 of 2

ANTHONY CARDWELL
09/06/2022

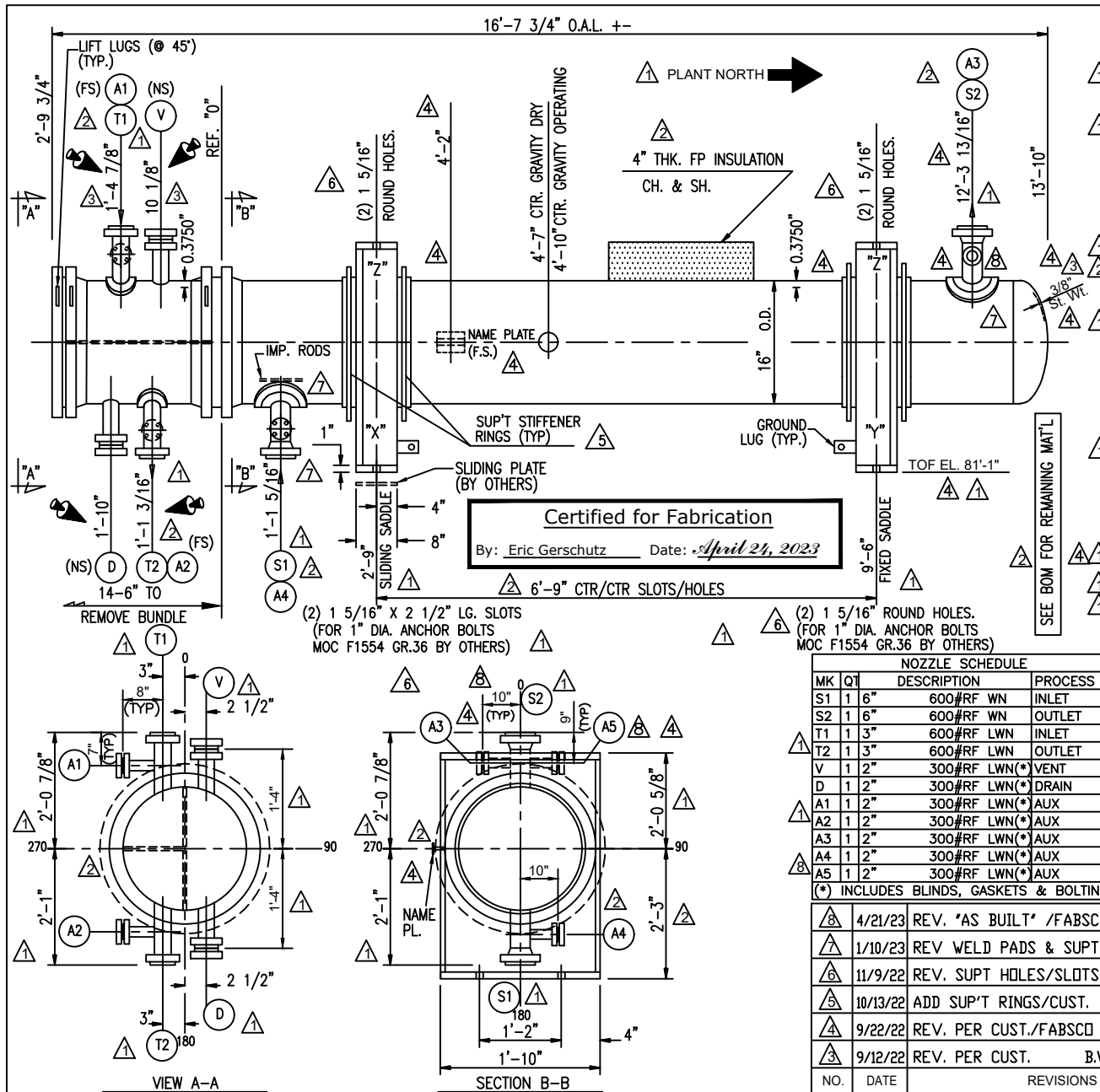
| R22-13258-9AN | | 21202122 | LN: 7 | T5151822-1 | DF230RFLN9NL2 |

Page 1 of 1

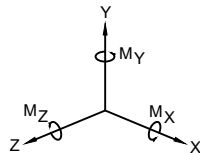
Mr. [illegible]

ANTHONY CARDWELL
10/17/2022

C

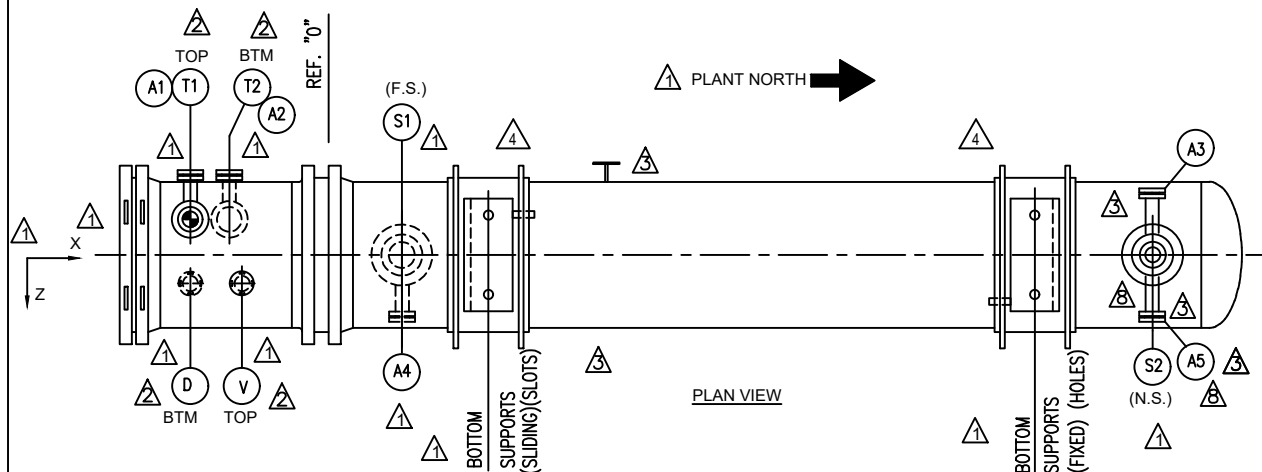
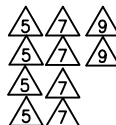


DESIGN DATA		SHELL	TUBE
DESIGN PRESSURE P.S.I.G.		375	400
M.A.W.P. P.S.I.G.		405	405
M.A.P. P.S.I.G.		485	485
LIMITED BY		TUBESHEET	TUBESHEET
VACUUM PRESSURE P.S.I.G.		15 @ 300° F.	15 @ 300° F.
TEST PRESSURE P.S.I.G.		SHOP-631/FIELD-527	SHOP-631/FIELD-527
DESIGN TEMP. Deg.F.		300	330
MDMT Deg. F.		5	32
CORROSION ALLOWANCE		1/8"	1/8"
NUMBER OF PASSES		1	4
RADIOGRAPHY		SPOT/UW-11(a)(5)(b)	SPOT/UW-11(a)(5)(b)
HEAT TREAT REQUIRED		NO	NO
ESTIMATED WEIGHTS, LBS. (PER UNIT)			
DRY: 5500 W/INSUL.: 5790 BUNDLE: 1400 WET/HYDROTEST: 6700 SHELL: 2000 CHAN.: 900			
SPECIFICATIONS			
ASME Code Section VIII, Division 1, 2021 Ed. (Stamp: Yes)			
TEMA Class R 10th Ed.; & Nat'l Bd Reg. is Req'd. API-660 9th Ed. ⚠			
Design Reviewed For Compliance With The Requirements of UG-120(d).			
Impact Test Exempt per UCS-66(a),(c),(g), Fig. UCS-66 Gen. Note (c), & UCS-67			
MATERIAL			
CHANNEL: SA-106-B		TUBESHEETS: SA-516-70N	
SHELL: SA-106-B		BAFFLES: SA-36 ⚠	
TUBES: SA-179(SMLS.)		(60) U's 3/4" O.D.X 0.083" (min.) X 13'-0" LG.	
TUBE PITCH 1" □		SURFACE 301	SQ.FT.
GENERAL NOTES			
ALL BOLT HOLES TO STRADDLE NATURAL CENTER LINES.			
INSULATION: SHELL = 4" FP; CHAN. = 4" FP (BY OTHERS)			
INSULATION SUPPORTS BY FABSCO			
FIRE PROOFING ON SADDLES IS REQ'D.			
STRESS RELIEVE U-BENDS PLUS 1'-0" OF STRAIGHT LENGTH			
SEAL WELD & EXPAND TUBES TO TUBESHEET			
SHELLSIDE FLAMMABLE & TOXIC; TUBESIDE FLAMMABLE			
THIS EXCHANGER STACKS UNDER ITEM 18-X-372A, JOB-S21-13258-9.			
SEE STACKING ARRANGEMENT ON DWG. S21-13258-10-1B.			
GASKETS: .1750" THK. 316 S.S. SPIRAL WOUND W/ GRAPHITE FILLER & 316 S.S. INNER & OUTER COMP. RINGS.			
10% SPARE BOLTING FOR BODY FLG'S.			
2 SETS OF SPARE GASKETS REQUIRED.			
PAINT: SEE DWG. -1A. ⚠			
PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT			
EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC			
SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER			
LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA			
PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER			
ITEM NO.: 18-X-372B			
AIR PRODUCTS P.O. NO.:4505600057 / A8KM-4-402-PO-2			
AP PROJECT NO: EN-20-7120			
VDR CODE NO.: HCO9			
SERIAL NO.: S21-13258-10			
ENGINEER: EG			
CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT			
AS/DD		ASSEMBLY AND SPECIFICATIONS FOR ONE ⚠ 15.25-156 A E U	
/CUST DD/DG			
/CUST DD/DG			
DD/DG			
B.W./DD			
N./DD			
DWN. BY EMG		Fabsco SHELL & TUBE, LLC	
DATE 12-31-21			
CKD. BY DiCarlo			
DWG.NO.		S21-13258-10-1	
		REV. 8	



NOZZLE LOADS

MK.	M _X LBF-FT	M _Y LBF-FT	M _Z LBF-FT	F _X LBF	F _Y LBF	F _Z LBF	LOAD BASES
S1	4005	6465	5070	2625	2100	2625	6"-300#; 1.5 x API-660
S2	4005	6465	5070	2625	2100	2625	6"-300#; 1.5 x API-660
T1	1900	2420	1500	1860	1480	1860	3"-300#; 2 x API-660
T2	1900	2420	1500	1860	1480	1860	3"-300#; 2 x API-660



PLAN VIEW

VESSEL DESIGN SEISMIC BASE SHEAR (ASD)

EMPTY CONDITION :	5978 LBS.
OPERATING CONDITION :	7330 LBS.



CHANNEL COVER TO CHANNEL FLANGE BOLTING INFO

STUD DIAMETER: 7/8" O.D.
NUMBER STUDS: (28)
STUD MATERIAL: SA-193-B7
BOLT TORQUE RANGE TO BE ACHIEVED: 373.7-378.7 FT. LBS.



CHAN. FLG./T'SHT./SHELL FLG. BOLTING INFO

STUD DIAMETER: 7/8" O.D.
NUMBER STUDS: (28)
STUD MATERIAL: SA-193-B7
BOLT TORQUE RANGE TO BE ACHIEVED: 373.7-378.7 FT. LBS.



DESIGN DATA	SHELL	TUBE
OPERATING PRESSURE PSIG	280	305
OPERATING TEMP. °F.	IN: 110.70 OUT: 157.45	IN: 247.40 OUT: 145
HYDROTEST TEMP. °F.	-----	-----
JOINT EFF.	1	1
FLUID NAME	STRIPPER FEED	DEBUTANIZED NAPHTHA
FLUID DENSITY lb/ft ³	IN: 34.28 OUT: 32.01	IN: 33.27 OUT: 37.45
LETHAL SERVICE	NO	NO
DESIGN DUTY Btu/hr	1613172.5/SHELL	
WIND CODE	ASCE 7-16 WIND SPEED: 101 MPH IMP. FACTOR: 1	
SEISMIC CODE	ASCE 7-16 IMP. FACTOR: 1.5 Fa: 1 Fv: 1.721	
	Ss: 1.616 Si: 0.579 Site Class: D Sd i 0.996	

PAINT: (PAINT SYSTEM 6)
SOLVENT CLEAN PER SSPC-SP10
SANDBLAST PER SSPC-SP10 (1.5-2.5 MILS ANCHOR PROFILE)
PRIMER: ONE COAT SHERWIN WILLIAMS PHENICON HS (8.0-10.0 MILS DFT) (COLOR: MILLWHITE)
FINISH :ONE COAT SHERWIN WILLIAMS PHENICON HS (8.0-10.0 MILS DFT) (COLOR: LIGHT GRAY RAL #7035)

SUPPORTS ONLY: (PAINT SYSTEM 4B)
ONE COAT SHERWIN WILLIAMS INTERNATIONAL INTERGARD 269 (1.0-2.0 MILS DFT)

APPLICABLE SPECIFICATIONS :

3-11-10, 4-11-11, 4WEQ-1051, 4WGN-10001, 4WPI-670210, A8KM-PP-000-40002-A, A8KM-PP-000-50720-A, A8KM-PP-000-200001-A, A8KM-PP-000-500005-A, A8KM-PP-000-500510-A, A8KM-PP-000-500512-A, A8KM-PP-000-500520-A, A8KM-PP-000-500550-A, FORM 8232, SPEC-ENG-DOC001, SPEC-ENG-DOC002, SPEC-ENG-MQ042, SPEC-ENG-MQ057, SPEC-MED-DOC001

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
ITEM NO.: 18-X-372B
AIR PRODUCTS P.O. NO.: 4505600057 / A8KM-4-402-PO-2
AP PROJECT NO: EN-20-7120
VDR CODE NO.: HC09
SERIAL NO.: S21-13258-10
ENGINEER: EG
CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

SUPPLEMENTAL INFORMATION

ONE 15.25-156 A E U

DWN. BY

B.W.

DATE

5/26/22

CKD. BY

DiCarlo

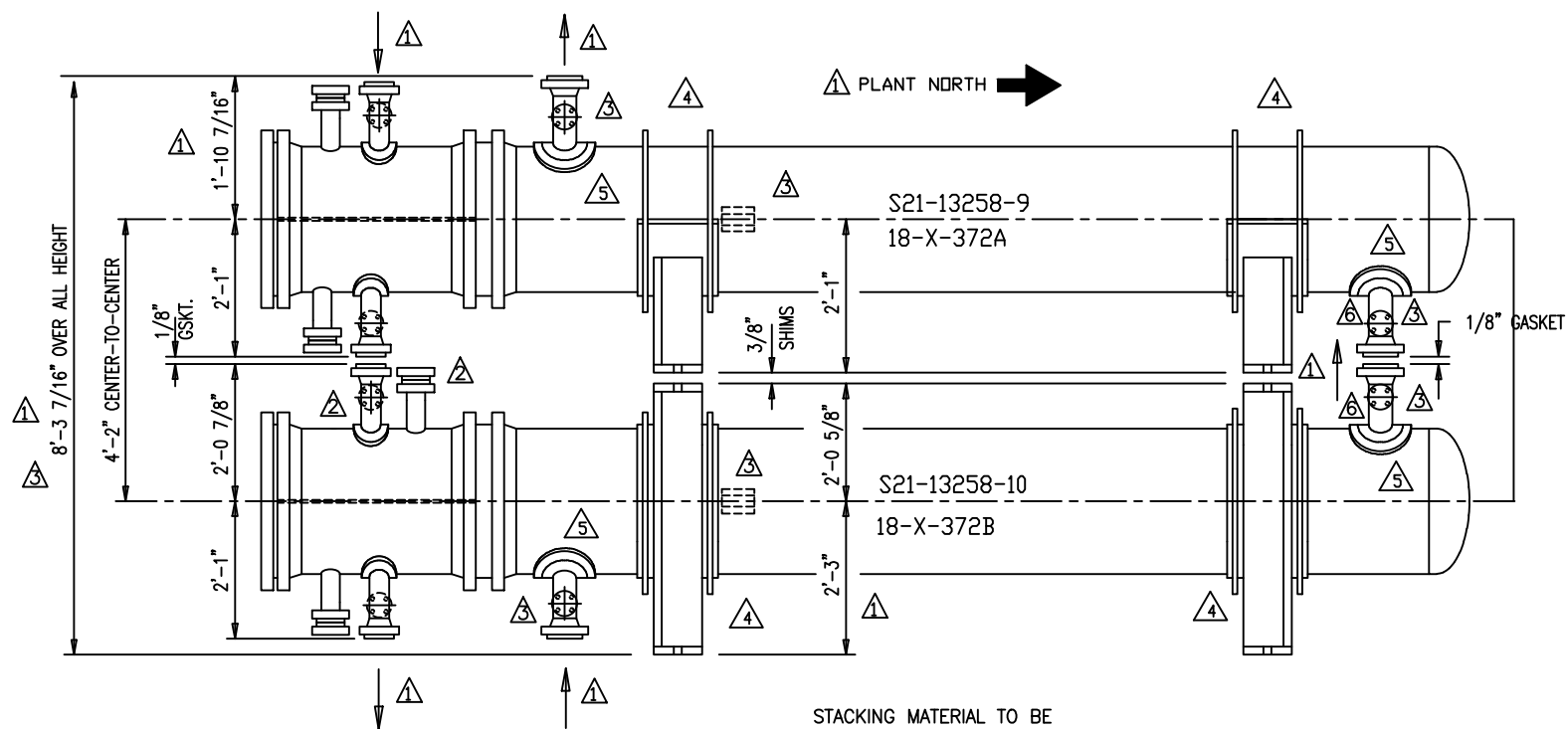
DWG.NO.

S21-13258-10-1A

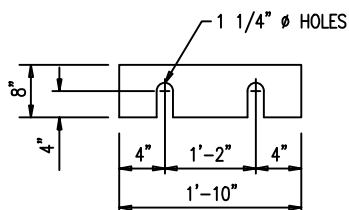
REV.

9

NO.	DATE	REVISIONS
9	6/6/23	REV. PER CUST. COMMENTS DD/DG
8	4/21/23	REV. 'AS BUILT' / FABSCD AS/DD
7	3/9/23	REV. PER CUST. COMMENTS DD/DG
6	1/10/23	REV. PER CUST. COMMENTS. DD/DG
5	11/9/22	REV. PER CUST. COMMENTS. DD/DG
4	10/13/22	REV. PER CUST. COMMENTS. DD/DG
3	9/22/22	REV. PER CUST. B.W./DD
2	9/12/22	REV. PER CUST. B.W./DD



STACKING MATERIAL TO BE
SUPPLIED BY FABSCO
(STUDS, NUTS, GASKETS, SHIMS)



STACKING SHIM DETAIL

(2) REQ'D. 1/4" THK.

(2) REQ'D. 10 Ga THK.

126

127

NOTE: TACK WELD SHIMS TO UPPER SUPPORTS ON
BOTTOM EXCHANGER PRIOR TO SHIPMENT.



WEIGHTS:
STACK W/ INSUL. - 11,580 LBS
OPERATING - 13,400 LBS

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
ITEM NO.: 18-X-372 A/B
AIR PRODUCTS P.O. NO.: 4505600057 / A8KM-4-402-PO-2
AP PROJECT NO.: EN-20-7120
VDR CODE NO.: BEO4
SERIAL NO.: S21-13258-9/10
ENGINEER: EG
CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

	4/21/23	REV. "AS BUILT" / FABSCO	AS/DD	STACKING ARRANGEMENT					
	1/10/23	REV. WELD PADS/CUST.	DD/DG						
	10/13/22	ADD SUP'T RINGS/CUST.	DD/DG	DWN. BY AS	Fabsco SHELL & TUBE, LLC				
	9/26/22	REV. PER CUST.	B.W./DD						
	9/12/22	REV. PER CUST.	B.W./DD	DATE 1/11/22					
	8/1/22	REV./CUST. COMMENTS	GD/DD	CKD. BY DiCarlo				DWG.NO. S21-13258-10-1B	REV 6
NO.	DATE	REVISIONS							

Fabscos
SHELL & TUBE, LLC

-----API-660-----

- 1) STENCIL THE FOLLOWING ON THE EXCHANGER IN
3" HIGH (MIN.) WHITE BLOCK LETTERS::
- P.O. NO.: 4505600057
- ITEM NO.: 18-X-372B
- SHIPPING WT.: 5,500#
- 2) STUDS, NUTS AND THREADED SURFACES SHALL BE COATED WITH MARKAL E-Z- BREAK COMPOUND BEFORE ASSEMBLY.
- 3) HYDRO TEST PRESSURE SHALL BE HELD FOR A MINIMUM OF ONE HOUR.
- 4) PLUG SHELL PORT INSIDE DIAMETER WITH A METAL TEMPLATE CONSISTING OF TWO DISCS (EACH HAVING A DIAMETER EQUAL TO THE DIAMETER OF THE BAFFLES) RIGIDLY MOUNTED PERPENDICULAR TO A SHAFT, AND SPACED 12" APART.
- 5) AT LEAST ONE SPOT RADIOGRAPH SHALL BE MADE OF EACH CIRCUMFERENTIAL AND LONGITUDINAL JOINT. SPOT RADIOGRAPHS SHALL INCLUDE EACH START, STOP AND BURN-THROUGH OF WELDS MADE BY THE AUTOMATIC SUBMERGED ARC PROCESS.
- 6) SPOT RADIOGRAPHS SHALL BE AT LEAST 10" LONG, OR SHALL BE FULL LENGTH WHERE WELDS ARE LESS THAN 10 INCHES LONG.
- 7) THE FLATNESS TOLERANCE (MAXIMUM DEVIATION FROM A PLANE) ON PERIPHERAL GASKET CONTACT SURFACES SHALL BE $\pm 1/32"$. USE OF A STRAIGHT EDGE TO DETERMINE FLATNESS TOLERANCE IS ACCEPTABLE.
- 8) FLATNESS OF GASKET SURFACES SHALL BE MEASURED WITH A DIAL INDICATOR. PASS PLATE GROOVES CAN BE MEASURED WITH A STRAIGHT EDGE.

-----API-660 CONT.-----

- 9) WELD METAL AND HAZ. HARDNESS EXAMINATION REQUIREMENTS ARE AS FOLLOWS (AFTER PWHT, IF REQUIRED):
 - 225 BHN, MAXIMUM.
 - A 10mm BALL IS REQUIRED FOR TESTING.
 - TEST ONE LONGITUDINAL AND ONE CIRCUMFERENTIAL WELD AND EACH CONNECTION TO COMPONENT WELD OF NOZZLES 2" NPT AND LARGER.
 - IF MORE THAN ONE WELDING PROCEDURE IS USED TO PERFORM LONGITUDINAL OR CIRCUMFERENTIAL WELDS, HARDNESS READINGS SHALL BE MADE OF THE WELDS DEPOSITED BY EACH PROCEDURE.
 - HARDNESS READINGS AND LOCATIONS SHALL BE RECORDED.
 - TESTING TO BE DONE ON INSIDE SURFACE IF ACCESSIBLE.
- 10) COAT EXPOSED MACHINED SURFACES WITH AN EASILY REMOVABLE RUST PREVENTATIVE.
- 11) NOTIFY CUSTOMER FIVE (5) DAYS PRIOR TO START OF FABRICATION, WITNESS OR HOLD POINTS.
- 12) MATCH MARKS SHALL BE PROVIDED TO ENSURE PROPER ALIGNMENT OF BOLTED JOINTS.
- 13) STAMP THE SERIAL No. ON O.D. OF TUBESHEETS, FLANGES AND CHANNEL COVERS.
- 14) HYDRO TEST CHARTS REQUIRED.
- 15) NOZZLE WELD PADS & SUPT PADS SHALL BE AIR & SOAP TESTED W/15 PSI (MIN), 25 PSI (MAX) AIR PRESSURE.
- 16) SHELLSIDE HYDRO TEST SHALL BE PERFORMED WITH CHANNEL COVER REMOVED.
- 17) TUBE WALL REDUCTION SHALL BE 8% MAXIMUM.

-----STANDARD SHOP PRACTICES-----

- 1) ALL BOLT HOLES SHALL STRADDLE NATURAL CENTERLINES.
- 2) GRIND INSIDE WELDS FLUSH WITH SHELL.
- 3) GRIND INSIDE WELDS SMOOTH WITH CHANNELS.
- 4) RADIUS ALL NOZZLES 1/8" INSIDE AT CYLINDER I.D.
- 5) SEAL WELD SUPPORT SADDLES WITH 1/4"(MIN) FILLET WELD.
- 6) EXCHANGER SHALL BE CLEANED INSIDE AND OUTSIDE OF WELD SPATTER, DIRT, WELD ROD AND OTHER DEBRIS.
- 7) FOR MDMT OF +30° F. (MINIMUM), HYDRO TEST WATER TEMPERATURE SHALL NOT TO BE LESS THAN 40°F.
- 8) ALL EXTERNAL ATTACHMENTS TO BE SEAL WELDED.
- 9) HYDROSTATIC TEST, USE CLEAN WATER WITH A CORROSION INHIBITOR ADDED.
VOLUME OF WATER SHELLSIDE = 100 GALLONS (APPROXIMATELY)
VOLUME OF WATER TUBESIDE = 50 GALLONS (APPROXIMATELY)
- 10) ALL LIFTING DEVICE ATTACHMENT WELDS SHALL BE EXAMINED BY THE PT METHOD.
- 11) INSTALL SHIPPING COVERS ON ALL NOZZLES.
- 12) ALL SEAL WELDED EXTERNAL NON PRESSURE ATTACHMENTS REQUIRE A 1/4" NPT VENT HOLE.
- 13) AFTER THE HYDRO TEST, THE HEAT EXCHANGER SHALL BE COMPLETELY DRAINED AND THOROUGHLY DRIED.

-----NDT REQUIREMENTS-----

- 1) SHELL: SPOT/UW-11(a)(5)(b) RADIOGRAPH.
- 2) CHANNELS: SPOT/UW-11(a)(5)(b) RADIOGRAPH.

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
ITEM NO.: 18-X-372B
AIR PRODUCTS P.O. NO.: 4505600057 / ABKM-4-402-PO-2
AP PROJECT NO: EN-20-7120
VDR CODE NO.: BE04
SERIAL NO.: S21-13258-10
ENGINEER: EG
CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

				JOB NOTES			
				DWN. BY GO	Fabsco SHELL & TUBE, LLC		
				DATE 8/1/22			
				CKD. BY DiCarlo		DWG. NO. S21-13258-10-1C	REV. 1
A	8/1/2022	ADDED DWG/FABSCO	GQ/DD				
NO.	DATE	REVISIONS					

-----CUST. NOTES CONT.-----

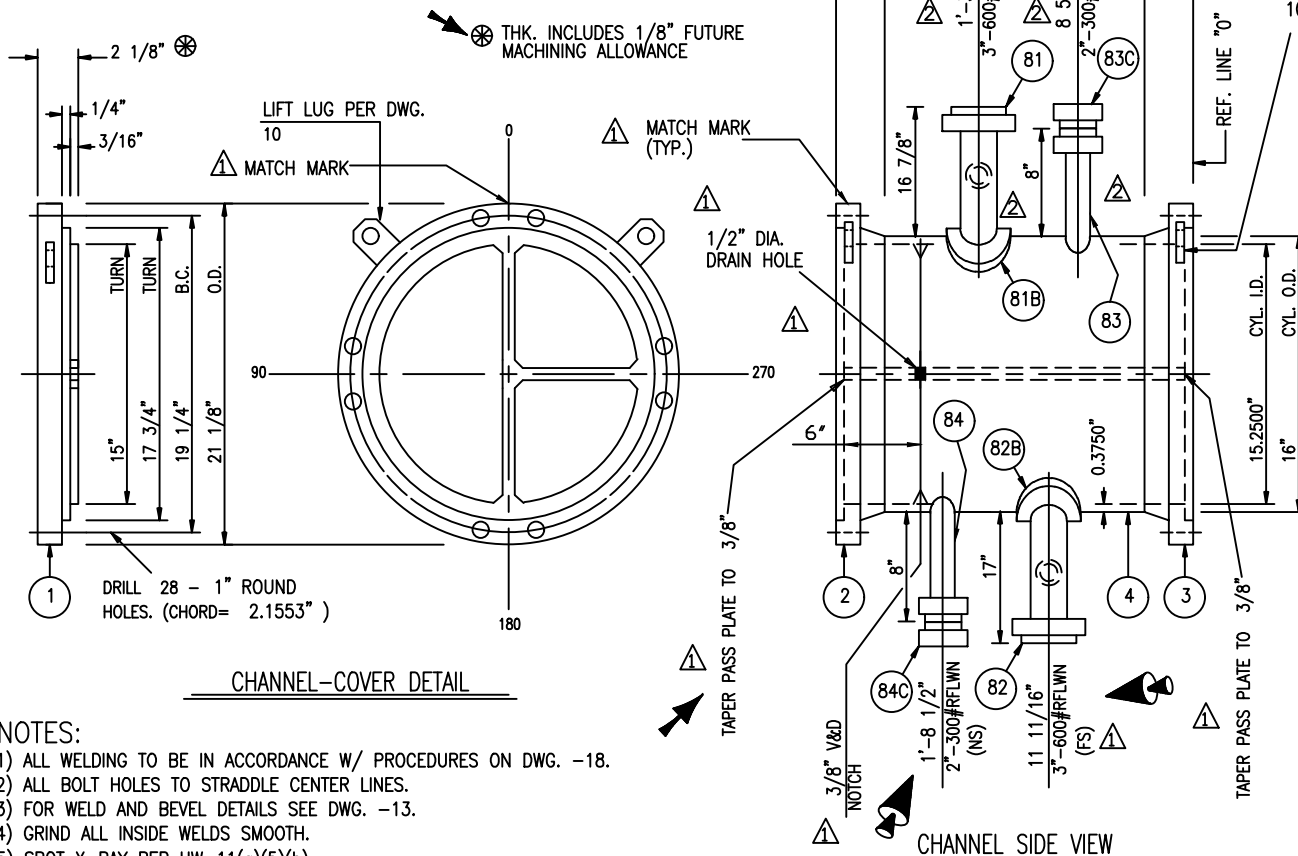
- 13) FINISHED EXCHANGER IS TO BE WEIGHTED.
TO BE WITHIN +/- 2% OR BETTER ACCURACY.
A CALIBRATED WEIGHT CERTIFICATE SHALL BE PROVIDED.
- 14) THE TEMPERATURE OF THE HYDRO TEST WATER & THE
EXCHANGER SHALL BE EQUALIZED PRIOR TO HYDROTEST.
- 15) STAMPING TO BE DONE WITH "LOW STRESS" STAMPS.
- 16) LIFTING POINTS & CENTER OF GRAVITY SHALL BE
MARKED ON EXCHANGER.
- 17) THE ENTIRE SURFACE OF FORGINGS INCLUDING WELD
BEVEL SHALL BE EXAMINED BY MT AFTER FINISH
MACHINING & PRIOR TO WELDING.
- 18) EXCHANGER SHALL BE IN A MANNER WHICH KEEPS
NOZZLES FROM TOUCHING THE TRUCK BEDS AND/OR
SURFACES AT OFF-LOADING AREA AT JOBSITE.
- 19) PRIOR TO WELDING, JOINTS SHALL BE VISUALLY
INSPECTED FOR CLEANLINESS, CONDITION OF TACK
WELDS IF PRESENT, PREHEAT IF SPECIFIED, AND
FILLER METAL TO BE USED.
- 20) REQUIRED PREHEAT TEMPERATURE SHALL ALSO
APPLY TO THERMAL CUTTING AND TACK WELDING.
- 21) PREHEAT ALL JOINT TO A MINIMUM OF 125° F. WHEN
MOISTURE REMOVAL IS REQUIRED.
- 22) RADIOGRAPH OF WELDS IN PIPE EQ/OR SMALLER THAN
3" NPS, MAY BE DONE BY THE ELLIPTICAL PROJECTION
TECHNIQUE. AT LEAST TWO SEPARATE EXPOSURES
ARE REQ'D. AT 90° APART.
- 23) FOR SET ON NOZZLES THE BASE METAL ADJACENT TO
AUX. NOZZLE OPENINGS ON THE MAIN NOZZLES
SHALL BE THOROUGHLY U.T. & M.P.E. TO ENSURE
THERE ARE NO FLAWS. (ETC LAMINATION).
- 24) WELDS FROM EACH WELD PROCEDURE,
WELDER/WELDING OPERATOR SHALL BE
SPOT RADIOGRAPHED IF ACCESSIBLE.
- 25) NON PRESSURE PARTS TO PRESSURE CONTAINING
COMPONENT WELDS SHALL BE 100% M.P.E. OR D.P.E.

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
ITEM NO.: 18-X-372B
AIR PRODUCTS P.O. NO.: 4505600057 / A8KM-4-402-PO-2
AP PROJECT NO: EN-20-7120
VDR CODE NO.: BE04
SERIAL NO.: S21-13258-10
ENGINEER: SD
CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

			JOB NOTES (CONT.)			
			DWN. BY G.O.		Fabsco SHELL & TUBE, LLC	
			DATE 8/1/22			
△	8/1/22	ADDED DWG./FABSCD G.O./DD	CKD. BY DiCarlo		DWG. NO. S21-13258-10-1D	REV. 1
NO.	DATE	REVISIONS				

COVER NOTES:

- 1) MACHINE ALL COVER SURFACES TO 250 RMS EXCEPT GASKET FACES TO BE 125 RMS.
- 2) ALL COVER PASS PLATE GROOVE WIDTHS TO BE 5/8" WIDE.
- 3) ALL COVER PASS PLATE GROOVE JUNCTIONS TO BE NOTCHED 3/8" AT 45 Deg.



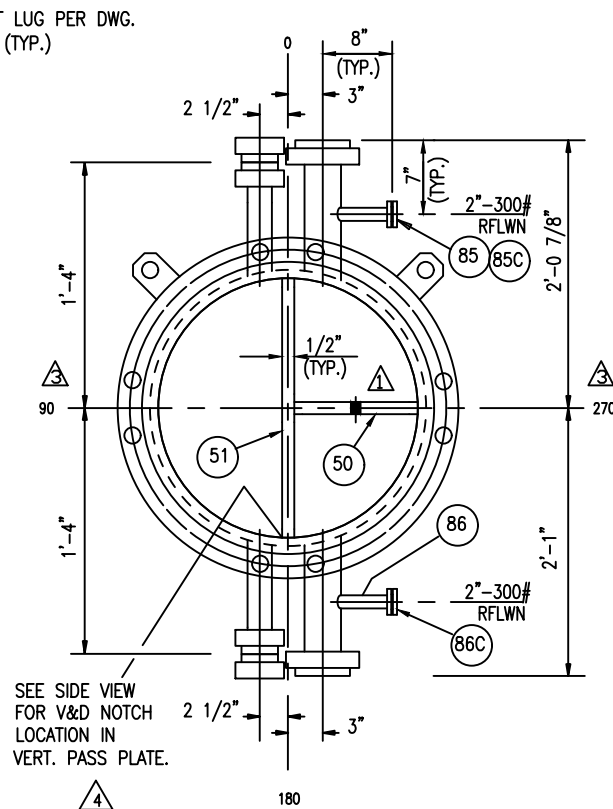
CHANNEL-COVER DETAIL

NOTES:

- 1) ALL WELDING TO BE IN ACCORDANCE W/ PROCEDURES ON DWG. -18.
- 2) ALL BOLT HOLES TO STRADDLE CENTER LINES.
- 3) FOR WELD AND BEVEL DETAILS SEE DWG. -13.
- 4) GRIND ALL INSIDE WELDS SMOOTH.
- 5) SPOT X-RAY PER UW-11(a)(5)(b)

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
 EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
 SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
 LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
 PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
 ITEM NO.: 18-X-372B
 AIR PRODUCTS P.O. NO: 4505600057 / A8KM-4-402-PO-2
 AP PROJECT NO: EN-20-7120
 VDR CODE NO.: BE04
 SERIAL NO.: S21-13258-10
 ENGINEER: EG
 CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

* MACHINE GASKET FACING TO 125 RMS AFTER ALL WELDING.
 FOR FLANGE DETAILS SEE DWG. 12



CHANNEL END VIEW

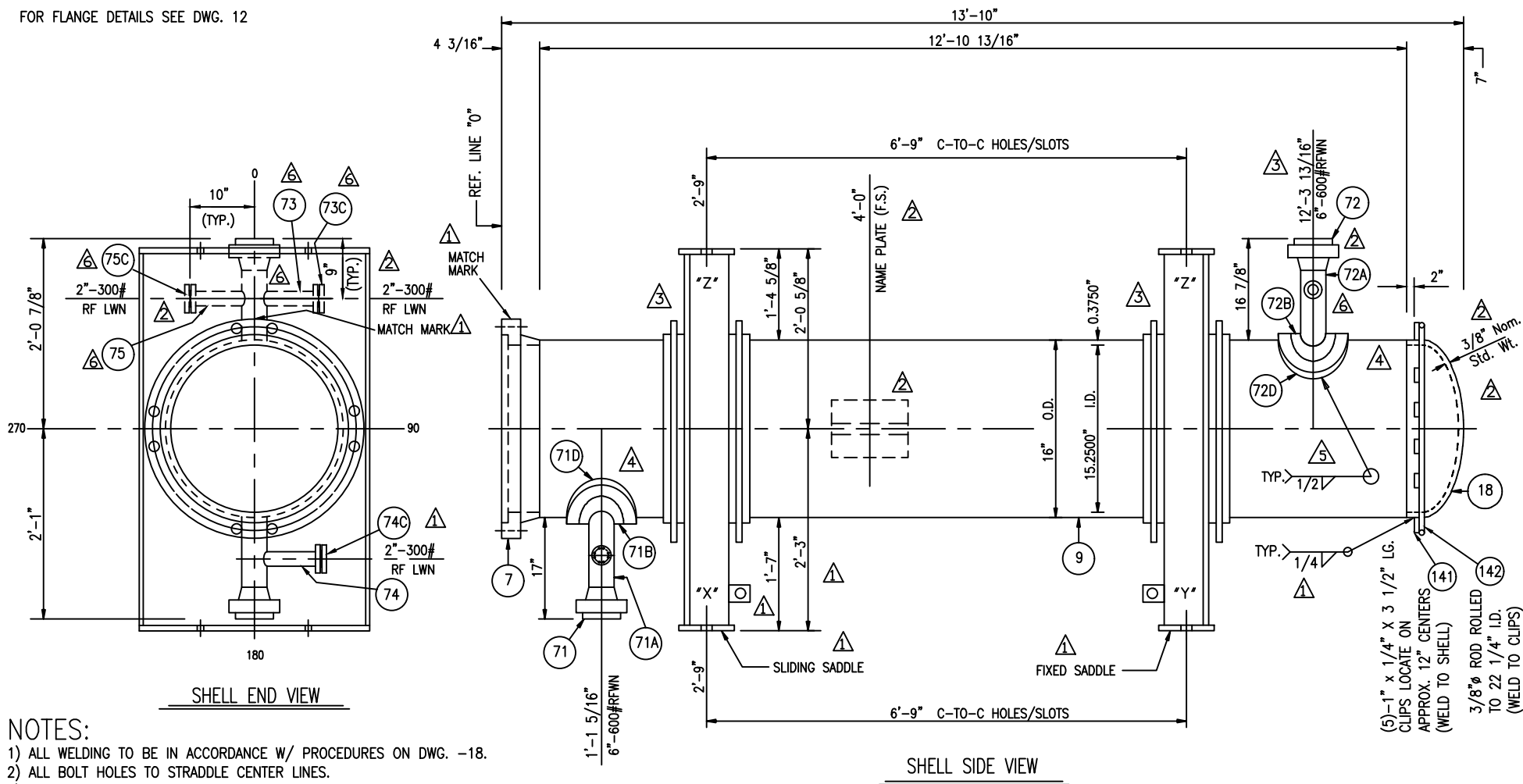
CHANNEL SIDE VIEW

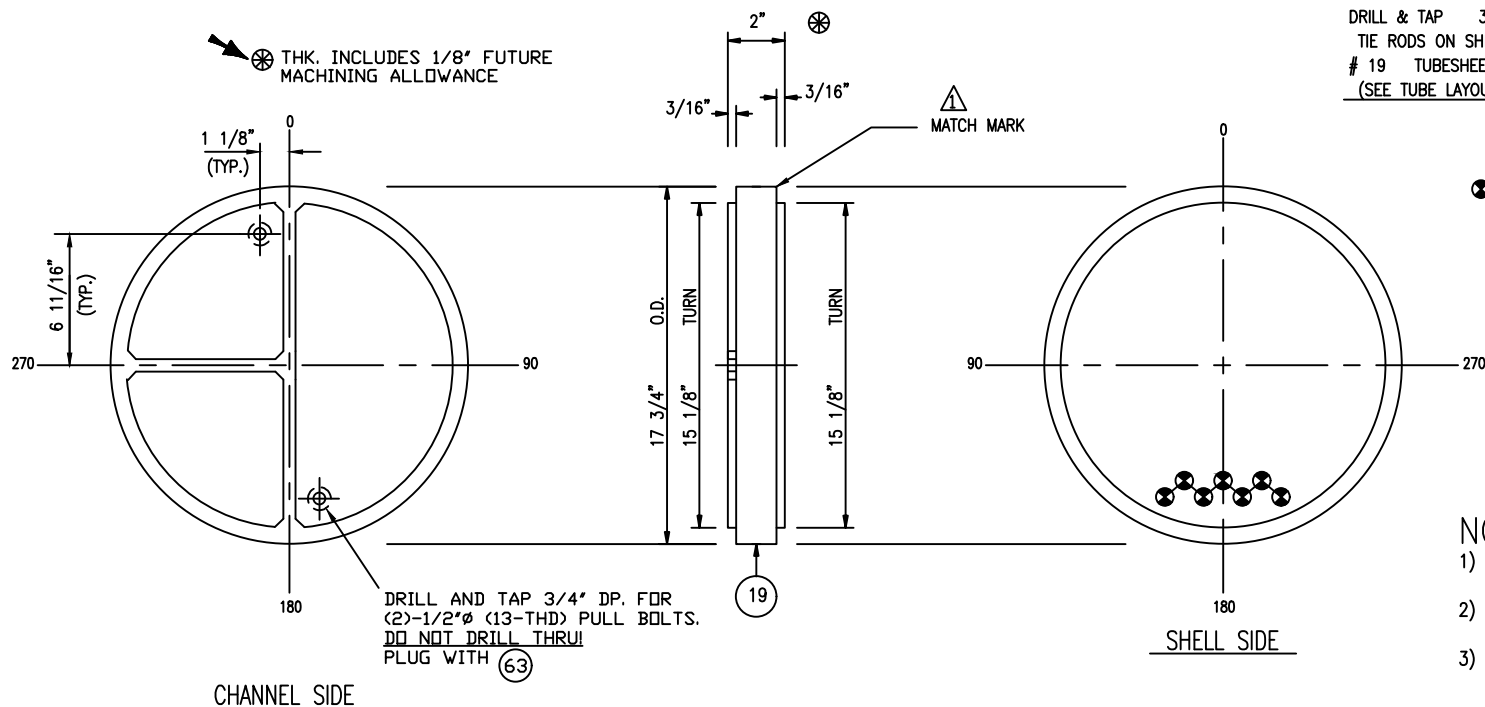
FRONT CHANNEL DETAILS

NO.	DATE	REVISIONS	DWN. BY B.W.	DATE 5/25/22	CKD. BY DiCarlo	DWG. NO. S21-13258-10-2	REV. 4
△	11/9/22	ADDED NOTE/CUST. DD/DG					
△	9/15/22	REV. PER FABSCO B.W./DD					
△	9/12/22	REV. PER CUST. B.W./DD					
△	8/1/2022	REV./CUST. COMMENTS GD/DD					

Fabsco
 SHELL & TUBE, LLC

FOR FLANGE DETAILS SEE DWG. 12



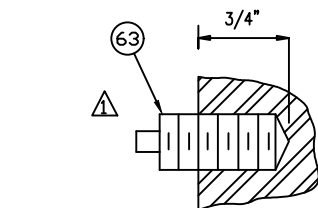


DRILL & TAP 3/4" DEEP FOR 8- 1/2" DIA. (13 THD)
TIE RODS ON SHELL SIDE OF
19 TUBESHEET. DO NOT DRILL THRU!!
(SEE TUBE LAYOUT FOR LOCATIONS.)

⊗ DRILL <7> 13/16" Ø HOLES
X 1/8" DEEP FOR IMP. RODS
IN SHELLSIDE ONLY.
SEE DWG. -5 FOR LOCATION.
DO NOT DRILL THRU!!

NOTES:

- 1) MACHINE ALL SURFACES TO 250 RMS
EXCEPT GASKET FACES TO BE 125 RMS.
- 2) ALL PASS PLATE GROOVE WIDTHS TO
BE 1/2" WIDE.
- 3) ALL PASS PLATE GROOVE JUNCTIONS
TO BE NOTCHED 3/8" AT 45 Deg.

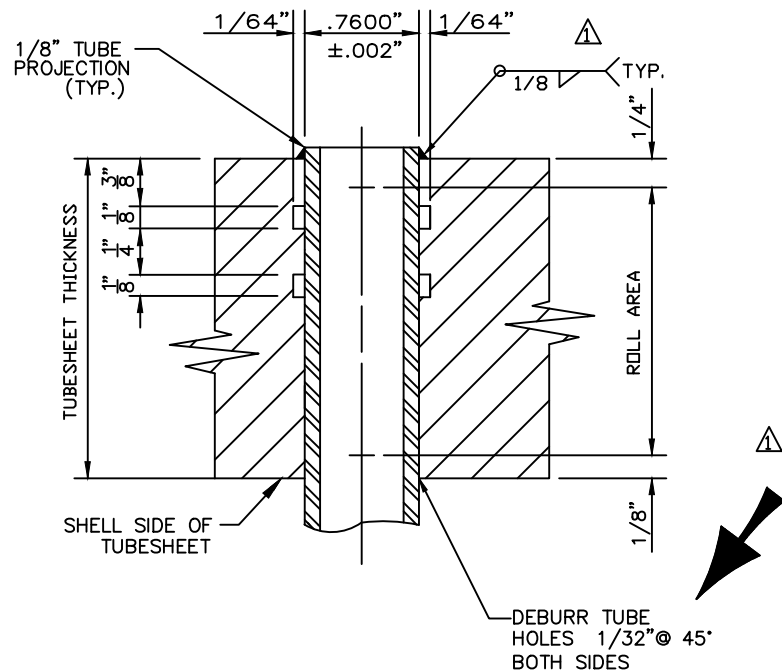


Ⓢ PULLBOLT SQUARE HEAD PLUG DETAIL
(EYE BOLT REQUIRED, TO SHIP LOOSE W/ EXCHANGER)

SEE DWG. -4A FOR SEAL WELD
& TUBE HOLE GROOVING DETAIL

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
ITEM NO.: 18-X-372B
AIR PRODUCTS P.O. NO.: 4505600057 / A8KM-4-402-PO-2
AP PROJECT NO.: EN-20-7120
VDR CODE NO.: BE04
SERIAL NO.: S21-13258-10
ENGINEER: EG
CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

			TUBESHEET DETAILS			
			DWN. BY B.W.	Fabsco SHELL & TUBE, LLC		
			DATE 5/26/22			
			CKD. BY DiCarlo			
△	8/1/2022	REV./CUST. COMMENTS	GO/DD	DWG.NO.	S21-13258-10-4	REV. 1
NO.	DATE	REVISIONS				

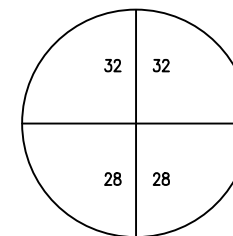
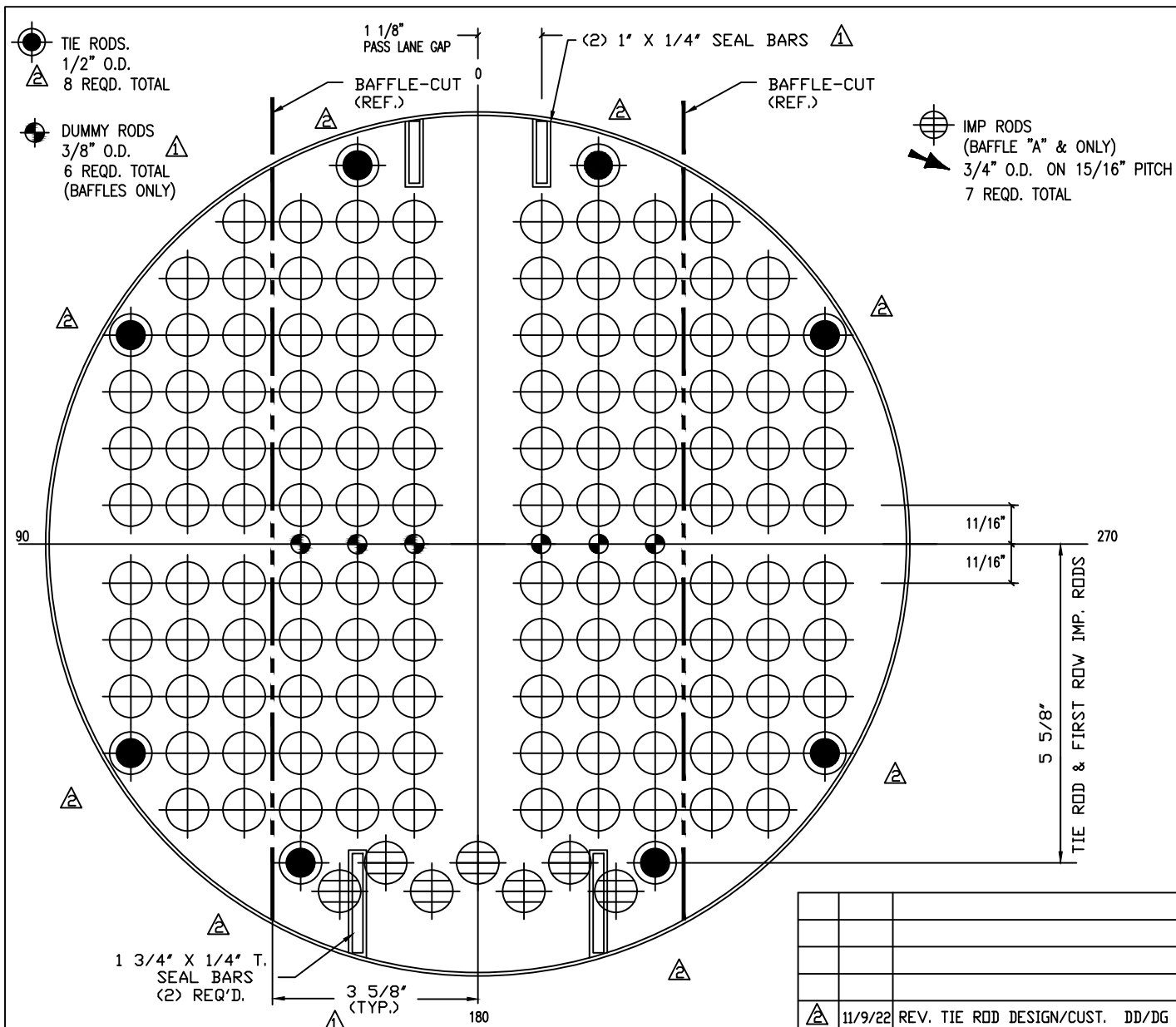


TUBE TO TUBESHEET SEAL WELD AND FABRICATION SEQUENCE

1. DRILL, REAM AND RING GROOVE TUBE HOLES PER DETAIL ABOVE.
2. CLEAN AREAS TO BE WELDED AND ROLLED WITH DEGREASER.
3. INSTALL TUBES IN BUNDLE AND SET PROJECTIONS.
4. FUSION WELD USING GTAW PROCESS USING WPS: T-266.
5. LIQUID PENETRANT EXAMINE ALL WELDS AND THEN CLEAN THEM WITH DEGREASER. REPAIR ANY DEFECTIVE WELDS AND RECHECK.
6. TUBE-TO-T'SHT. WELDS SHALL BE AIR & SOAP TESTED PRIOR TO FINAL ROLLING W/ 15 PSI (MAX.) AIR PRESSURE.
7. ROLL TUBES INTO TUBESHEET PER DETAIL ABOVE.
8. REPEAT STEP 5.
9. TUBE WALL REDUCTION TO BE 8% (MAX.)

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
ITEM NO.: 18-X-372B
AIR PRODUCTS P.O. NO.: 4505600057 / A8KM-4-402-PD-2
AP PROJECT NO.: EN-20-7120
VDR CODE NO.: BE04
SERIAL NO.: S21-13258-10
ENGINEER: EG
CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

			TUBE SEAL WELD & TUBE HOLE GROOVING DETAIL		
			DWN. BY	Fabsco SHELL & TUBE, LLC	
			B.W.		
			DATE		
			5/26/22		
			CKD. BY	DWG. NO.	REV.
			DiCarlo	S21-13258-10-4A	1
NO.	DATE	REV./CUST. COMMENTS	GO/DD		
		REVISIONS			



TUBE DISTRIBUTION

NOTES:

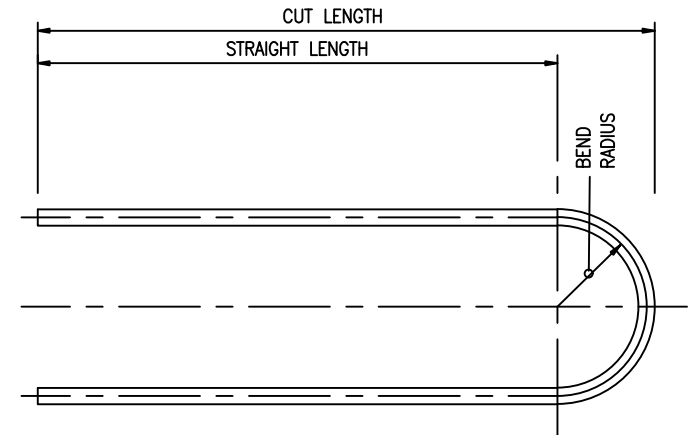
- 1) DRILL AND REAM TUBE HOLES IN TUBESHEETS TO 0.7600" $\pm$ 0.0020" DIA. FOR 60 - 3/4" O.D. U-TUBES. TOTAL HOLES = 120
- 2) TUBE PITCH = 1" SQUARE.
- 3) NUMBER OF PASSES = 4
- 4) SEE DRAWING 4 FOR TUBE GROOVING DETAILS.
- 5) BAFFLE O.D. = 15 1/8"
- 6) O.T.L. = 14 13/16"

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
 EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
 SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
 LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
 PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
 ITEM NO.: 18-X-372B
 AIR PRODUCTS P.O. NO.: 4505600057 / A8KM-4-402-PO-2
 AP PROJECT NO: EN-20-7120
 VDR CODE NO.: BE04
 SERIAL NO.: S21-13258-10
 ENGINEER: EG
 CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

VIEW LOOKING AT SHELL SIDE OF NO. 19 TUBESHEET

TUBE LAYOUT			
		DWN. BY	Fabsco
		B.W.	
		DATE	SHELL & TUBE, LLC
		5/26/22	
		CKD. BY	DWG.NO.
		DiCarlo	S21-13258-10-5
NO.	DATE	REVISIONS	REV.
			2

ROW	NO.OF TUBES	BEND RADIUS	BEND DIAMETER	BEND LENGTH	STRAIGHT LENGTH	CUT LENGTH	DEVELOPED LENGTH
A	11	1 1/8"	2 1/4"	0'-3 9/16"	13'-0"	13'-1 1/2"	26'-3 9/16"
B	11	2 1/8"	4 1/4"	0'-6 11/16"	13'-0"	13'-2 1/2"	26'-6 11/16"
C	11	3 1/8"	6 1/4"	0'-9 7/8"	13'-0"	13'-3 1/2"	26'-9 7/8"
D	11	4 1/8"	8 1/4"	1'-1"	13'-0"	13'-4 1/2"	27'-1"
E	10	5 1/8"	10 1/4"	1'-4 1/8"	13'-0"	13'-5 1/2"	27'-4 1/8"
F	6	6 1/8"	12 1/4"	1'-7 1/4"	13'-0"	13'-6 1/2"	27'-7 1/4"



TOTAL NO. REQUIRED: 60
 SIZE: 3/4" (.083" MIN.)
 MATERIAL: SA-179

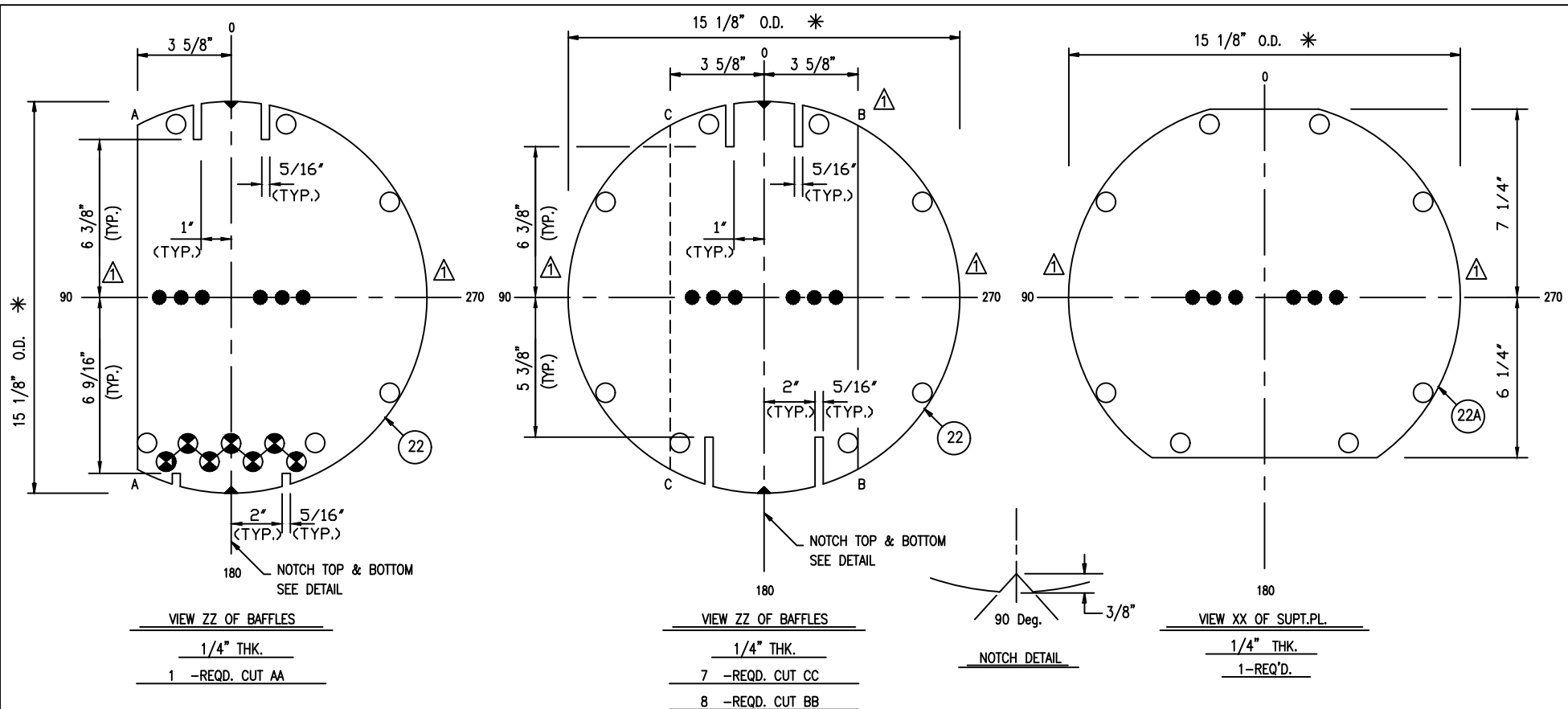
MAXIMUM OUT-OF-ROUNDNESS OF TUBES AT
 U-BENDS NOT TO EXCEED 10%.

QUANTITIES SHOWN ARE FOR
 ONE SET OF U-TUBES,
 1 -SET REQ'D. TOTAL.

STRESS RELIEF ANNEAL U-BENDS PLUS 1'-0" OF STRAIGHT LGTH.
 @ 1175°F. ±25°F. BY ELECTRIC RESISTANCE METHOD.

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
 EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
 SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
 LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
 PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
 ITEM NO.: 18-X-372B
 AIR PRODUCTS P.O. NO.: 4505600057 / A8KM-4-402-PO-2
 AP PROJECT NO: EN-20-7120
 VDR CODE NO.: BE04
 SERIAL NO.: S21-13258-10
 ENGINEER: EG
 CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

			TUBE BENDING SCHEDULE		
			DWN. BY	Fabsco SHELL & TUBE, LLC	
			B.W.		
			DATE		
			5/26/22		
			CKD. BY	DWG.NO.	REV.
NO.	DATE	REVISIONS	<i>DiCarlo</i>	S21-13258-10-6	0



⊗ DENOTES (7) 13/16" HOLES
FOR 3/4" O.D. IMP. RODS.
"DRILL BAFFLE 'A' ONLY"
(SEE TUBE LAYOUT FOR LOCATION)

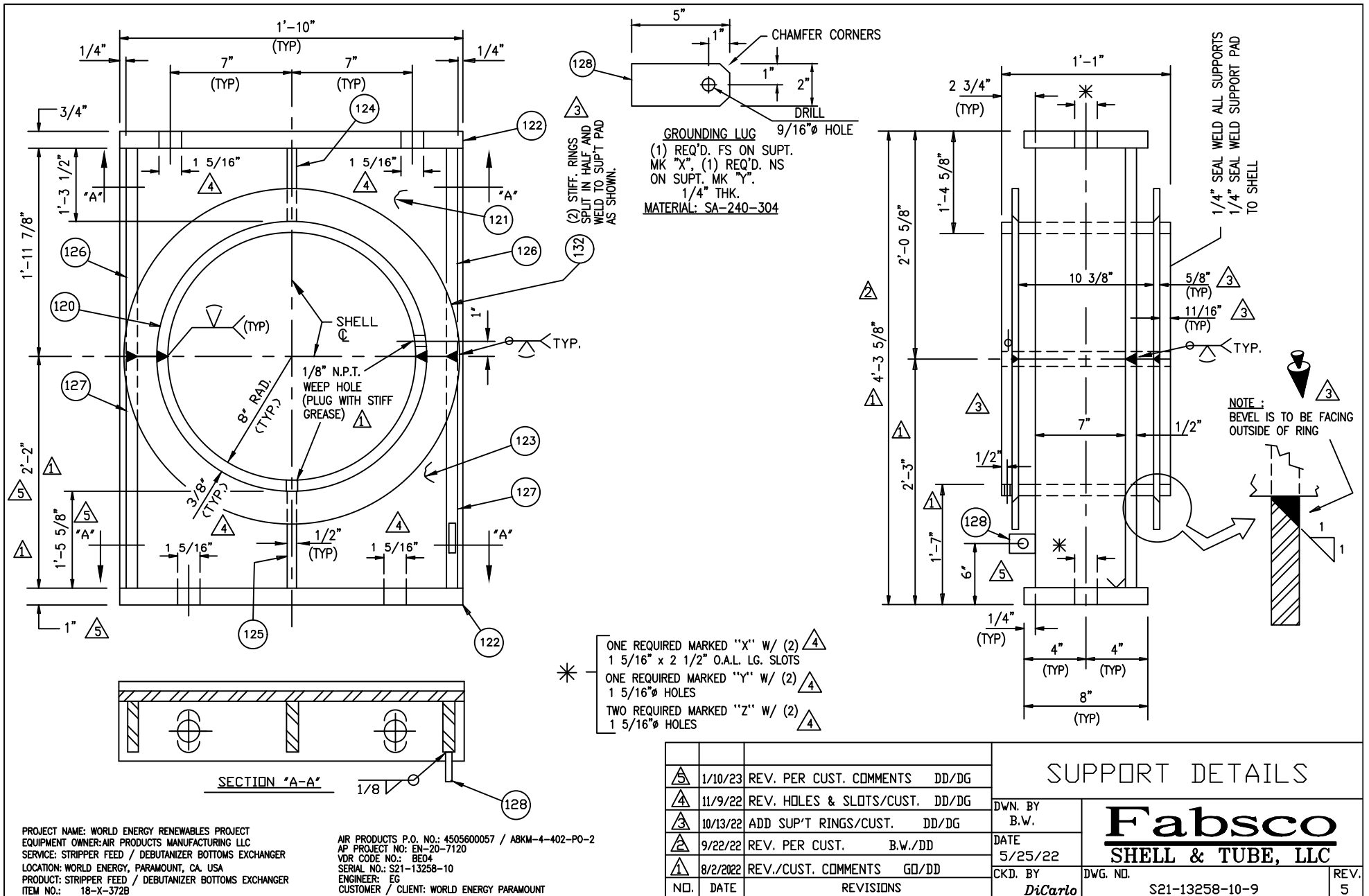
● DENOTES (6) 7/16" DIA. HOLES
FOR 3/8" DIA. DUMMY RODS.
(SEE TUBE LAYOUT FOR LOCATION)

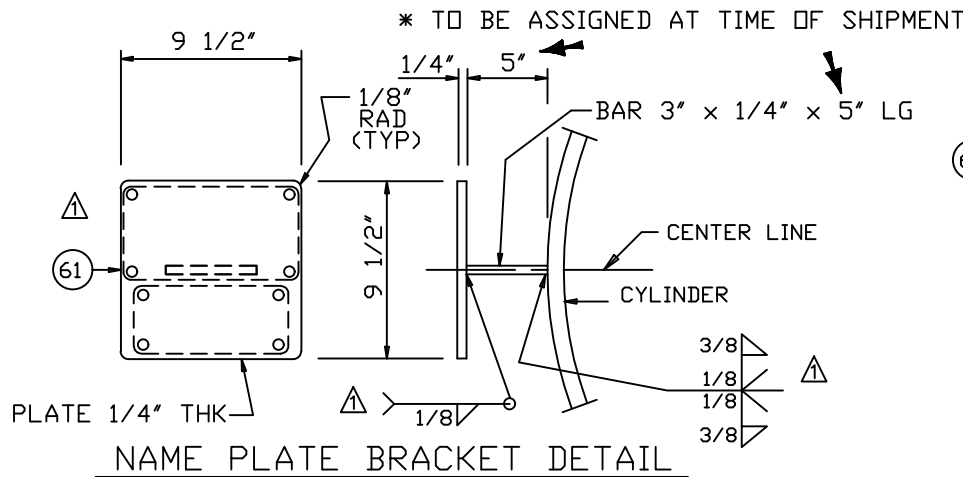
PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
ITEM NO.: 18-X-372B
AIR PRODUCTS P.O. NO.: 4505600057 / ABKM-4-402-PO-2
AP PROJECT NO: EN-20-7120
VDR CODE NO.: BE04
SERIAL NO.: S21-13258-10
ENGINEER: EG
CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

NOTES:

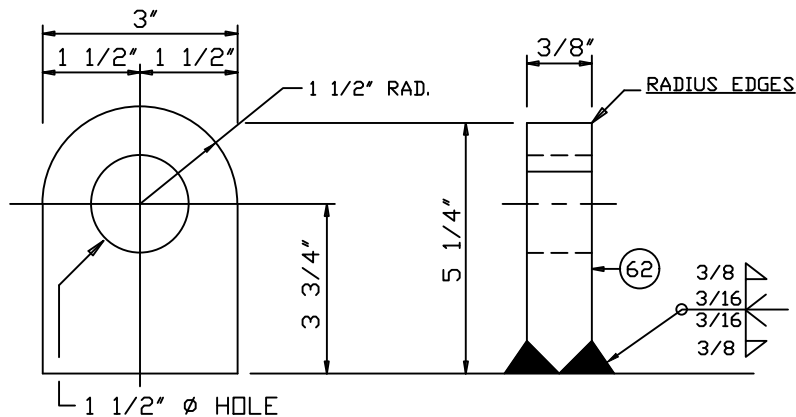
- 1) DRILL TUBE HOLES IN BAFFLES 25/32" DIA. & DEBURR.
- 2) DRILL TIE ROD HOLES 9/16" DIA.
SEE TUBE LAYOUT FOR LOCATION.
- 3) RADIUS ALL CORNERS ON BAFFLE CUTS.
- * 4) CHECK SHELL I.D. BEFORE MACHINING BAFFLE O.D.
- 5) MACHINE O.D. OF BAFFLES TO 250 RMS.

			BAFFLE DETAILS			
			DWN. BY B.W.		Fabsco SHELL & TUBE, LLC	
			DATE 5/20/22			
			CKD. BY DiCarlo		DWG.NO. S21-13258-10-8	
					REV 1	





(ONE) REQUIRED



3-REQUIRED

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
 EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
 SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
 LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
 PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
 ITEM NO.: 18-X-372B
 AIR PRODUCTS P.O. NO.: 4505600057 / ABKM-4-402-PO-2
 AP PROJECT NO.: EN-20-7120
 VDR CODE NO.: HC09
 SERIAL NO.: S21-13258-10
 ENGINEER: EG
 CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

MATERIAL: 18-8 STN. STL.(16 GA)

ASME U RT-4

NAT'L BD. *

CERTIFIED BY
FABSCO SHELL & TUBE, LLC
 SAPULPA, OKLAHOMA

	MAWP	PSI AT	MAWT	° F.
SHELL	405		300	
	MAEWP	PSI AT	MAWT	° F.
SHELL	15		300	
	MDMT	° F.	MAWP	PSI
SHELL	5		405	
	MAWP	PSI AT	MAWT	° F.
TUBES	405		330	
	MAEWP	PSI AT	MAWT	° F.
TUBES	15		300	
	MDMT	° F.	MAWP	PSI
TUBES	32		405	

SERIAL NUMBER	YEAR BUILT	ITEM/TAG NUMBER
S21-13258-10	2023	18-X-372B

P.O. NO.: 4505600057

DEBUTANIZER BOTTOMS EXCHANGER

INFORMATION NAME PLATE

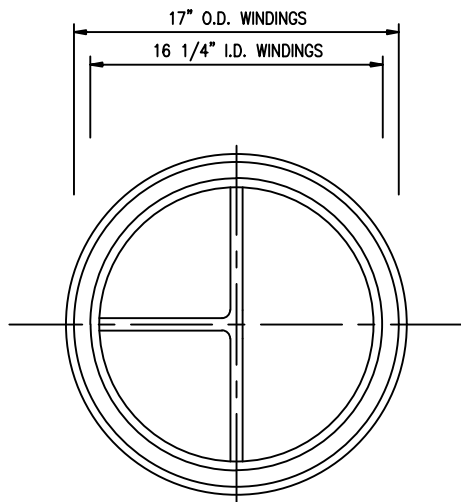
HYDRO TEST PRESS PSIG..TUBESIDE: SHOP-631/FIELD-527

HYDRO TEST PRESS PSIG..SHELLSIDE: SHOP-631/FIELD-527

DESIGN PRESS.: SHELLSIDE=375 PSIG; TUBESIDE=400 PSIG

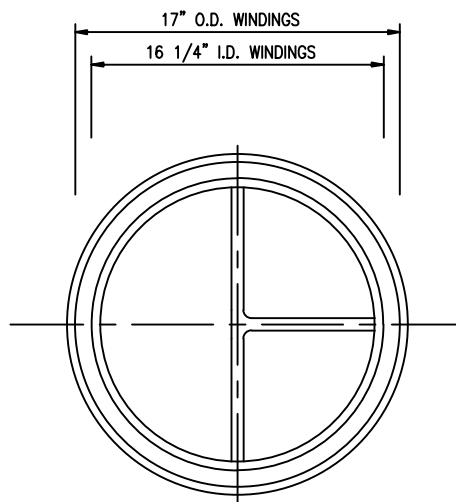
SECT. VIII, DIV 1, 2021 ED; API-660; TEMA "R"

LIFT LUG DETAIL w/ NAME PLATE & BRACKET		FABSCO SHELL & TUBE, LLC	
DWN. BY B.W.		DATE 5/26/22	
CKD. BY DiCarlo		DWG. NO. S21-13258-10-10	
NO.	DATE	REV./CUST. COMMENTS	REV.
		REVISIONS	1



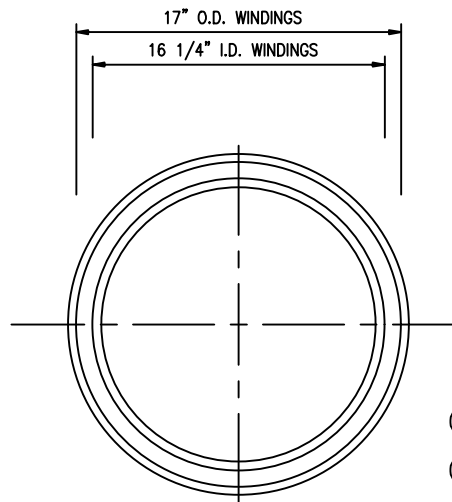
(1)–REQUIRED.
CHANNEL COVER GASKET.

0.175" THK. 316 S.S. SPIRAL WOUND
W/ GRAPHITE FILLER & INNER / OUTER COMP. RINGS (A)
RIB TO BE 3/16" THK X 7/16" WIDE 316 S.S. DBL.
JACKETED W/ GRAPHITE FILLER AND 1/64" THK. GRAPHITE
FACE ON BOTH SIDES
TEST PRESSURE:
SHOP: 631/FIELD: 527



(1)–REQUIRED.
CHANNEL GASKET.

0.175" THK. 316 S.S. SPIRAL WOUND
W/ GRAPHITE FILLER & INNER / OUTER COMP. RINGS (B)
RIB TO BE 3/16" THK X 7/16" WIDE 316 S.S. DBL.
JACKETED W/ GRAPHITE FILLER AND 1/64" THK. GRAPHITE
FACE ON BOTH SIDES
TEST PRESSURE:
SHOP: 631/FIELD: 527



(1)–REQUIRED.
SHELL GASKET.

0.175" THK. 316 S.S. SPIRAL WOUND
W/ GRAPHITE FILLER & INNER / OUTER COMP. RINGS (C)
TEST PRESSURE:
SHOP: 631/FIELD: 527

===== COMPRESSION RINGS =====

- (A) 17.7500 O.D. X .1250 THICK: MATERIAL=SA-240-316
15.5000 I.D. X .1250 THICK: MATERIAL=SA-240-316
(B) 17.7500 O.D. X .1250 THICK: MATERIAL=SA-240-316
15.5000 I.D. X .1250 THICK: MATERIAL=SA-240-316
(C) 17.7500 O.D. X .1250 THICK: MATERIAL=SA-240-316
15.5000 I.D. X .1250 THICK: MATERIAL=SA-240-316

NOTES:

- 1) QUANTITIES SHOWN FOR ONE SET
(3)–SET REQUIRED TOTAL.
ONE SET OF GASKETS TO BE USED IN EXCH. AND
(2) SETS TO BE BOXED, MARKED WITH
P.O. & ITEM NO. & SHIPPED WITH EXCHANGER.
2) ALL RADII TO BE 1/4"

CHANNEL COVER TO CHANNEL FLANGE BOLTING INFO

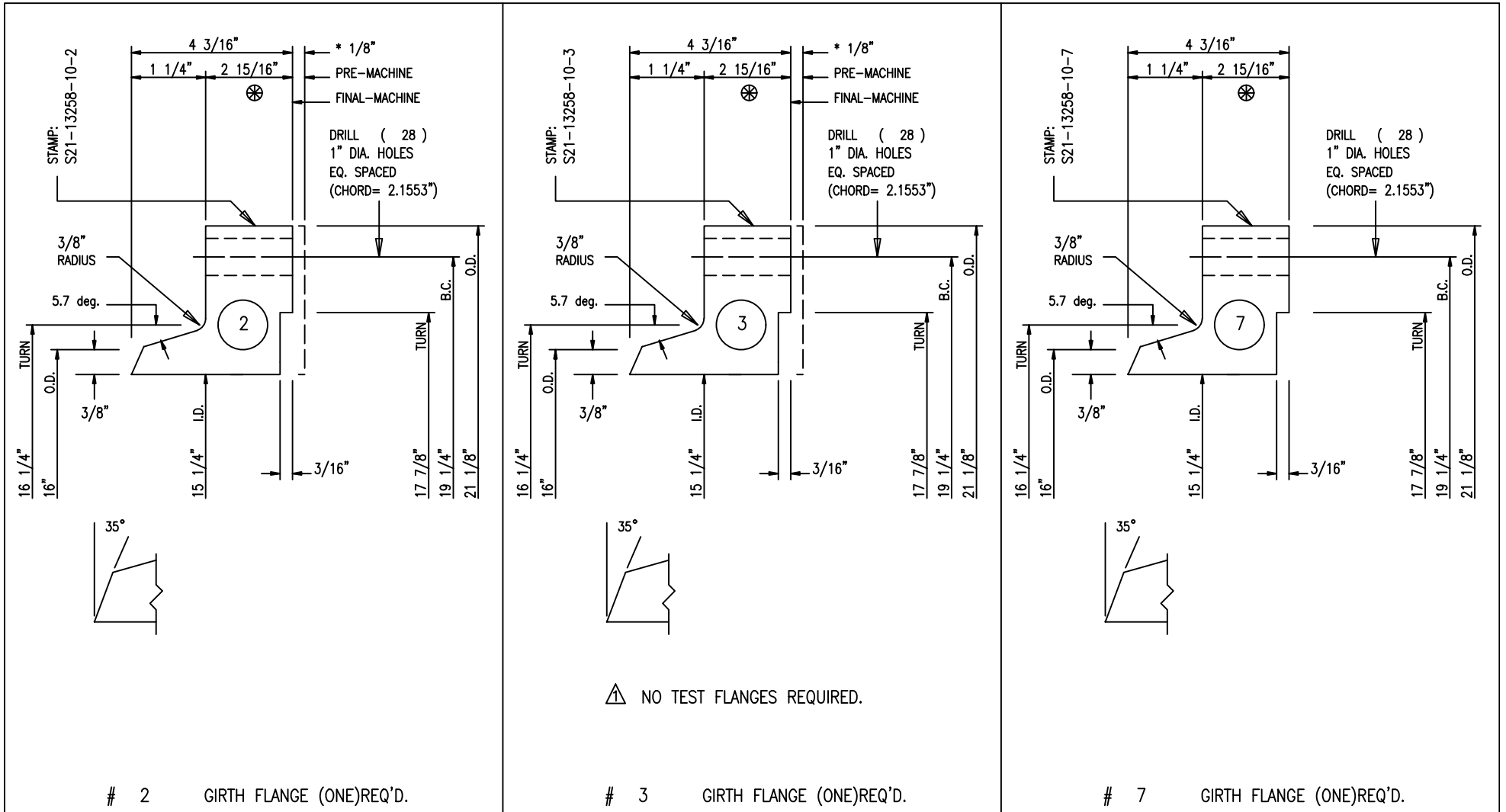
STUD DIAMETER: 7/8" O.D.
NUMBER STUDS: (28)
STUD MATERIAL: SA-193-B7
BOLT TORQUE RANGE TO BE ACHIEVED: 373.7–378.7 FT. LBS

CHAN. FLG./T'SHT./SHELL FLG. BOLTING INFO

STUD DIAMETER: 7/8" O.D.
NUMBER STUDS: (28)
STUD MATERIAL: SA-193-B7
BOLT TORQUE RANGE TO BE ACHIEVED: 373.7–378.7 FT. LBS.

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
ITEM NO.: 18-X-372B
AIR PRODUCTS P.O. NO.: 4505600057 / A8KM-4-402-PO-2
AP PROJECT NO: EN-20-7120
VDR CODE NO.: BE04
SERIAL NO.: S21-13258-10
ENGINEER: EG
CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

			GASKET DETAILS			
			DWN. BY B.W.	Fabsco SHELL & TUBE, LLC		
			DATE 5/26/22			
△	8/2/2022	REV./CUST COMMENTS	GO/DD	CKD. BY <i>DiCarlo</i>	DWG.NO. S21-13258-10-11	REV 1
NO.	DATE	REVISIONS				



NOTES:		PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT				GIRTH FLANGES	
1) MACHINE ALL SURFACES TO 250 RMS EXCEPT GASKET SURFACES MACHINE TO 125 RMS.		EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC					
2) ALL BOLT HOLES TO STRADDLE NATURAL C.L.		SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER				DWN. BY B.W.	
3) * FINAL MACHINE FACING AFTER FINAL WELDING.		LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA				DATE	
		PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER				5/26/22	
		ITEM NO.: 18-X-372B				CKD. BY	
		AIR PRODUCTS P.O. NO.: 4505600057 / A8KM-4-402-PO-2				DiCarlo	
		AP PROJECT NO: EN-20-7120				DWG.NO.	
		VDR CODE NO.: BE04				S21-13258-10-12	
		SERIAL NO.: S21-13258-10				REV.	
		ENGINEER: EG				1	
		CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT					
		NO.	DATE	REV./CUST. COMMENTS	GD/DD		
				REVISIONS			

THK. INCLUDES 1/8" FUTURE MACHINING ALLOWANCE

THK. INCLUDES 1/8" FUTURE
MACHINING ALLOWANCE

MK.NO.	QUAN.	DESCRIPTION	MATERIAL	NOZ MK.	SUPPLIER	P.O. NO.	DUE
21	△	TUBES 3/4" O.D.X 0.0830" MIN. THK PER BEND SCHEDULE	SA-179				
△							
△		FORGED RING MATERIAL					
2	△	1 FLG 21 1/8" O.D.X 15 1/4" I.D.X 4 3/16" THK (f) 6/7/8/12)	SA-350LF2CL1				
3	△	1 FLG 21 1/8" O.D.X 15 1/4" I.D.X 4 3/16" THK (f) 6/7/8/12)	SA-350LF2CL1				
7	△	1 FLG 21 1/8" O.D.X 15 1/4" I.D.X 4 3/16" THK (f) 6/7/8/12)	SA-350LF2CL1				
△							
△		TUBESHEETS & COVERS					
19	△	1 TUBESHEET 17 3/4" O.D.X 2" THK (f) 7/8/12/13)	SA-516-70N				
1	△	1 COVER 21 1/8" O.D.X 2 1/8" THK (f) 7/8/12/13)	SA-516-70				
△							
△		BAFFLES					
22	△	16 BAFFLES PER DWG. -8	SA-36				
22A	△	1 SUPT PL. PER DWG. -8	SA-36				
△							
△		HEAD					
18	△	1 WELD CAP 16" (.375" THK. Std. SCH) 8)12)	SA-234WPB				
△							
△		CYLINDERS					
9	△	1 SMLS,PIPE 16" X(0.3750" SchStd)X 12'-10 13/16" LG. 8)12)	SA-106-B				
4	△	1 SMLS,PIPE 16" X(0.3750" SchStd)X 1'-10" LG. 8)12)	SA-106-B				
△							
△		EYE BOLTS MATERIAL (TO SHIP LOOSE W/ EXCHANGER)					
65	△	2 EYE BOLT W/ SHOULDER: 1/2" OD (13 THD.) W/ 2" LG. SHANK	ASTM A489				
△							
△		NOZZLE COVER SHIPPING MATERIAL (REMOVE BEFORE SERVICE)					
150	△	2 ASME 3" - 600# RF BLIND FLG.	SA-105N				
151	△	16 STUDS: 3/4" DIA. (10-THD.) X 7 3/8" LG. (3"-600# RF)	SA-193-B7				
152	△	64 NUTS: 3/4" (10-THD.) HWY. HEX (3"-600# RF)	SA-194-2H				
153	△	32 3/4" NARROW SERIES WASHERS	F-436-1				
154	△	2 GASKETS: 0.175" THK. 304 S.S. SPIRAL WOUND GRAPHITE					
△		FILLED, STYLE "CG", C-STL. COMP RING FOR (3"-600# RF)					
155	△	2 PL. 14" O.D. X 3/8" THK. W/ (12) 9/16" DIA. HOLES	C.STL.				
△		EQUALLY SPACED ON 11 1/2" B.C. (6"-600#)					
156	△	2 GASKETS: 0.175" THK. 304 S.S. SPIRAL WOUND GRAPHITE					
△		FILLED, STYLE "CG", C-STL. COMP RING FOR (6"-600# RF)					
157	△	24 1/2" HEX HD. ALL THD. BOLTS X 4 1/4" LG. W/(2) HEX NUT	C.-STL.				
△		AND (2) FLAT WASHERS EACH (6"-600#)					
△							
△		NITROGEN PURGE MATERIAL					
108	△	2 1/4" NPT GAGE W/ -30 TO 30 PSI (MINIMUM) DIAL	C.-STL.				
109	△	2 1/4" X 1" NPT BUSHING	C.-STL.				
110	△	2 1" - 3000 # SCREWED TEE	SA-234-WPB				
111	△	4 1" NPT PIPE NIPPLE 0.179" (SCH. 80) X 2" LG. (TOE)	SA-106-B				
112	△	4 1" NPT PIPE NIPPLE 0.179" (SCH. 80) X 1 1/2" LG. (TBE)	SA-106-B				
113	△	4 1" - 50 # (MAX.) THD. BALL VALVE	C-STL.				
114	△	4 1" - 3000 # HEX HEAD PLUG	C-STL.				
115	△	2 1" 3M FS THRD 90 ELL	SA-105				
△							
△		SEE DWG. -17 FOR BILL OF MATERIAL NOTES					

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
SERVICE: STRIPPER FEED/DEBUTANIZER BTMS EXCH
LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
PRODUCT: STRIPPER FEED/DEBUTANIZER BTMS EXCH
ITEM NO.: 18-X-372B
AIR PRODUCTS P.O. NO.: 4505600057/
AP PROJECT NO.: EN-20-7120
VDR CODE NO.: FA01
SERIAL NO.: S21-13258-10
ENGINEER: EG
CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

BILL OF MATERIAL

Fabsco
SHELL & TUBE, LLC

DWN. BY
B.W.
DATE
5/26/22
CKD. BY
DiCarlo

REV.	DATE	REVISIONS
3	5/26/22	REV. PER FABSCD B.W./DD
2	8/2/2022	REV./CUST. COMMENTS GD/DD
1	1/10/22	REV. PER CUST. COMMENTS DD/DG

REV.
3

DWG. NO. S21-13258-10-14

MK.NO.	QUAN.	DESCRIPTION	MATERIAL	NOZ MK.	SUPPLIER	P.O. NO.	DUE
		BOLTING & GASKETS					
40	1	LOT OF GASKETS PER DWG. -11					
41	28	7/8" ROUND X 9-THREAD STUDS X 9 5/8" LG. 1&2 12)	SA-193-B7				
42	28	7/8" ROUND X 9-THREAD STUDS X 12 1/8" LG. 3&7 12)	)SA-193-B7				
43	224	7/8" HEAVY HEX NUTS 9-THREAD 12)	SA-194-2H				
44	112	7/8" NARROW SERIES WASHERS	F-436-1				
		SPARE STUDS & NUTS (TO SHIP LOOSE W/EXCH.)					
151	3	7/8" DIA. (9-THD.) STUDS X 9 5/8" LG. 1&2 12)	SA-193-B7				
152	3	7/8" DIA. (9-THD.) STUDS X 12 1/8" LG. 3&7 12)	SA-193-B7				
153	24	7/8" Hvy HEX NUTS (9-THD.) 12)	SA-194-2H				
154	12	7/8" NARROW SERIES WASHERS	F-436-1				
		MISC. MATERIAL					
60	1	STD. NAME PLATE	STN.STL.				
61	1	NAME PL BRKT (PER DWG. -10)	SA-36				
62	6	LIFTING LUGS (PER DWG. -10)	SA-516-70				
23	104	FT. 1/2" O.D. TIE RODS	SA-36				
23B	16	1/2" TIE ROD HEX NUTS	SA-563A				
23A	104	FT. 3/4" O.D. SPACER TUBING	SA-214				
22D	6	DUMMY RODS: 3/8" O.D. X 11'-6 3/4" LG.	SA-36				
221	7	3/4" O.D. IMP. RODS X 1'-4 3/8" LG.	SA-36				
22S	2	SEAL BARS 1 3/4" X 1/4" THK X 10'-9 3/4" LG.	SA-36				
50	1	PASS PLATES 7 1/4" X 1/2" THK X 30 5/8" LG. 8)12)	SA-516-70				
51	1	PASS PLATES 15 1/8" X 1/2" THK X 30 5/8" LG. 8)12)	SA-516-70				
63	2	SQUARE HEAD PULLBOLT PLUGS: 1/2" DIA. (13-THD.) X 3 1/2" LG.	SA-36				
141	5	INS. CLIPS: 1" X 1/4" THK. X 3 1/2" LG.	SA-36				
142	1	INS. ROD: 3/8" DIA. ROD X 6'-1" LG. (ROLL TO 22 1/4" IR)	SA-36				
22T	2	SEAL BARS 1" X 1/4" THK X 10'-9 3/4" LG.	SA-36				
		SUPPORT MATERIAL					
120	2	R&W CYL: 16" I.D. X 3/8" THK. X 13" LG. 8)12)	SA-516-70				
121	2	PLATE 22" X 1/2" THK X 23 7/8" LG.	SA-516-70				
122	4	PLATE 8" X 1" THK X 22" LG.	SA-516-70				
123	2	PLATE 22" X 1/2" THK X 26" LG.	SA-516-70				
124	2	PLATE 7" X 1/2" THK X 15 1/2" LG.	SA-516-70				
125	2	PLATE 7" X 1/2" THK X 17 5/8" LG.	SA-516-70				
126	4	PLATE 7" X 1/2" THK X 23 7/8" LG.	SA-516-70				
127	4	PLATE 7" X 1/2" THK X 26" LG.	SA-516-70				
128	2	GROUNDING LUGS: 2" X 1/4" THK. X 5" LG.	SA-240-304				
129	2	SHIMS 8" X 1/4" THK. X 22" LG.	C-STL.				
130	2	SHIMS 8" X 10 GA. (.1345") THK. X 22" LG.	C-STL.				
131	4	STACK BOLT: 1" DIA. (8-THD) X 3 3/4" LG.	C-STL.				
		W/ (1) HX. NUT & (2) WASHERS EACH.					
132	4	RING: 26" O.D. X 17" I.D. X 5/8" THK. (SPLIT IN HALF)	SA-516-70				
		FOR BILL OF MATERIAL NOTES, SEE DWG. -17					
		"DELETED"					
		"DELETED"					
		PAINT PER DWG. -1B					

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
SERVICE: STRIPPER FEED/DEBUTANIZER BTMS EXCH
LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
PRODUCT: STRIPPER FEED/DEBUTANIZER BTMS EXCH
ITEM NO.: 18-X-372B
AIR PRODUCTS P.O. NO.: 4505600057/
AP PROJECT NO: EN-20-7120
VDR CODE NO.: FA01
SERIAL NO.: S21-13258-10
ENGINEER: EG
CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

BILL OF MATERIAL

Fabsco
SHELL & TUBE, LLC

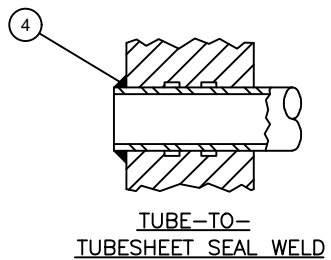
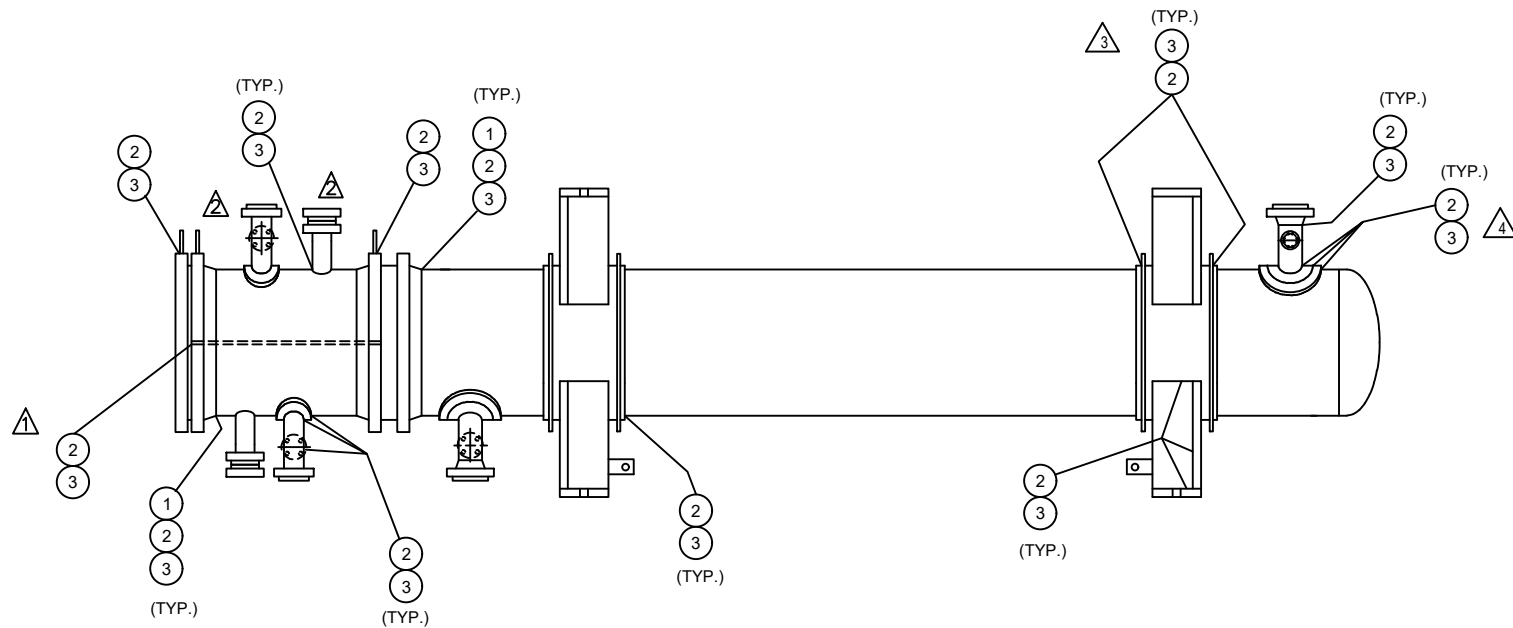
DWN. BY
B.W.

DATE
5/26/22

CKD. BY
DtiCarrio

DWG. NO. S21-13258-10-16

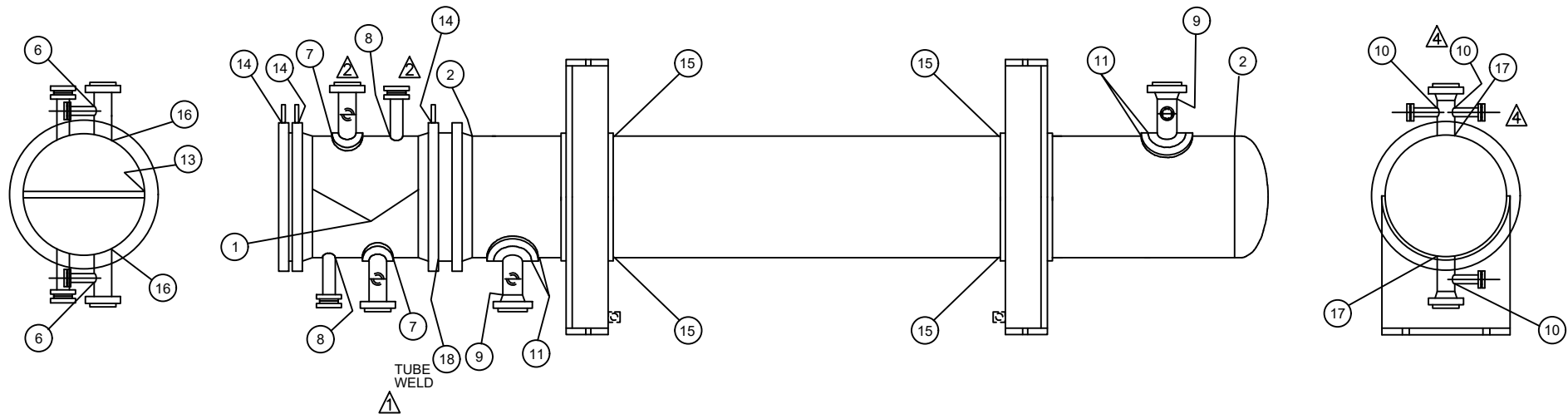
REV.
5



MK.	PROC. #
1	A-344
2	F-148
3	M-360
4	T-266

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
 EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
 SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
 LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
 PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
 ITEM NO.: 18-X-372B
 AIR PRODUCTS P.O. NO.: 4505600057 / A8KM-4-402-PO-2
 AP PROJECT NO: EN-20-7120
 VDR CODE NO.: QD07
 SERIAL NO.: S21-13258-10
 ENGINEER: EG
 CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

			WELD MAP			
④	1/10/23	REV. PER CUST. COMMENT	DD/DG	DWN. BY	Fabsco SHELL & TUBE, LLC	
③	10/13/22	ADD SUP'T RINGS/CUST.	DD/DG	B.W.		
②	9/12/22	REV. PER CUST.	B.W./DD	DATE		
①	7/12/2022	REV./CUST. COMMENTS	GD/DD	5/25/22		
NO.	DATE	REVISIONS		CKD. BY	DWG. No.	REV.
				MO	S21-13258-10-18	4

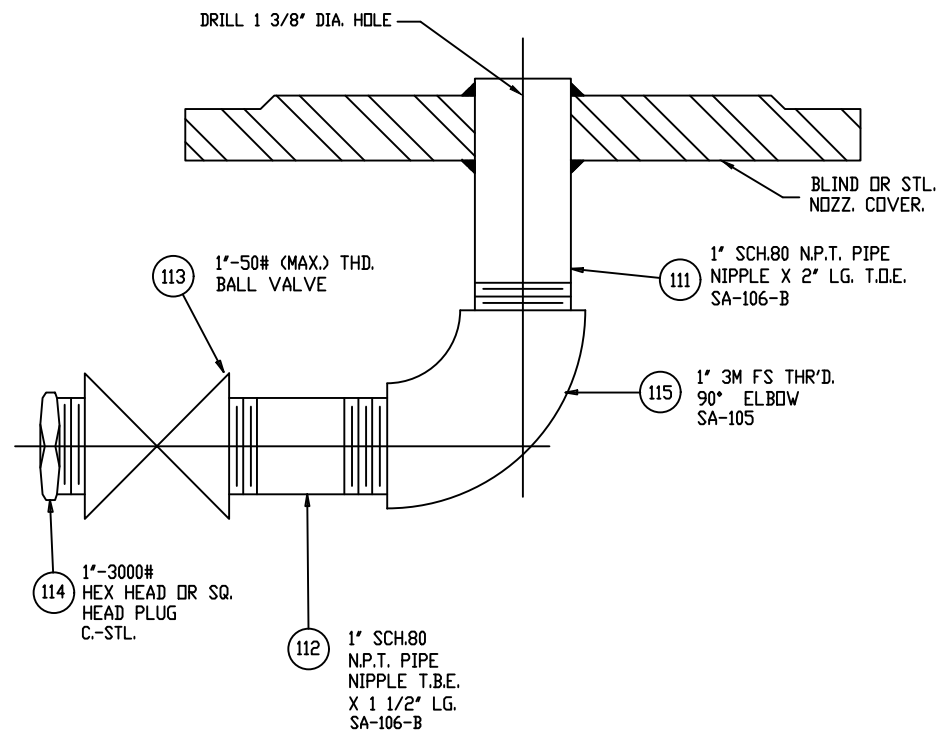
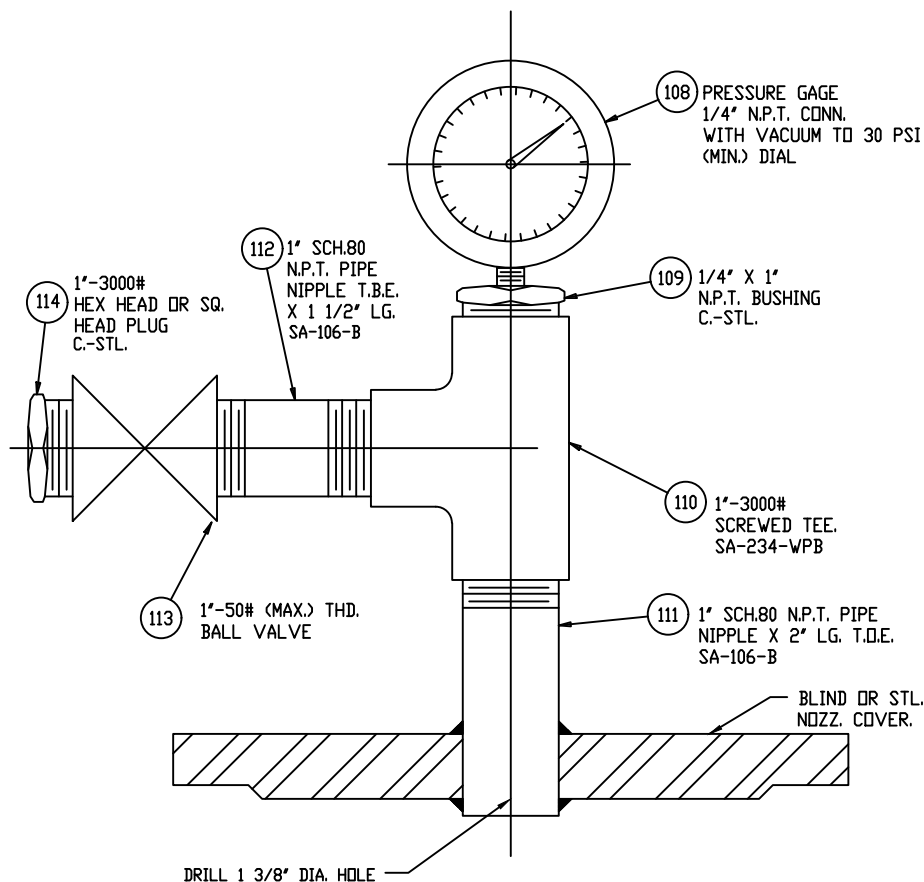


	X-RAY	U.T.	M.T.	P.T.	W.F.M.T.	BRINELL	MK.
CHANNEL CIRCULAR SEAM	X		X	X	X	X	(1)
SHELL CIRCULAR SEAM	X		X	X	X	X	(2)
DELETED							
DELETED							
DELETED							
CHANNEL AUX. TO PIPE		X	X	X	X	X	(6)
CHANNEL WELD PAD TO CYLINDER		X	X	X	X	X	(7)
CHANNEL V & D TO CYLINDER		X	X	X	X	X	(8)
SHELL NOZZLE FLANGE TO PIPE	X	X	X	X	X	X	(9)
SHELL AUX. TO PIPE			X	X	X	X	(10)
SHELL WELD PAD TO CYLINDER		X	X	X	X	X	(11)
DELETED							
PASS PLATE TO CYLINDER		X	X	X	X	X	(13)
LIFT LUG WELDS			X	X			(14)
SUPPORT PAD TO CYLINDER			X	X	X	X	(15)
CHANNEL NOZZLE TO CYLINDER		X	X	X			(16)
SHELL NOZZLE TO CYLINDER		X	X	X			(17)
TEMPORARY ATTACHMENT LOCATIONS			X	X			
TUBE SEAL WELD				X			(18)

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
 EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
 SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
 LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
 PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
 ITEM NO.: 18-X-372B
 AIR PRODUCTS P.O. NO.: 4505600057 / A8KM-4-402-PO-2
 AP PROJECT NO: EN-20-7120
 VDR CODE NO.: QD07
 SERIAL NO.: S21-13258-10
 ENGINEER: EG
 CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

NDE MAP			
	4/21/23	REV. "AS BUILT" / FABSCO AS/DD	DWN. BY
	1/10/23	REV. PER CUST. COMMENTS DD/DG	B.W.
	9/12/22	REV. PER CUST. B.W./DD	DATE
	7/12/2022	REV./CUST. COMMENTS GD/DD	5/24/22
NO.	DATE	REVISIONS	CKD. BY
			MO
			DWG. No.
			S21-13258-10-19
			REV.
			4

Fabsco
 SHELL & TUBE, LLC



NOTES:

- 1) A VACUUM MUST BE CREATED INSIDE EXCHANGER WHICH IS TO BE BROKEN BY INTRODUCING 10 PSI DRY NITROGEN THROUGH VALVE.
- 2) POSITIVE PRESS. TO READ 10 PSI CONTINUOUS.
- 3) GAGE & VALVE TO REMAIN ON EXCHANGER AND BE PROTECTED AGAINST BREAKAGE DURING SHIPMENT.
- 4) STENCIL ON CAUTION TAG & WIRE TO NOZZ. CVR., "WARNING, THIS EXCHANGER IS UNDER POSITIVE PRESSURE, RELIEVE PRESSURE BEFORE OPENING ANY CLOSURE."
- 5) ALL OPENINGS TO BE PLUGGED OR CAPPED BEFORE SHIPMENT.
- 6.) 2-GAGE REQUIRED. (1-SHELLSIDE & 1-TUBESIDE).

PROJECT NAME: WORLD ENERGY RENEWABLES PROJECT
 EQUIPMENT OWNER: AIR PRODUCTS MANUFACTURING LLC
 SERVICE: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
 LOCATION: WORLD ENERGY, PARAMOUNT, CA. USA
 PRODUCT: STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER
 ITEM NO.: 18-X-372B
 AIR PRODUCTS P.O. NO.: 4505600057 / A8KM-4-402-PO-2
 AP PROJECT NO.: EN-20-7120
 VDR CODE NO.: BE04
 SERIAL NO.: S21-13258-10
 ENGINEER: EG
 CUSTOMER / CLIENT: WORLD ENERGY PARAMOUNT

PRESSURE GAGE & VALVE DETAIL FOR NITROGEN PURGE

DWN. BY
DD

DATE
1/10/23

CKD. BY
DG

Fabsco
SHELL & TUBE, LLC

DWG. NO. S21-13258-10-20

REV.
1

NO.	DATE	REVISIONS
1	1/10/23	ADDED DETAIL PER CUST.

D

Mechanical Design Calculations

FABSCO SHELL & TUBE, LLC

Sapulpa, Oklahoma, USA

Item/Tag no: 18-X-372A/B

Doc. No: S21-13258-9/10-CP

P.O. no: 4505600057

Certified Correct for Fabrication **by Fabsco Shell & Tube, LLC**

By: Eric Gerschutz

Date: 2021 Dec. 30th

- Jurisdictional Code Requirements: Design, Materials, Fabrication, Inspection, Testing and Documentation in accordance with the ASME Code Section VIII, Division 1, 2021 Edition and so stamped.
- Impact test requirements: Exempt from Impact Testing per UCS-66(a), (c), (g), Fig. UCS-66 general note (c) and UCS-67.
- Loadings per ASME code para. UG-22 that have been defined by the user or his designated agent have been considered in the design process.
- This design has been reviewed for compliance with the requirements of UG-120(d).

Customer: WORLD ENERGY PARAMOUNT HORIZONTAL
Service : STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER U-TUBE
No. Shells: 1 Par. 1 Ser. 2 Surface: 301 TotalSq.Ft. Each
Size: 15.25" x 156" Type: A E U Stacked

60 Tubes x 0.750 OD x 0.083" Thk (min.) x 156 " Lg 1.0000 SQUARE Pitch
Tubes : SA-179
Shell : SA-106-B
Channel : SA-106-B
Tubesheets : SA-516-70
Cross Baffles : SA-516-70 No. 16 Pitch 8.500 Cut 0.27 SGL SEG VERT

Code requirements:	SHELL SECT VIII STAMP YES	CHANNEL SECT VIII STAMP YES
Natl. Board #YES	Canadian Reg. #	Tema R
Weight Ea Dry: 5500 Lbs	Wet 6660 Lbs	Bundle 1400 Lbs
	Shell	Tubes
Design Press/Ext	375.0 / 15.0 psig	400.0 / 15.0 psig
M.A.W.P.	405 psig	405 psig
M.A.P.	485 psig	485 psig
Test Pressure (field)	527.0 psig	527.0 psig
Design Temp/MDMT	300 / 5 deg.F	330 / 32 deg.F
Corrosion Allowance	0.1250"	0.1250"
No. of Passes	1	4
Radiograph	SPOT/UW-11(a)(5)(b)	SPOT/UW-11(a)(5)(b)
Stress Relieve	0 deg.F	U-Bends 1150deg.F

Revisions to this Document					
No.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc./Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

////////////////////////////////////
 ///// MATERIALS AND GASKETS /////
 //////////////////////////////////////

NO.	PART	MATERIAL	MT#	Ratio So/Sa	
21	TUBES	SA-179	34	1.00000 @	330 deg.F
19	TUBSHT	SA-516-70	6	1.00000 @	330 deg.F
9	SHL CYL	SA-106-B	33	1.00000 @	300 deg.F
7	#7 FLG	SA-350LF2CL1	74	1.00000 @	300 deg.F
18	REAR COV	SA-234WPB	22	1.00000 @	300 deg.F
4	CHAN CYL	SA-106-B	33	1.00000 @	330 deg.F
1	CHAN COV	SA-516-70	6	1.00000 @	330 deg.F
2	#2 FLG	SA-350LF2CL1	74	1.00000 @	330 deg.F
3	#3 FLG	SA-350LF2CL1	74	1.00000 @	330 deg.F
B2	BOLTS	SA-193-B7	91	1.00000 @	330 deg.F
B3	BOLTS	SA-193-B7	91	1.00000 @	330 deg.F
22	BAFFLES	SA-516-70	6		
22A	SUPT PL.	SA-516-70	6		
23	TIE RODS	SA-36	16		
23A	SPACERS	SA-214	61		
4A	PASS PL.	SA-516-70	6		

//////////////////////////////////// GASKETS //////////////////////////////////////
 GASKET TO # 2 FLANGE 0.1750" THK 316 SW-GPHT CGI GASKET CODE= 122
 GASKET TO # 3 FLANGE 0.1750" THK 316 SW-GPHT CGI GASKET CODE= 122
 GASKET TO # 7 FLANGE 0.1750" THK 316 SW-GPHT CGI GASKET CODE= 122

FIELD HYDRO TEST SHELL SIDE - 405 x 1.3 x 1 = 527 PSIG
 FIELD HYDRO TEST TUBE SIDE - 405 x 1.3 x 1 = 527 PSIG
 SHOP HYDRO TEST SHELL SIDE - 485 x 1.3 = 631 PSIG
 SHOP HYDRO TEST TUBE SIDE - 485 x 1.3 = 631 PSIG

THERMAL EXPANSION BETWEEN SUPPORTS:
 81 BETWEEN SUPPORTS x 6.9(10-6) COEF. THERMAL EXPANSION x 230 (DESIGN TEMP. - 70°F)
 81 x 6.9(10-6) x 230 = 0.128"

Slot Length = Anchor Bolt Dia. + 2 x Thermal Expansion + 0.3125 =
 1" + 2 x 0.128 + 0.3125" = 1.5685 (2.5" Used)

STATIC HEAD SHELL SIDE = 0.546 PSIG
 STATIC HEAD TUBE SIDE = 0.546 PSIG

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

SHELL SIDE

```

=====
NOM.
SIZE      PRESS.      TEMP.      C.A.      RT      H.T.      TEMA
16.000"   375.0psig    300deg.F  0.1250"   SPOT      0deg.F    R
=====

```

ASME CODE SEC.VIII DIV.I UG-27 [CYLINDER]

====DESIGN CONDITIONS=====CYLINDER CALCULATIONS ON O.D. FORMULA=====

SHELL CYL

```

MATERIAL: SA-106-B      PRESS = 375.0psig  TEMP = 300deg.F
O.D.      NOM. THK.      RW=0/PIPE=1  CORR.ALLOW  EFFICIENCY
16.0000"   0.3750"            1      0.1250"    1.00
ATM.STRS   DES.STRS   STRS/STRS   MAWP N-C    MAWP CORR.
17100.0psi 17100.0psi  1.000      713.066psig 438.635psig

```

P*(R0)

----- = 0.17391" + CORR. ALLOW. = 0.29891" + MTOL. = 0.34161"

S*E+(.4*P)

ASME CODE SEC.VIII DIV.I UG-32

[ELLIPTICAL HEAD]

====DESIGN CONDITIONS=====ELLIPTICAL HEAD CALCULATIONS ON O.D. FORMULA=====

SHELL HEAD

```

MATERIAL: SA-234WPB      PRESS = 375.0psig  TEMP = 300deg.F
O.D.      (nom)THK.      CORR.ALLOW  EFFICIENCY
16.0000"   0.3750"            0.1250"    1.00
ATM.STRS   DES.STRS   STRS/STRS   MAWP N-C    MAWP CORR.
17100.0psi 17100.0psi  1.000      692.308psig 409.417psig

```

P*(R0)

0.0625

----- = 0.17204" + CORR. ALLOW. = 0.29704" + MTOL. = 0.35954"

S*E+(.9*P)

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Shell Cylinder

----- External Pressure Calculations -----

```

Ext Press Chart....=      1  CS-2
Actual Chart Used..=      1  CS-2
Material.....=      SA-106-B
OD.....=      16.00000
T.....=      0.20312
L.....=      154.81250
Temp.....=      300.00000
Stress from MT.....=      17100.00000
Yield from MT.....=      31000.00000
2 x Stress.....=      34200.00000
B1 from Chart@Right=      0.00000
Yield= 2 x B1 x 0.9=      0.00000
S.....=      0.00000
DO/T.....=      78.76923
L/DO.....=      9.67578
A.....=      0.00020
B.....=      2834.10498
PA1.....=      0.00000
PA2.....=      0.00000
PA.....=      47.97313

```

Errors/Warnings:

- None

Ellip. Head External pressure calculations:

Shell Head

```

Ext Press Chart....=      1  CS-2
Actual Chart Used..=      1  CS-2
Material.....=      SA-234WPB
OD.....=      16.00000
RO.....=      14.40000
T.....=      0.18750
Temp.....=      300.00000
Stress from MT.....=      17100.00000
Yield from MT.....=      31000.00000
A.....=      0.00163
B.....=      14140.75195
PA.....=      184.12437

```

Errors/Warnings:

- None

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

FRONT CHAN.

```

=====
NOM.
SIZE          PRESS.      TEMP.      C.A.      RT      H.T.      TEMA
16.000"      400.0psig    330deg.F  0.1250"   SPOT      0deg.F    R
=====
ASME CODE SEC.VIII DIV.I UG-27 [ CYLINDER ]
====DESIGN CONDITIONS=====CYLINDER CALCULATIONS ON O.D. FORMULA====
CHAN. CYL
MATERIAL: SA-106-B      PRESS = 400.0psig  TEMP = 330deg.F
O.D.      NOM. THK.      RW=0/PIPE=1  CORR.ALLOW  EFFICIENCY
16.0000"   0.3750"           1          0.1250"    1.00
ATM.STRS  DES.STRS      STRS/STRS    MAWP N-C    MAWP CORR.
17100.0psi 17100.0psi 1.000      713.066psig 438.635psig

P*(R0)
----- = 0.18540" + CORR. ALLOW. = 0.31040" + MTOL. = 0.35474"
S*E+(.4*P)
*****

```

Channel Cylinder

```

----- External Pressure Calculations -----
Ext Press Chart....= 1 CS-2
Actual Chart Used..= 1 CS-2
Material.....= SA-106-B
OD.....= 16.00000
T.....= 0.20312
L.....= 22.00000
Temp.....= 330.00000
Stress from MT.....= 17100.00000
Yield from MT.....= 30700.00000
2 x Stress.....= 34200.00000
B1 from Chart@Right= 0.00000
Yield= 2 x B1 x 0.9= 0.00000
S.....= 0.00000
DO/T.....= 78.76923
L/DO.....= 1.37500
A.....= 0.00137
B.....= 13002.85547
PA1.....= 0.00000
PA2.....= 0.00000
PA.....= 220.10040

```

Errors/Warnings:
- None

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

NOZZLE REINFORCEMENT CALCULATIONS/ ASME SEC.VIII DIV.I UG-37 & UG-16

NOZ NO= 1/2 6.00" 600 LB RF WN
 [INLET & OUTLET] SHELL SIDE
 PRESSURE = 375.0psig TEMP = 300.0deg.F

-----CYLINDER-----NOZZLE-----

SA-106-B		SA-106-B	
OPER STRS=	17100.0 psi	OPER STRS=	17100.0 psi
ATM STRS =	17100.0 psi	ATM STRS =	17100.0 psi
C.A. =	0.12500"	C.A. =	0.12500"
I.D. =	15.34375"	I.D. =	5.76100"
O.D. =	16.00000"	O.D. =	6.62500"
THK. =	0.32812"	THK. XH=	0.43200"
T =	0.20312"	TN =	0.30700"
TR =	0.17391"	TRN =	0.07201"
ET =	0.02921"	ETN =	0.23499"

MIN STD. WT. PIPE+C.A.= 0.37000" TR+C.A.= 0.29891"
 LIMITS= 12.02200"
 fr1= 1.0000 fr2= 1.0000 fr3= 1.0000 fr4= 1.0000 F= 1.00000
 Min weld sizes:NS= 0.0000" NP= 0.3039" PS= 0.1436" IF= 0.0000"

AREA REQD. A = 1.04539in^2
 EXCESS IN CYL. A1= 0.17559in^2
 EXCESS IN NOZ.(OUTSIDE) A2= 0.23866in^2 H = 0.50781"
 AREA OF FILLETS = 0.14062in^2
 AREA AVAILABLE = 0.55488in^2

NOZ. NECK WELD= 0.37500" AREA= 0.14062in^2

PAD MATL.= SA-516-70 S= 20000.psi
 PAD O.D.= 13.62500" THK.= 0.50000" AREA= 2.69850in^2
 PAD TO CYL. WELD= 0.5000" AREA= 0.00000in^2
 ARC= 6.831"
 PAD RET. DIM.= 13.625" X 13.875"

< AREA REQD-AREA AVAILABLE > = -2.20799in^2

MAWP N-C= 1044.0psig LIMITED BY AR
 MAWP COR= 985.0psig LIMITED BY AR

All Weld Paths are stronger than the required strength /[UG-41 UG-45 UW-15]

(*) Subtracted 12 1/2% pipe tolerance and is therefore conservatively calculated.

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

NOZZLE REINFORCEMENT CALCULATIONS/ ASME SEC.VIII DIV.I UG-37 & UG-16
 NOZ NO= 1/2 6.00" 600 LB RF WN
 [INLET & OUTLET] SHELL SIDE EXT. PRESS. CASE
 PRESSURE = -15.0psig TEMP = 300.0deg.F

-----CYLINDER-----NOZZLE-----

SA-106-B		SA-106-B	
OPER STRS=	17100.0 psi	OPER STRS=	17100.0 psi
ATM STRS =	17100.0 psi	ATM STRS =	17100.0 psi
C.A. =	0.12500"	C.A. =	0.12500"
I.D. =	15.34375"	I.D. =	5.76100"
O.D. =	16.00000"	O.D. =	6.62500"
THK. =	0.32812"	THK. XH=	0.43200"
T =	0.20312"	TN =	0.30700"
TR =	0.13442"	TRN =	0.02540"
ET =	0.06870"	ETN =	0.28160"

MIN STD. WT. PIPE+C.A.= 0.37000" TR[using abs(P)]+C.A.= 0.13202"
 LIMITS= 12.02200"
 fr1= 1.0000 fr2= 1.0000 fr3= 1.0000 fr4= 1.0000 F= 1.00000
 Min weld sizes: NS= 0.0000" NP= 0.3039" PS= 0.1436" IF= 0.0000"

AREA REQD.	A =	0.40401in ²	
EXCESS IN CYL.	A1=	0.41296in ²	
EXCESS IN NOZ.(OUTSIDE)	A2=	0.28600in ²	H = 0.50781"
AREA OF FILLETS	=	0.14062in ²	
AREA AVAILABLE	=	0.83958in ²	

NOZ. NECK WELD= 0.37500" AREA= 0.14062in²

PAD MATL.= SA-516-70 S= 20000.psi
 PAD O.D.= 13.62500" THK.= 0.50000" AREA= 2.69850in²
 PAD TO CYL. WELD= 0.50000" AREA= 0.00000in²
 ARC= 6.831"
 PAD RET. DIM.= 13.625" X 13.875"

< AREA REQD-AREA AVAILABLE > = -3.13407in²

All Weld Paths are stronger than the required strength /[UG-41 UG-45 UW-15]

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

STRESSES DUE TO NOZZLE LOADINGS/WRC BULLETIN 107
(6"-600# RF WN SHELL SIDE INLET & OUTLET)

(ALL LOADS IN LBS; ALL MOMENTS FT-LBS; ALL STRESSES IN PSI; ALL DIMENSIONS in.)

CYLINDER O.D. = 16.0000 CYLINDER THICKNESS = 0.3281 CA=0.12500
 NOZZLE O.D. = 6.6250 PAD THICKNESS = 0.5000 P= 375.00
 RADIAL LOAD P = -2100. SHEAR LOAD VC = 2625. SHEAR LOAD VL = 2625.
 CIRC. MOMENT MC= 4005. LONG MOMENT ML= 5070. TORSIONAL MOMENT MT= 6465.
 STRESS CONCENTRATION FACTORS: MEMBRANE LOAD = 1.0000 BENDING LOAD = 1.0000
 GEOMETRIC PARAMETERS; GAMMA = 11.5888 BETA = 0.3557

AU	AL	BU	BL	CU	CL	DU	DL	VALUE FROM CURVE
-609.	-609.	-609.	-609.	-424.	-424.	-424.	-424.	1.662/ 1.157
-885.	885.	-885.	885.	-1456.	1456.	-1456.	1456.	0.035/ 0.057
0.	0.	0.	0.	1450.	1450.	-1450.	-1450.	0.5010
0.	0.	0.	0.	16180.	-16180.	-16180.	16180.	0.0804
-5131.	-5131.	5131.	5131.	0.	0.	0.	0.	1.4004
-6731.	6731.	6731.	-6731.	0.	0.	0.	0.	0.0264

								SUMMATION
-13355.	1875.	10367.	-1325.	15750.	-13698.	-19511.	15763.	CIRC. STRESSES

-424.	-424.	-424.	-424.	-609.	-609.	-609.	-609.	1.157/ 1.662
-1456.	1456.	-1456.	1456.	-885.	885.	-885.	885.	0.057/ 0.035
0.	0.	0.	0.	2995.	2995.	-2995.	-2995.	1.0350
0.	0.	0.	0.	8275.	-8275.	-8275.	8275.	0.0411
-1891.	-1891.	1891.	1891.	0.	0.	0.	0.	0.5161
-11676.	11676.	11676.	-11676.	0.	0.	0.	0.	0.0458

								SUMMATION
-15447.	10818.	11686.	-8753.	9776.	-5004.	-12764.	5555.	LONG. STRESSES

1600.	1600.	1600.	1600.	1600.	1600.	1600.	1600.	
359.	359.	-359.	-359.	0.	0.	0.	0.	
0.	0.	0.	0.	-359.	-359.	359.	359.	

								SUMMATION
1959.	1959.	1242.	1242.	1242.	1242.	1959.	1959.	SHEAR STRESSES

								COMBINED STRS.
16622.	11228.	12433.	8955.	15998.	13872.	20039.	16126.	INTENSITY

PRESSURE STRESSES: CIRCUMFERENTIAL=				4383.		LONGITUDINAL=		2004.

								COMBINED STRS.
15182.	13362.	15571.	10117.	20314.	10552.	16880.	20444.	INTENSITY@PRES

MAXIMUM STRESS =				20444.				
DESIGN STRESS =				17100.				
DESIGN FACTOR =				3.0000				
ALLOWABLE STRESS =				51300.				

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

UG-44(b)REDUCED EQUIVALENT PRESSURE DUE TO MOMENTS AND LOADS FOR NOZZLE NO. 1/2
(6"-600# RF WN SHELL INLET & OUTLET)

ALL LOADS IN LBS; ALL MOMENTS FT-LBS; ALL STRESSES IN PSI; ALL DIMENSIONS in.
LEFT AND RIGHT SIDE EQUATION VALUES ARE IN IN-LB

DESIGN PRESSURE = 375.0 DESIGN TEMP (F)= 300.0 FLG P/T RATING = 1310.0
NOM. NOZ. DIAMETER = 6 NOZ FLG RATING = 600 MATERIAL = SA-105
CIRUM. MOMENT= 6860.0 LONG. MOMENT= 8700.0 AXIAL LOAD = 3580.0
GASKET TYPE = SW GASKET O.D. = 8.2500 GASKET I.D. = 6.8800
GASKET G DIM. = 7.7848

OUTPUT:

Me (RESULTANT COMB MOMENT)= 11079.2 Fm (MOMENT FACTOR, TABLE UG-44-1)= 0.5
PE (EQUIVALENT PRESSURE) = 1510.5 PD+PE (TOTAL EQUIVALENT PRES)= 1885.5
ALLOWABLE COMB PRESSURE) = 1965.0
LEFT SIDE EQ. IN UG-44(b)(4)= 2238692. RIGHT SIDE EQ IN UG-44(b)(4)= 2356587.

Equation satisfied, nozzle flange is adequate

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

NOZZLE REINFORCEMENT CALCULATIONS/ ASME SEC.VIII DIV.I UG-37 & UG-16

NOZ NO= 17/18 2.00" 300 LB RF LWN
 [AUX. A3/A4] SHELL SIDE
 PRESSURE = 375.0psig TEMP = 300.0deg.F

```

-----CYLINDER-----NOZZLE-----
SA-106-B                      SA-350LF2CL1
OPER STRS= 17100.0 psi        OPER STRS= 20000.0 psi
ATM STRS = 17100.0 psi        ATM STRS = 20000.0 psi
C.A.      = 0.12500"          C.A.      = 0.12500"
I.D.      = 5.76100"          I.D.      = 2.00000"
O.D.      = 6.62500"          O.D.      = 3.31250"
THK.      = 0.43200"          THK.      = 0.65625"
T         = 0.30700"          TN         = 0.53125"
TR        = 0.06679"          TRN        = 0.02133"
ET        = 0.24021"          ETN        = 0.50992"
    
```

MIN STD. WT. PIPE+C.A.= 0.25975" TR+C.A.= 0.19179"
 LIMITS= 4.50000"
 fr1= 1.0000 fr2= 1.0000 fr3= 0.0000 fr4= 0.0000 F= 1.00000
 Min weld sizes: NS= 0.3039" NP= 0.0000" PS= 0.0000" IF= 0.0000"

AREA REQD. A = 0.15028in^2
 EXCESS IN CYL. A1= 0.54048in^2
 EXCESS IN NOZ.(OUTSIDE) A2= 0.78272in^2 H = 0.76750"
 AREA OF FILLETS = 0.14062in^2
 AREA AVAILABLE = 1.46382in^2

NOZ. NECK WELD= 0.37500" AREA= 0.14062in^2

< AREA REQD-AREA AVAILABLE > = -1.31355in^2

MAWP N-C= 2352.0psig LIMITED BY SHELL TK
 MAWP COR= 1645.0psig LIMITED BY SHELL TK

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

NOZZLE REINFORCEMENT CALCULATIONS/ ASME SEC.VIII DIV.I UG-37 & UG-16

NOZ NO= 17/18 2.00" 300 LB RF LWN
 [AUX. A3/A4] SHELL SIDE EXT. PRESS. CASE
 PRESSURE = -15.0psig TEMP = 300.0deg.F

```

-----CYLINDER-----NOZZLE-----
SA-106-B                      SA-350LF2CL1
OPER STRS= 17100.0 psi        OPER STRS= 20000.0 psi
ATM STRS = 17100.0 psi        ATM STRS = 20000.0 psi
C.A.      = 0.12500"          C.A.      = 0.12500"
I.D.      = 5.76100"          I.D.      = 2.00000"
O.D.      = 6.62500"          O.D.      = 3.31250"
THK.      = 0.43200"          THK.      = 0.65625"
T         = 0.30700"          TN         = 0.53125"
TR         = 0.05860"          TRN        = 0.01695"
ET         = 0.24840"          ETN        = 0.51430"
    
```

MIN STD. WT. PIPE+C.A.= 0.25975" TR[using abs(P)]+C.A.= 0.12764"
 LIMITS= 4.50000"
 fr1= 1.0000 fr2= 1.0000 fr3= 0.0000 fr4= 0.0000 F= 1.00000
 Min weld sizes: NS= 0.3039" NP= 0.0000" PS= 0.0000" IF= 0.0000"

AREA REQD. A = 0.06593in^2
 EXCESS IN CYL. A1= 0.55890in^2
 EXCESS IN NOZ.(OUTSIDE) A2= 0.78945in^2 H = 0.76750"
 AREA OF FILLETS = 0.14062in^2
 AREA AVAILABLE = 1.48898in^2

NOZ. NECK WELD= 0.37500" AREA= 0.14062in^2

< AREA REQD-AREA AVAILABLE > = -1.42305in^2

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

NOZZLE REINFORCEMENT CALCULATIONS/ ASME SEC.VIII DIV.I UG-37 & UG-16
 NOZ NO=11/12 3.00" 600 LB RF LWN
 [INLET & OUTLET] FRONT CHANNEL SIDE
 PRESSURE = 400.0psig TEMP = 330.0deg.F
 OFFSET VERTICAL NOZZLE: OFFSET = 3.00000"

-----CYLINDER-----NOZZLE-----
 SA-106-B SA-350LF2CL1
 OPER STRS= 17100.0 psi OPER STRS= 20000.0 psi
 ATM STRS = 17100.0 psi ATM STRS = 20000.0 psi
 C.A. = 0.12500" C.A. = 0.12500"
 I.D. = 15.34375" I.D. = 3.00000"
 O.D. = 16.00000" O.D. = 4.62500"
 THK. = 0.32812" THK. = 0.81250"
 T = 0.20312" TN = 0.68750"
 TR = 0.18540" TRN = 0.03289"
 ET = 0.01773" ETN = 0.65461"

MIN STD. WT. PIPE+C.A.= 0.31400" TR+C.A.= 0.31040"
 LIMITS= 6.50000"
 fr1= 1.0000 fr2= 1.0000 fr3= 1.0000 fr4= 1.0000 F= 1.00000
 Min weld sizes:NS= 0.0000" NP= 0.3536" PS= 0.1436" IF= 0.0000"

AREA REQD. A = 0.60255in^2
 EXCESS IN CYL. A1= 0.05761in^2
 EXCESS IN NOZ.(OUTSIDE) A2= 0.66483in^2 H = 0.50781"
 AREA OF FILLETS = 0.14062in^2
 AREA AVAILABLE = 0.86307in^2

NOZ. NECK WELD= 0.37500" AREA= 0.14062in^2

PAD MATL.= SA-516-70 S= 20000.psi
 PAD O.D.= 8.62500" THK.= 0.50000" AREA= 0.93750in^2
 PAD TO CYL. WELD= 0.37500" AREA= 0.00000in^2
 ARC= 5.122"
 PAD RET. DIM.= 8.625" X 9.125"

< AREA REQD-AREA AVAILABLE > = -1.19802in^2

MAWP N-C= 1148.0psig LIMITED BY AR
 MAWP COR= 894.0psig LIMITED BY AR

All Weld Paths are stronger than the required strength /[UG-41 UG-45 UW-15]

RE-PAD REQUIRED DUE TO NOZZLE LOADS

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

NOZZLE REINFORCEMENT CALCULATIONS/ ASME SEC.VIII DIV.I UG-37 & UG-16
 NOZ NO=11/12 3.00" 600 LB RF LWN
 [INLET & OUTLET] FRONT CHANNEL SIDE EXT. PRESS CASE
 PRESSURE = -15.0psig TEMP = 330.0deg.F
 OFFSET VERTICAL NOZZLE: OFFSET = 3.00000"

```

-----CYLINDER-----NOZZLE-----
SA-106-B                      SA-350LF2CL1
OPER STRS= 17100.0 psi        OPER STRS= 20000.0 psi
ATM STRS = 17100.0 psi        ATM STRS = 20000.0 psi
C.A.      = 0.12500"          C.A.      = 0.12500"
I.D.      = 15.34375"         I.D.      = 3.00000"
O.D.      = 16.00000"         O.D.      = 4.62500"
THK.      = 0.32812"          THK.      = 0.81250"
T          = 0.20312"          TN         = 0.68750"
TR         = 0.05932"          TRN        = 0.02050"
ET         = 0.14380"          ETN        = 0.66700"

```

MIN STD. WT. PIPE+C.A.= 0.31400" TR[using abs(P)]+C.A.= 0.13202"
 LIMITS= 6.50000"
 fr1= 1.0000 fr2= 1.0000 fr3= 1.0000 fr4= 1.0000 F= 1.00000
 Min weld sizes:NS= 0.0000" NP= 0.3536" PS= 0.1436" IF= 0.0000"

AREA REQD. A = 0.09640in^2
 EXCESS IN CYL. A1= 0.46735in^2
 EXCESS IN NOZ.(OUTSIDE) A2= 0.67742in^2 H = 0.50781"
 AREA OF FILLETS = 0.14062in^2
 AREA AVAILABLE = 1.28540in^2

NOZ. NECK WELD= 0.37500" AREA= 0.14062in^2

PAD MATL.= SA-516-70 S= 20000.psi
 PAD O.D.= 8.62500" THK.= 0.50000" AREA= 0.93750in^2
 PAD TO CYL. WELD= 0.37500" AREA= 0.00000in^2
 ARC= 5.122"
 PAD RET. DIM.= 8.625" X 9.125"

< AREA REQD-AREA AVAILABLE > = -2.12649in^2

All Weld Paths are stronger than the required strength /[UG-41 UG-45 UW-15]

RE-PAD REQUIRED DUE TO NOZZLE LOADS

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

STRESSES DUE TO NOZZLE LOADINGS/WRC BULLETIN 107
(3"-600# RF LWN TUBE SIDE INLET & OUTLET)

(ALL LOADS IN LBS; ALL MOMENTS FT-LBS; ALL STRESSES IN PSI; ALL DIMENSIONS in.)

CYLINDER O.D. = 16.0000 CYLINDER THICKNESS = 0.3281 CA=0.12500
 NOZZLE O.D. = 4.6250 PAD THICKNESS = 0.5000 P= 400.00
 RADIAL LOAD P = -1480. SHEAR LOAD VC = 1860. SHEAR LOAD VL = 1860.
 CIRC. MOMENT MC= 1900. LONG MOMENT ML= 1500. TORSIONAL MOMENT MT= 2420.
 STRESS CONCENTRATION FACTORS: MEMBRANE LOAD = 1.0000 BENDING LOAD = 1.0000
 GEOMETRIC PARAMETERS; GAMMA = 11.5888 BETA = 0.2483

AU	AL	BU	BL	CU	CL	DU	DL	VALUE FROM CURVE
489.	489.	489.	489.	401.	401.	401.	401.	1.893/ 1.551
1069.	-1069.	1069.	-1069.	1570.	-1570.	1570.	-1570.	0.060/ 0.087
0.	0.	0.	0.	809.	809.	-809.	-809.	0.4111
0.	0.	0.	0.	12033.	-12033.	-12033.	12033.	0.0880
-2103.	-2103.	2103.	2103.	0.	0.	0.	0.	1.3546
-4043.	4043.	4043.	-4043.	0.	0.	0.	0.	0.0375

								SUMMATION
-4588.	1360.	7705.	-2520.	14812.	-12394.	-10871.	10055.	CIRC. STRESSES

401.	401.	401.	401.	489.	489.	489.	489.	1.551/ 1.893
1570.	-1570.	1570.	-1570.	1069.	-1069.	1069.	-1069.	0.087/ 0.060
0.	0.	0.	0.	1507.	1507.	-1507.	-1507.	0.7661
0.	0.	0.	0.	6601.	-6601.	-6601.	6601.	0.0483
-648.	-648.	648.	648.	0.	0.	0.	0.	0.4172
-6767.	6767.	6767.	-6767.	0.	0.	0.	0.	0.0627

								SUMMATION
-5444.	4950.	9386.	-7289.	9665.	-5674.	-6549.	4514.	LONG. STRESSES

1229.	1229.	1229.	1229.	1229.	1229.	1229.	1229.	
364.	364.	-364.	-364.	0.	0.	0.	0.	
0.	0.	0.	0.	-364.	-364.	364.	364.	

								SUMMATION
1593.	1593.	865.	865.	865.	865.	1593.	1593.	SHEAR STRESSES

								COMBINED STRS.
6666.	5555.	9751.	7441.	14954.	12504.	11395.	10481.	INTENSITY

PRESSURE STRESSES: CIRCUMFERENTIAL=				4676.		LONGITUDINAL=		2138.

								COMBINED STRS.
5006.	8240.	12917.	7508.	19584.	8959.	8198.	15033.	INTENSITY@PRES

MAXIMUM STRESS				=		19584.		
YIELD				=		17100.		
YIELD FACTOR				=		3.0000		
ALLOWABLE STRESS				=		51300.		

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

UG-44(b)REDUCED EQUIVALENT PRESSURE DUE TO MOMENTS AND LOADS FOR NOZZLE NO.11
 (3"-600# RF LWN CHAN. IN & OUT)
 ALL LOADS IN LBS; ALL MOMENTS FT-LBS; ALL STRESSES IN PSI; ALL DIMENSIONS in.
 LEFT AND RIGHT SIDE EQUATION VALUES ARE IN IN-LB

DESIGN PRESSURE = 400.0 DESIGN TEMP (F)= 330.0 FLG P/T RATING = 1296.5
 NOM. NOZ. DIAMETER = 3 NOZ FLG RATING = 600 MATERIAL = SA-350LF2CL1
 CIRCUM. MOMENT= 1360.0 LONG. MOMENT= 1080.0 AXIAL LOAD = 1480.0
 GASKET TYPE = SW GASKET O.D. = 4.7500 GASKET I.D. = 4.0000
 GASKET G DIM. = 4.3750

OUTPUT:

Me (RESULTANT COMB MOMENT)= 1736.7 Fm (MOMENT FACTOR, TABLE UG-44-1)= 0.5
 PE (EQUIVALENT PRESSURE) = 1365.9 PD+PE (TOTAL EQUIVALENT PRES)= 1765.9
 ALLOWABLE COMB PRESSURE) = 1944.8 MAX ALLOWABLE PRESSURE = 578.8
 LEFT SIDE EQ. IN UG-44(b)(4)= 359339. RIGHT SIDE EQ IN UG-44(b)(4)= 406389.

Equation satisfied, nozzle flange is adequate

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

NOZZLE REINFORCEMENT CALCULATIONS/ ASME SEC.VIII DIV.I UG-37 & UG-16
 NOZ NO=13/14 2.00" 300 LB RF LWN
 [VENT & DRAIN] FRONT CHANNEL SIDE
 PRESSURE = 400.0psig TEMP = 330.0deg.F
 OFFSET VERTICAL NOZZLE: OFFSET = 2.50000"

```

-----CYLINDER-----NOZZLE-----
SA-106-B                      SA-350LF2CL1
OPER STRS= 17100.0 psi        OPER STRS= 20000.0 psi
ATM STRS = 17100.0 psi        ATM STRS = 20000.0 psi
C.A.      = 0.12500"          C.A.      = 0.12500"
I.D.      = 15.34375"         I.D.      = 2.00000"
O.D.      = 16.00000"         O.D.      = 3.31250"
THK.      = 0.32812"          THK.      = 0.65625"
T          = 0.20312"          TN          = 0.53125"
TR         = 0.18540"          TRN        = 0.02277"
ET         = 0.01773"          ETN        = 0.50848"
  
```

MIN STD. WT. PIPE+C.A.= 0.25975" TR+C.A.= 0.31040"
 LIMITS= 4.50000"
 fr1= 1.0000 fr2= 1.0000 fr3= 0.0000 fr4= 0.0000 F= 1.00000
 Min weld sizes: NS= 0.2011" NP= 0.0000" PS= 0.0000" IF= 0.0000"

AREA REQD. A = 0.41715in^2
 EXCESS IN CYL. A1= 0.03988in^2
 EXCESS IN NOZ.(OUTSIDE) A2= 0.51642in^2 H = 0.50781"
 AREA OF FILLETS = 0.14062in^2
 AREA AVAILABLE = 0.69693in^2

NOZ. NECK WELD= 0.37500" AREA= 0.14062in^2

< AREA REQD-AREA AVAILABLE > = -0.27978in^2

MAWP N-C= 713.0psig LIMITED BY SHELL TK
 MAWP COR= 438.0psig LIMITED BY SHELL TK

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

NOZZLE REINFORCEMENT CALCULATIONS/ ASME SEC.VIII DIV.I UG-37 & UG-16
 NOZ NO=13/14 2.00" 300 LB RF LWN
 [VENT & DRAIN] FRONT CHANNEL SIDE EXT. PRESS. CASE
 PRESSURE = -15.0psig TEMP = 300.0deg.F
 OFFSET VERTICAL NOZZLE: OFFSET = 2.50000"

```

-----CYLINDER-----NOZZLE-----
SA-106-B                      SA-350LF2CL1
OPER STRS= 17100.0 psi        OPER STRS= 20000.0 psi
ATM STRS = 17100.0 psi        ATM STRS = 20000.0 psi
C.A.      = 0.12500"          C.A.      = 0.12500"
I.D.      = 15.34375"         I.D.      = 2.00000"
O.D.      = 16.00000"         O.D.      = 3.31250"
THK.      = 0.32812"          THK.      = 0.65625"
T          = 0.20312"          TN         = 0.53125"
TR         = 0.04522"          TRN        = 0.01695"
ET         = 0.15790"          ETN        = 0.51430"

```

MIN STD. WT. PIPE+C.A.= 0.25975" TR[using abs(P)]+C.A.= 0.13202"
 LIMITS= 4.50000"
 fr1= 1.0000 fr2= 1.0000 fr3= 0.0000 fr4= 0.0000 F= 1.00000
 Min weld sizes: NS= 0.2011" NP= 0.0000" PS= 0.0000" IF= 0.0000"

AREA REQD. A = 0.05088in^2
 EXCESS IN CYL. A1= 0.35528in^2
 EXCESS IN NOZ.(OUTSIDE) A2= 0.52234in^2 H = 0.50781"
 AREA OF FILLETS = 0.14062in^2
 AREA AVAILABLE = 1.01824in^2

NOZ. NECK WELD= 0.37500" AREA= 0.14062in^2

< AREA REQD-AREA AVAILABLE > = -0.96736in^2

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

NOZZLE REINFORCEMENT CALCULATIONS/ ASME SEC.VIII DIV.I UG-37 & UG-16
 NOZ NO=14/15 2.00" 300 LB RF LWN
 [AUX. A1/A2] FRONT CHANNEL SIDE
 PRESSURE = 400.0psig TEMP = 330.0deg.F
 OFFSET VERTICAL NOZZLE: OFFSET = 2.50000"

-----CYLINDER-----NOZZLE-----
 SA-350LF2CL1 SA-105
 OPER STRS= 20000.0 psi OPER STRS= 20000.0 psi
 ATM STRS = 20000.0 psi ATM STRS = 20000.0 psi
 C.A. = 0.12500" C.A. = 0.12500"
 I.D. = 3.00000" I.D. = 2.00000"
 O.D. = 4.62500" O.D. = 3.31250"
 THK. = 0.81250" THK. = 0.65625"
 T = 0.68750" TN = 0.53125"
 TR = 0.03289" TRN = 0.02277"
 ET = 0.65461" ETN = 0.50848"

MIN STD. WT. PIPE+C.A.= 0.25975" TR+C.A.= 0.15789"
 LIMITS= 4.68750"
 fr1= 1.0000 fr2= 1.0000 fr3= 0.0000 fr4= 0.0000 F= 1.00000
 Min weld sizes: NS= 0.3536" NP= 0.0000" PS= 0.0000" IF= 0.0000"

AREA REQD. A = 0.07401in^2
 EXCESS IN CYL. A1= 1.59560in^2
 EXCESS IN NOZ.(OUTSIDE) A2= 1.35064in^2 H = 1.32812"
 AREA OF FILLETS = 0.14062in^2
 AREA AVAILABLE = 3.08687in^2

NOZ. NECK WELD= 0.37500" AREA= 0.14062in^2

< AREA REQD-AREA AVAILABLE > = -3.01285in^2

NOTE: [LARGE DIAMETER OPENING] Rn/R= 0.6923
 2/3 OF REINFORCEMENT(AREA REQD)= 0.04934"
 LIMITS FOR 2/3 OF REINFORCEMENT= 4.68750"
 AREA AVAILABLE = 3.08687in^2
 < AREA REQD-AREA AVAILABLE > = -3.03752in^2

MAWP N-C= 6936.0psig LIMITED BY AR
 MAWP COR= 5146.0psig LIMITED BY AR

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

NOZZLE REINFORCEMENT CALCULATIONS/ ASME SEC.VIII DIV.I UG-37 & UG-16
 NOZ NO=14/15 2.00" 300 LB RF LWN
 [AUX. A1/A2] FRONT CHANNEL SIDE EXT. PRESS. CASE
 PRESSURE = -15.0psig TEMP = 330.0deg.F
 OFFSET VERTICAL NOZZLE: OFFSET = 2.50000"

-----CYLINDER-----		-----NOZZLE-----	
SA-350LF2CL1		SA-105	
OPER STRS=	20000.0 psi	OPER STRS=	20000.0 psi
ATM STRS =	20000.0 psi	ATM STRS =	20000.0 psi
C.A. =	0.12500"	C.A. =	0.12500"
I.D. =	3.00000"	I.D. =	2.00000"
O.D. =	4.62500"	O.D. =	3.31250"
THK. =	0.81250"	THK. =	0.65625"
T =	0.68750"	TN =	0.53125"
TR =	0.02890"	TRN =	0.01695"
ET =	0.65860"	ETN =	0.51430"

MIN STD. WT. PIPE+C.A.= 0.25975" TR[using abs(P)]+C.A.= 0.12622"
 LIMITS= 4.68750"
 fr1= 1.0000 fr2= 1.0000 fr3= 0.0000 fr4= 0.0000 F= 1.00000
 Min weld sizes:NS= 0.3536" NP= 0.0000" PS= 0.0000" IF= 0.0000"

AREA REQD.	A =	0.03251in^2	
EXCESS IN CYL.	A1=	1.60534in^2	
EXCESS IN NOZ.(OUTSIDE)	A2=	1.36611in^2	H = 1.32812"
AREA OF FILLETS	=	0.14062in^2	
AREA AVAILABLE	=	3.11207in^2	

NOZ. NECK WELD= 0.37500" AREA= 0.14062in^2

< AREA REQD-AREA AVAILABLE > = -3.07956in^2

NOTE: [LARGE DIAMETER OPENING] Rn/R= 0.6923
 2/3 OF REINFORCEMENT(AREA REQD)= 0.02168"
 LIMITS FOR 2/3 OF REINFORCEMENT= 4.68750"
 AREA AVAILABLE = 3.11207in^2
 < AREA REQD-AREA AVAILABLE > = -3.09039in^2

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

ASME SEC.VIII DIV.1 APPENDIX 2 Front Channel to cover flange

DESIGN CONDITIONS GASKET and BOLTING CALCULATIONS TABLE

Design Pres= 400.0 psig Eff.Gsk OD= 17.0000" No.Passes= 4

Neg. Pres= 15.0 psig Eff.Gsk ID= 16.2500" N= 0.375"

Design Temp= 330 deg.F THK= 0.1750" col.=2 b= 0.188

Flg Matl=SA-350LF2CL1 Gsk Matl=316 SW-GPHT CGI y= 10000psi

Bolt Matl=SA-193-B7 Gsk Face=FLAT FACE w= 0.0000" m= 3.000

Corr Allow= 0.1250" Wm2= 201523 # Am = 8.3102in^2

Flange Desn Sfo 20000.0 psi Hp = 48365 # Ab = 11.7320in^2

Atm. Sfa 20000.0 psi H = 86830 # W = 250527 #

Bolting Desn Sb 25000.0 psi Wm1= 135196 # Wm1= 135196 #

Atm. Sa 25000.0 psi Gasket Width Check Nmin = 0.2808"

CONDITION LOAD x LEVER ARM = MOMENT

HD = 75476 # hD= 1.68750" MD= 127366 in#

Operating HG = 48365 # hG= 1.31250" MG= 63479 in#

HT = 11353 # hT= 1.59375" MT= 18095 in#

Mo= 208941 in#

Gasket

Seating HG = 250527 # hG= 1.31250" mo= 328817 in#

Allow.Stress-STRESS CALCULATIONS-Operating SHAPE CONSTANTS

1.5 Sfo&2.5 Sno Long Hub,SH 13305.3 psi K = 1.3629 h/ho= 0.6350

Sfo Radial Flg,SR 672.5 psi T = 1.7703 F = 0.8305

Sfo Tang Flg,ST 10339.0 psi Z = 3.3323 V = 0.2891

Sfo .5(SH+SR)or.5(SH+ST) 11822.1 psi Y = 6.4305 f = 1.0000

J(APP.2-14)= 0.4233 U = 7.0664 e = 0.4219in^-1

Allow.Stress-STRESS CALCULATIONS-Gsk.Seating g1/go= 1.5000 d = 3.008In^3

1.5 Sfa&2.5 Sna Long Hub,SH 20938.9 psi ho = 1.9685"

Sfa Radial Flg,SR 1058.3 psi

Sfa Tang Flg,ST 16270.7 psi

Sfa .5(SH+SR)or.5(SH+ST) 18604.8 psi

J(APP.2-14)= 0.6383

OTHER STRESS FORMULA FACTORS

t 2.6250"

Alpha 2.1074

Beta 2.4766

Gamma 1.1904

Delta 6.0141

Lambda 7.2046

M 13480 #

m 21214 #

(A) 1/8" FUTURE MACHINING ALLOWANCE

O.D. = 21.1250" THK. = 2.9375"

I.D. = 15.2500" T-Adder = 0.1250" (A)

GO = 0.3750" G1 = 0.5000"

HUB O.D. = 16.2500" HUB LEN = 1.2500"

HUB ANG = 5.7106deg RIB LENGTH = 27.6250"

G(MEAN) = 16.6250" G(CALC) = 16.6250"

B.C. = 19.2500" B.S.C.F. = 1.0000

No. BOLTS = 28 BOLT DIAMETER = 0.8750"

R = 1.5000" E = 0.9375"

BOLT SPAC = 2.1553" TORQUE = 155ft#

MIN. SPAC = 2.0625" TEMA MAX. SPAC= 6.2500"

FLG TURN = 0.1875" FACING = RECESS

BPRIME = 0.0000" BG1 = 0.0000"

FLG RWT = 199Lbs FLG FWT = 139Lbs

Flange stress factor=0.9700 Bolting stress factor=0.9700

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

///// FRONT COVER CALCULATIONS /////

EXCHANGER TYPE....= A E U MATERIAL.....= SA-516-70
 PRESSURE.....= 400.0 psig CORROSION ALLOWANCE= 0.1250"
 TURN LOW.....= 0.1875" TURN HIGH.....= 0.2500"
 S COVER STRESS...= 20000.0 psi E.....= 1.0
 Sb STRESS BOLTS..= 25000.0 psi Ab.....= 11.7320 in^2
 d.....= 16.6250" C.....= 0.3000
 W.....= 250527 # Wm1.....= 135196 #
 hG (ASME).....= 1.3125" hG (TEMA).....= 1.3125"
 G (TEMA).....= 16.6250" E (MOD.) x (10)-6..= 28.0 psi
 COVER THK SET HOLD= [NO]

[PER ASME SECT.VIII UG-34 USING Wm1 (OPERATING)]

$$THK = d - \frac{\frac{C P}{S E} + \frac{1.9 Wm1 hG}{S E d^3}}{\frac{C P}{S E} + \frac{1.9 Wm1 hG}{S E d^3}} = 1.6347"$$

[PER ASME SECT.VIII UG-34 USING W (GASKET SEATING)]

$$THK = d - \frac{\frac{1.9 W hG}{S E d^3}}{\frac{1.9 W hG}{S E d^3}} = 1.3708"$$

[PER TEMA RCB-9.2 FLAT CHANNEL COVER]

MAXIMUM DEFLECTION = 0.0300"
 DEFLECTION at 1.7539" THICK = 0.0300"

$$Y = \frac{G}{E (1.812)^3} \frac{0.0435 G^3 P + 0.5 Sb Ab hG}{E (1.812)^3} = 0.0272"$$

[COV THK Min] TEMA Deflection = 1.7539" + 0.1875" = 1.9414"
 [COV THK Min] CODE Operating = 1.6347" + 0.1875" = 1.8222"
 [COV THK Min] CODE Gasket Seating = 1.3708" + 0.1875" = 1.5583"
 ACTUAL COVER THICKNESS USED (SET HOLD[NO])= 2.0000" (B)

(B) TOTAL THK. INCLUDING 1/8" FUTURE MACHINING ALLOWANCE = 2 1/8"

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

MAIN FLG IS FLANGE MARK # 2
 COMP FLG IS FLANGE MARK # 0

/// INDIVIDUAL COMPONENTS ///

MAWP CORR. MAIN FLG = 632.0 Limited by: Go
 MAWP CORR. COVER = 491.0

MAWP N-C MAIN FLG = 677.0 Limited by: Flange stress.
 MAWP N-C COVER = 491.0

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Bolting/Gasket Assembly Stress per API-660, ASME PCC-1 App. O,WRC Bulletin 538
Front Channel to Cover Flange

Input Data-----

Sgmax, Max. Gskt Stress (psi) 55000. Sgmin-s,Min. Gskt Stress(psi) 20000.
Sgmin-o,Min Gskt Op Str (psi) 14000. Bolt Yield Str (Ambient)(psi) 105000.
Sbmax, Max. Bolt Stress (psi) 73500. Sbmin, Min. Bolt Stress (psi) 42000.
K, Nut Friction Factor 0.20 Gasket Relaxation Factor 0.70

Flange Design Data-----

Design Press.(psi) 400. Number of Studs 28. Bolt Dia. (in.) 0.8750
Blt Amb Alw(psi) 25000. Blt Amb Yld (psi) 105000. Flg Amb Yld(psi) 36000.
Mo (flg)(in-lb) 208942. hg (flange) (in.) 1.3125 Tot Blt Area(in2) 11.73
Gskt O.D. (in.) 17.0000 Gasket I.D. (in.) 16.2500 Gskt Rib Area(in2) 10.4
h(fl g hub)(in.) 1.2500 h0 (flange) (in.) 1.9685 Tot Gskt Area(in2) 29.9
g0 (flg-cor)(in.) 0.2500 g1 (flg-cor)(in.) 0.3750 f (flange) 1.0000
SH (flg) (psi) 13305. SR (flg) (psi) 672. ST (flg) (psi) 10339.

Analysis from WRC Bulletin 538-----

g1/g0 (flange) 1.50000 h/ho (flange) 0.63500 f2 (App B) 0.29714

Sfmax-Bolt Str for Flange(psi) 61976. Mod. Mo for Flg Str (in-lb) 954326.

Stress (psi)	Allowable Stress (psi)
Long. Hub Stress (Mod.) at Hub/Flg (Sh/f)	60771.
Long. Hub Stress at Hub/Flg Junction (Sh)	60771. (2.0XSyf) 72000.
Radial Stress at Hub/Flg. Junction (Sr)	3072. (2.0XSyf) 72000.
Tangential Stress at Hub/Flg Junction (St)	47222. (1.5XSyf) 54000.
Tangential Stress at Hub/Flg Junction (Sto)	18058. (1.0XSyf) 36000.
Combined Stress at Hub/Flg Junction (Sh/f+St)	107993. (3.0XSyf) 108000.
Combined Stress at Hub/Flg Junction (Sr+St)	50294. (3.0XSyf) 108000.
Combined Stress at Hub/Shl Junction (Sh+Sto)	78828. (3.0XSyf) 108000.

Gasket Max Stress Check (Gasket Crushing) per 0-9-----

Sgbmax-Max Bolt Stress to Avoid Crushing Gasket (psi) 140384.

Upper Bolt Stress Limit-----

Max Bolt Str (Lesser: Sfmax,Sgbmax,Sbmax)(psi) 61976. Torque(ft-lb) 378.7

Gasket Assembly Seating Stress per (0-7)-----

Sbmin-s-Min Bolt Stress Reqd to Seat Gskt(psi) 51049.

Gasket Operating Stress per (0-8)-----

Sbmin-o-Min Blt Str to Keep Gskt Seat Op.(psi) 61150.

Lower Bolt Stress Limit-----

Min Bolt Str (Max.:Sbmin-s,Sbmin-o,Sbmin)(psi) 61150. Torque(ft-lb) 373.7

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

ASME SEC.VIII DIV.1 APPENDIX 2 Front chan to tubesheet flange

DESIGN CONDITIONS GASKET and BOLTING CALCULATIONS TABLE

Design Pres= 400.0 psig Eff.Gsk OD= 17.0000" No.Passes= 4

Neg. Pres= 15.0 psig Eff.Gsk ID= 16.2500" N= 0.375"

Design Temp= 330 deg.F THK= 0.1750" col.=2 b= 0.188

Flg Matl=SA-350LF2CL1 Gsk Matl=316 SW-GPHT CGI y= 10000psi

Bolt Matl=SA-193-B7 Gsk Face=FLAT FACE w= 0.0000" m= 3.000

Corr Allow= 0.1250" Wm2= 201523 # Am = 8.3102in^2

Flange Desn Sfo 20000.0 psi Hp = 48365 # Ab = 11.7320in^2

Atm. Sfa 20000.0 psi H = 86830 # W = 250527 #

Bolting Desn Sb 25000.0 psi Wm1= 135196 # Wm1= 135196 #

Atm. Sa 25000.0 psi Gasket Width Check Nmin = 0.2808"

CONDITION LOAD x LEVER ARM = MOMENT

HD = 75476 # hD= 1.68750" MD= 127366 in#

Operating HG = 48365 # hG= 1.31250" MG= 63479 in#

HT = 11353 # hT= 1.59375" MT= 18095 in#

Mo= 208941 in#

Gasket

Seating HG = 250527 # hG= 1.31250" mo= 328817 in#

Allow.Stress-STRESS CALCULATIONS-Operating SHAPE CONSTANTS

1.5 Sfo&2.5 Sno Long Hub,SH 13305.3 psi K = 1.3629 h/ho= 0.6350

Sfo Radial Flg,SR 672.5 psi T = 1.7703 F = 0.8305

Sfo Tang Flg,ST 10339.0 psi Z = 3.3323 V = 0.2891

Sfo .5(SH+SR)or.5(SH+ST) 11822.1 psi Y = 6.4305 f = 1.0000

J(APP.2-14)= 0.4233 U = 7.0664 e = 0.4219in^-1

Allow.Stress-STRESS CALCULATIONS-Gsk.Seating g1/go= 1.5000 d = 3.008In^3

1.5 Sfa&2.5 Sna Long Hub,SH 20938.9 psi ho = 1.9685"

Sfa Radial Flg,SR 1058.3 psi

Sfa Tang Flg,ST 16270.7 psi

Sfa .5(SH+SR)or.5(SH+ST) 18604.8 psi

J(APP.2-14)= 0.6383

OTHER STRESS FORMULA FACTORS

t 2.6250"

Alpha 2.1074

Beta 2.4766

Gamma 1.1904

Delta 6.0141

Lambda 7.2046

M 13480 #

m 21214 #

(A) 1/8" FUTURE MACHINING ALLOWANCE

O.D. = 21.1250" THK. = 2.9375"

I.D. = 15.2500" T-Adder = 0.1250" (A)

GO = 0.3750" G1 = 0.5000"

HUB O.D. = 16.2500" HUB LEN = 1.2500"

HUB ANG = 5.7106deg RIB LENGTH = 27.6250"

G(MEAN) = 16.6250" G(CALC) = 16.6250"

B.C. = 19.2500" B.S.C.F. = 1.0000

No. BOLTS = 28 BOLT DIAMETER = 0.8750"

R = 1.5000" E = 0.9375"

BOLT SPAC = 2.1553" TORQUE = 155ft#

MIN. SPAC = 2.0625" TEMA MAX. SPAC= 6.2500"

FLG TURN = 0.1875" FACING = RECESS

BPRIME = 0.0000" BG1 = 0.0000"

FLG RWT = 199Lbs FLG FWT = 139Lbs

Flange stress factor=0.9700 Bolting stress factor=0.9700

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

ASME SEC.VIII DIV.1 APPENDIX 2 Shell to tubesheet flange

DESIGN CONDITIONS GASKET and BOLTING CALCULATIONS TABLE
 Design Pres= 375.0 psig Eff.Gsk OD= 17.0000" No.Passes= 1
 Neg. Pres= 15.0 psig Eff.Gsk ID= 16.2500" N= 0.375"
 Design Temp= 300 deg.F THK= 0.1750" col.=2 b= 0.188
 Flg Matl=SA-350LF2CL1 Gsk Matl=316 SW-GPHT CGI y= 10000psi
 Bolt Matl=SA-193-B7 Gsk Face=FLAT FACE w= 0.0000" m= 3.000
 Corr Allow= 0.1250" Wm2= 201523 # Am = 8.3102in^2
 Flange Desn Sfo 20000.0 psi Hp = 22034 # Ab = 11.7320in^2
 Atm. Sfa 20000.0 psi H = 81403 # W = 250527 #
 Bolting Desn Sb 25000.0 psi Wm1= 135196 # Wm1= 135196 #
 Atm. Sa 25000.0 psi Gasket Width Check Nmin = 0.2808"
 CONDITION LOAD x LEVER ARM = MOMENT
 HD = 70759 # hD= 1.68750" MD= 119406 in#
 Operating HG = 53792 # hG= 1.31250" MG= 70602 in#
 HT = 10644 # hT= 1.59375" MT= 16964 in#
 Mo= 206973 in#

Gasket
 Seating HG = 250527 # hG= 1.31250" mo= 328817 in#
 Allow.Stress-STRESS CALCULATIONS-Operating SHAPE CONSTANTS
 1.5 Sfo&2.5 Sno Long Hub,SH 13179.9 psi K = 1.3629 h/ho= 0.6350
 Sfo Radial Flg,SR 666.1 psi T = 1.7703 F = 0.8305
 Sfo Tang Flg,ST 10241.6 psi Z = 3.3323 V = 0.2891
 Sfo .5(SH+SR)or.5(SH+ST) 11710.8 psi Y = 6.4305 f = 1.0000
 J(APP.2-14)= 0.4175 U = 7.0664 e = 0.4219in^-1
 Allow.Stress-STRESS CALCULATIONS-Gsk.Seating g1/go= 1.5000 d = 3.008In^3
 1.5 Sfa&2.5 Sna Long Hub,SH 20938.9 psi ho = 1.9685"
 Sfa Radial Flg,SR 1058.3 psi
 Sfa Tang Flg,ST 16270.7 psi OTHER STRESS FORMULA FACTORS
 Sfa .5(SH+SR)or.5(SH+ST) 18604.8 psi t 2.6250"
 J(APP.2-14)= 0.6383 Alpha 2.1074
 Beta 2.4766
 Gamma 1.1904
 Delta 6.0141
 Lambda 7.2046
 M 13353 #
 m 21214 #

(A) 1/8" FUTURE MACHINING ALLOWANCE

O.D. = 21.1250" THK. = 2.9375"
 I.D. = 15.2500" T-Adder = 0.1250" (A)
 GO = 0.3750" G1 = 0.5000"
 HUB O.D. = 16.2500" HUB LEN = 1.2500"
 HUB ANG = 5.7106deg RIB LENGTH = 0.0000"
 G(MEAN) = 16.6250" G(CALC) = 16.6250"
 B.C. = 19.2500" B.S.C.F. = 1.0000
 No. BOLTS = 28 BOLT DIAMETER = 0.8750"
 R = 1.5000" E = 0.9375"
 BOLT SPAC = 2.1553" TORQUE = 155ft#
 MIN. SPAC = 2.0625" TEMA MAX. SPAC= 6.2500"
 FLG TURN = 0.1875" FACING = RECESS
 BPRIME = 0.0000" BG1 = 0.0000"
 FLG RWT = 199Lbs FLG FWT = 139Lbs
 Flange stress factor=0.9700 Bolting stress factor=0.9700

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

MAIN FLG IS FLANGE MARK # 3
 COMP FLG IS FLANGE MARK # 7

/// INDIVIDUAL COMPONENTS ///

MAWP CORR. MAIN FLG = 632.0 Limited by: Go
 MAWP CORR. COMP FLG = 632.0 Limited by: Go

MAWP N-C MAIN FLG = 677.0 Limited by: Flange stress.
 MAWP N-C COMP FLG = 799.0 Limited by: Flange stress.

/// AS MATING FLANGES (NO VACCUUM INCLUDED) ///

MAWP CORR. MAIN FLG = 632.0
 MAWP CORR. COMP FLG = 632.0

MAWP N-C MAIN FLG = 677.0 Limited by: Flange stress.
 MAWP N-C COMP FLG = 681.0 Limited by: Flange stress.

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Bolting/Gasket Assembly Stress per API-660, ASME PCC-1 App. O,WRC Bulletin 538
Front Channel to Tubesheet Flange

Input Data-----

Sgmax, Max. Gskt Stress (psi) 55000. Sgmin-s,Min. Gskt Stress(psi) 20000.
Sgmin-o,Min Gskt Op Str (psi) 14000. Bolt Yield Str (Ambient)(psi) 105000.
Sbmax, Max. Bolt Stress (psi) 73500. Sbmin, Min. Bolt Stress (psi) 42000.
K, Nut Friction Factor 0.20 Gasket Relaxation Factor 0.70

Flange Design Data-----

Design Press.(psi) 400. Number of Studs 28. Bolt Dia. (in.) 0.8750
Blt Amb Alw(psi) 25000. Blt Amb Yld (psi) 105000. Flg Amb Yld(psi) 36000.
Mo (flg)(in-lb) 208942. hg (flange) (in.) 1.3125 Tot Blt Area(in2) 11.73
Gskt O.D. (in.) 17.0000 Gasket I.D. (in.) 16.2500 Gskt Rib Area(in2) 10.4
h(flg hub)(in.) 1.2500 h0 (flange) (in.) 1.9685 Tot Gskt Area(in2) 29.9
g0 (flg-cor)(in.) 0.2500 g1 (flg-cor)(in.) 0.3750 f (flange) 1.0000
SH (flg) (psi) 13305. SR (flg) (psi) 672. ST (flg) (psi) 10339.

Analysis from WRC Bulletin 538-----

g1/g0 (flange) 1.50000 h/ho (flange) 0.63500 f2 (App B) 0.29714

Sfmax-Bolt Str for Flange(psi) 61976. Mod. Mo for Flg Str (in-lb) 954326.

Stress (psi)	Allowable Stress (psi)
Long. Hub Stress (Mod.) at Hub/Flg (Sh/f)	60771.
Long. Hub Stress at Hub/Flg Junction (Sh)	60771. (2.0XSyf) 72000.
Radial Stress at Hub/Flg. Junction (Sr)	3072. (2.0XSyf) 72000.
Tangential Stress at Hub/Flg Junction (St)	47222. (1.5XSyf) 54000.
Tangential Stress at Hub/Flg Junction (Sto)	18058. (1.0XSyf) 36000.
Combined Stress at Hub/Flg Junction (Sh/f+St)	107993. (3.0XSyf) 108000.
Combined Stress at Hub/Flg Junction (Sr+St)	50294. (3.0XSyf) 108000.
Combined Stress at Hub/Shl Junction (Sh+Sto)	78828. (3.0XSyf) 108000.

Gasket Max Stress Check (Gasket Crushing) per 0-9-----
Sgbmax-Max Bolt Stress to Avoid Crushing Gasket (psi) 140384.

Upper Bolt Stress Limit-----
Max Bolt Str (Lesser: Sfmax,Sgbmax,Sbmax)(psi) 61976. Torque(ft-lb) 378.7

Gasket Assembly Seating Stress per (0-7)-----
Sbmin-s-Min Bolt Stress Req'd to Seat Gskt(psi) 51049.

Gasket Operating Stress per (0-8)-----
Sbmin-o-Min Blt Str to Keep Gskt Seat Op.(psi) 61150.

Lower Bolt Stress Limit-----
Min Bolt Str (Max.:Sbmin-s,Sbmin-o,Sbmin)(psi) 61150. Torque(ft-lb) 373.7

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Bolting/Gasket Assembly Stress per API-660, ASME PCC-1 App. O,WRC Bulletin 538
Shell to Tubesheet Flange

Input Data-----

Sgmax, Max. Gskt Stress (psi) 55000. Sgmin-s,Min. Gskt Stress(psi) 20000.
Sgmin-o,Min Gskt Op Str (psi) 14000. Bolt Yield Str (Ambient)(psi) 105000.
Sbmax, Max. Bolt Stress (psi) 73500. Sbmin, Min. Bolt Stress (psi) 42000.
K, Nut Friction Factor 0.20 Gasket Relaxation Factor 0.70

Flange Design Data-----

Design Press.(psi) 375. Number of Studs 28. Bolt Dia. (in.) 0.8750
Blt Amb Alw(psi) 25000. Blt Amb Yld (psi) 105000. Flg Amb Yld(psi) 36000.
Mo (flg)(in-lb) 206973. hg (flange) (in.) 1.3125 Tot Blt Area(in2) 11.73
Gskt O.D. (in.) 17.0000 Gasket I.D. (in.) 16.2500 Gskt Rib Area(in2) 0.0
h(fl g hub)(in.) 1.2500 h0 (flange) (in.) 1.9685 Tot Gskt Area(in2) 19.6
g0 (flg-cor)(in.) 0.2500 g1 (flg-cor)(in.) 0.3750 f (flange) 1.0000
SH (flg) (psi) 13180. SR (flg) (psi) 666. ST (flg) (psi) 10242.

Analysis from WRC Bulletin 538-----

g1/g0 (flange) 1.50000 h/ho (flange) 0.63500 f2 (App B) 0.29714

Sfmax-Bolt Str for Flange(psi) 61976. Mod. Mo for Flg Str (in-lb) 954321.

Stress (psi)	Allowable Stress (psi)
Long. Hub Stress (Mod.) at Hub/Flg (Sh/f)	60771.
Long. Hub Stress at Hub/Flg Junction (Sh)	60771. (2.0XSyf) 72000.
Radial Stress at Hub/Flg. Junction (Sr)	3071. (2.0XSyf) 72000.
Tangential Stress at Hub/Flg Junction (St)	47222. (1.5XSyf) 54000.
Tangential Stress at Hub/Flg Junction (Sto)	18058. (1.0XSyf) 36000.
Combined Stress at Hub/Flg Junction (Sh/f+St)	107993. (3.0XSyf) 108000.
Combined Stress at Hub/Flg Junction (Sr+St)	50294. (3.0XSyf) 108000.
Combined Stress at Hub/Shl Junction (Sh+Sto)	78828. (3.0XSyf) 108000.

Gasket Max Stress Check (Gasket Crushing) per 0-9-----

Sgbmax-Max Bolt Stress to Avoid Crushing Gasket (psi) 91819.

Upper Bolt Stress Limit-----

Max Bolt Str (Lesser: Sfmax,Sgbmax,Sbmax)(psi) 61976. Torque(ft-lb) 378.7

Gasket Assembly Seating Stress per (0-7)-----

Sbmin-s-Min Bolt Stress Req'd to Seat Gskt(psi) 33389.

Gasket Operating Stress per (0-8)-----

Sbmin-o-Min Blt Str to Keep Gskt Seat Op.(psi) 42859.

Lower Bolt Stress Limit-----

Min Bolt Str (Max.:Sbmin-s,Sbmin-o,Sbmin)(psi) 42859. Torque(ft-lb) 261.9

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

ASME SEC.VIII DIV.1 UHX-12

(U-Tube) Configuration d

No or EPC=Elastic-Plastic	Calcs SSC=Simply Supported Calcs	=NO
MT Tubes	=SA-179	MT Tubesheets =SA-516-70
MT Channel	=SA-106-B	MT Shell =SA-106-B
Diameter (Do)	= 14.8125"	Pass Lane Area (AL) = 50.602in^2
Perimeter of layout (CP)	= 46.5348"	Area enclosed by CP (AP) = 172.324in^2
Tubesheet thickness (h)	= 1.7500"	Tubesheet thickness HOLD = NO
Tube Pitch (p)	= 1.0000"	Pitch type = Square (90 Deg)
Diameter of tube (dt)	= 0.7500"	Tube thickness (tt) = 0.0830"
Exp length of tube (ltx)	= 1.6250"	Exp depth ratio (Rho) = 0.9500
Groove channel side (hg)	= 0.1875"	Groove shell side = 0.0000"
Channel I.D. (Dc)	= 15.2500"	Channel thickness (Tc) = 0.3750"
Shell I.D. (Ds)	= 15.2500"	Shell thickness (Ts) = 0.3750"
Stat TS diameter (A)	= 15.1250"	Bolt circle (C) = 19.2500"
G Channel side (Gc or G1)	= 16.6250"	G Shell side (Gs or G1) = 16.6250"
Bolt load Chan side (Wc)	=250527.83#	Bolt load Sh side (Ws) =250527.83#
1.8*sqrt(Dc*Tc)	= 0.0000"	1.8*sqrt(Ds*(Ts or Ts1)) = 0.0000"
Thickness at Top TS (tr)	= 1.3750"	Outer Tube Circle = 14.8125"
hr Ch Wm1	= 0.0#	hr Ch W = 0.0#
hr Sh Wm1	= 0.0#	hr Sh W = 0.0#
hr Ch Op= 0.0000" Ch Atm= 0.0000"		Sh Op= 0.0000" Sh Atm = 0.0000"
DE Stationary Tubesheet =16.25000"		DE Floating Tubesheet = 0.0"
Tubes welded Backside TS =NO		Hole Size in Tubesheet = 0.0000"
Design Press Chan (Pt)	= 405.0psig	Design Press Shell (Ps) = 405.0psig
Design Temp Chan	= 330.0deg.	Design Temp Shell = 300.0deg.
Corr Chan	= 0.12500"	Corr Shell = 0.12500"
Corr Chan side TS (ct)	= 0.12500"	Corr Shell side TS (cs) = 0.12500"

‘(C) TOTAL THICKNESS INCLUDING 1/8” FUTURE MACHINING ALLOWANCE BOTH SIDES = 2”

Page 29 of 148

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6”-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

(U-Tube) Configuration d

Tubesheet Thickness (h) = 1.5000"
 Exp length of tube (ltx) = 1.4250" Exp depth ratio (Rho) = 0.9500"
 Channel I.D. (Dc) = 15.5000" Channel thickness (Tc) = 0.2500"
 Shell I.D. (Ds) = 15.5000" Shell thickness (Ts) = 0.2500"
 Perimeter of layout (CP) = 46.5348" Area enclosed by CP (AP) = 172.324in²
 Press Chan (Pt) = 405.0psi Press Shell (Ps) = -15.0psi
 Corr Chan = 0.12500" Corr Shell = 0.12500"
 Corr Chan side TS (ct) = 0.12500" Corr Shell side TS (cs) = 0.12500"
 Temp Stress Yield Modulus Coef Poisson Prim Plus
 x10⁶ x10⁻⁶ Ratio Stress
 Temp TS T = 330deg.F S = 20000psi Sy = 33270psi E = 27.9800psi V = .300 Sps = 0psi
 Temp TFE T = 330deg.F Sfe= 20000psi
 Temp TBS Tt= 330deg.F St = 13400psi Syt= 0psi Et = 27.9800psi Vt= .300
 Temp TBS T = 330deg.F St = 13400psi Et = 27.9800psi
 Temp CH Tc= 330deg.F Sc = 17100psi Syc= 30670psi Ec = 27.9800psi Vc= .300 Spsc= 61340psi
 Temp SH Ts= 300deg.F Ss = 17100psi Sys= 31000psi Es = 28.1000psi Vs= .300 Spss= 62000psi

Mu=0.2500 d*=0.6443" P*=1.18984" Mu*=0.4585 hg'=0.0625" hgs'= 0.0" hrDE=0.1066"
 W* = 135196.1250# Rho s = 1.122362852
 Rho c = 1.122362852 Mts = -1592.524414In-Lb/In h/p = 1.500000000
 E* = 15270766.00psi v* = 0.304124236 Beta s = 0.0in⁻¹
 Kappa s = 0.0# Lambda s = 0.0psi Delta s = 0.0In³/Lb
 Delta c = 0.0In³/Lb Beta c = 0.0in⁻¹ Kappa c = 0.0#
 Lambda c = 0.0psi Omega s = 0.0in² Omega c = 0.0in²
 K = 1.021097064 F = 0.026619460 M* = -1592.524414In-Lb/In
 Mp = -1476.561523In-Lb/In Mo = -6234.101074In-Lb/In M = 6234.101074In-Lb/In
 Sigma s,m= 0.0psi Sigma s,b= 0.0psi Sigma s = 0.0psi
 Sigma c,m= 0.0psi Sigma c,b= 0.0psi Sigma c = 0.0psi
 Sigma 39482 psi <= 2S 40000 psi [OK]
 Tau 4147 psi <= Smax 16000 psi [OK] Smax=Min(0.8S,0.533Sy)

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

(U-Tube) Configuration d

Tubesheet Thickness (h) = 1.5000"
 Exp length of tube (ltx) = 1.4250" Exp depth ratio (Rho) = 0.9500"
 Channel I.D. (Dc) = 15.5000" Channel thickness (Tc) = 0.2500"
 Shell I.D. (Ds) = 15.5000" Shell thickness (Ts) = 0.2500"
 Perimeter of layout (CP) = 46.5348" Area enclosed by CP (AP) = 172.324in²
 Press Chan (Pt) = -15.0psi Press Shell (Ps) = 405.0psi
 Corr Chan = 0.12500" Corr Shell = 0.12500"
 Corr Chan side TS (ct) = 0.12500" Corr Shell side TS (cs) = 0.12500"

Temp	Stress	Yield	Modulus x10 ⁶	Coef x10 ⁻⁶	Poisson Ratio	Prim Plus Stress
Temp TS T = 330deg.F	S = 20000psi	Sy = 33270psi	E = 27.9800psi	V = .300	Sps =	0psi
Temp TFE T = 330deg.F	Sfe= 20000psi					
Temp TBS Tt= 330deg.F	St = 13400psi	Syt= 0psi	Et = 27.9800psi	Vt= .300		
Temp TBS T = 330deg.F	St = 13400psi		Et = 27.9800psi			
Temp CH Tc= 330deg.F	Sc = 17100psi	Syc= 30670psi	Ec = 27.9800psi	Vc= .300	SpSC=	61340psi
Temp SH Ts= 300deg.F	Ss = 17100psi	Sys= 31000psi	Es = 28.1000psi	Vs= .300	SpSS=	62000psi

Mu=0.2500 d*=0.6443" P*=1.18984" Mu*=0.4585 hg'=0.0625" hgs'= 0.0" hrDE=0.1066"
 W* = 135196.1250# Rho s = 1.122362852
 Rho c = 1.122362852 Mts = 1592.524414In-Lb/In h/p = 1.500000000
 E* = 15270766.00psi v* = 0.304124236 Beta s = 0.0in⁻¹
 Kappa s = 0.0# Lambda s = 0.0psi Delta s = 0.0In³/Lb
 Delta c = 0.0In³/Lb Beta c = 0.0in⁻¹ Kappa c = 0.0#
 Lambda c = 0.0psi Omega s = 0.0in² Omega c = 0.0in²
 K = 1.021097064 F = 0.026619460 M* = 1592.524414In-Lb/In
 Mp = 1476.561523In-Lb/In Mo = 6234.101074In-Lb/In M = 6234.101074In-Lb/In
 Sigma s,m= 0.0psi Sigma s,b= 0.0psi Sigma s = 0.0psi
 Sigma c,m= 0.0psi Sigma c,b= 0.0psi Sigma c = 0.0psi
 Sigma 39482 psi <= 2S 40000 psi [OK]
 Tau 4147 psi <= Smax 16000 psi [OK] Smax=Min(0.8S,0.533Sy)

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

(U-Tube) Configuration d

Tubesheet Thickness (h) = 1.5000"
 Exp length of tube (ltx) = 1.4250" Exp depth ratio (Rho) = 0.9500"
 Channel I.D. (Dc) = 15.5000" Channel thickness (Tc) = 0.2500"
 Shell I.D. (Ds) = 15.5000" Shell thickness (Ts) = 0.2500"
 Perimeter of layout (CP) = 46.5348" Area enclosed by CP (AP) = 172.324in²
 Press Chan (Pt) = 405.0psi Press Shell (Ps) = 405.0psi
 Corr Chan = 0.12500" Corr Shell = 0.12500"
 Corr Chan side TS (ct) = 0.12500" Corr Shell side TS (cs) = 0.12500"

Temp	Stress	Yield	Modulus x10 ⁶	Coef x10 ⁻⁶	Poisson Ratio	Prim Plus Stress
Temp TS T = 330deg.F	S = 20000psi	Sy = 33270psi	E = 27.9800psi	V = .300	Sps =	0psi
Temp TFE T = 330deg.F	Sfe= 20000psi					
Temp TBS Tt= 330deg.F	St = 13400psi	Syt= 0psi	Et = 27.9800psi	Vt= .300		
Temp TBS T = 330deg.F	St = 13400psi		Et = 27.9800psi			
Temp CH Tc= 330deg.F	Sc = 17100psi	Syc= 30670psi	Ec = 27.9800psi	Vc= .300	SpSC=	61340psi
Temp SH Ts= 300deg.F	Ss = 17100psi	Sys= 31000psi	Es = 28.1000psi	Vs= .300	SpSS=	62000psi

Mu=0.2500 d*=0.6443" P*=1.18984" Mu*=0.4585 hg'=0.0625" hgs'= 0.0" hrDE= 0.0"
 W* = 135196.1250# Rho s = 1.122362852
 Rho c = 1.122362852 Mts = 0.0In-Lb/In h/p = 1.500000000
 E* = 15270766.00psi v* = 0.304124236 Beta s = 0.0in⁻¹
 Kappa s = 0.0# Lambda s = 0.0psi Delta s = 0.0In³/Lb
 Delta c = 0.0In³/Lb Beta c = 0.0in⁻¹ Kappa c = 0.0#
 Lambda c = 0.0psi Omega s = 0.0in² Omega c = 0.0in²
 K = 1.021097064 F = 0.026619460 M* = 0.0In-Lb/In
 Mp = 0.0In-Lb/In Mo = 0.0In-Lb/In M = 0.0In-Lb/In
 Sigma s,m= 0.0psi Sigma s,b= 0.0psi Sigma s = 0.0psi
 Sigma c,m= 0.0psi Sigma c,b= 0.0psi Sigma c = 0.0psi
 Sigma 0 psi <= 2S 40000 psi [OK]
 Tau 0 psi <= Smax 16000 psi [OK] Smax=Min(0.8S,0.533Sy)

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

(U-Tube) Configuration d

Tubesheet Thickness (h) = 1.5000"
 Exp length of tube (ltx) = 1.4250" Exp depth ratio (Rho) = 0.9500"
 Channel I.D. (Dc) = 15.5000" Channel thickness (Tc) = 0.2500"
 Shell I.D. (Ds) = 15.5000" Shell thickness (Ts) = 0.2500"
 Perimeter of layout (CP) = 46.5348" Area enclosed by CP (AP) = 172.324in²
 Press Chan (Pt) = -15.0psi Press Shell (Ps) = -15.0psi
 Corr Chan = 0.12500" Corr Shell = 0.12500"
 Corr Chan side TS (ct) = 0.12500" Corr Shell side TS (cs) = 0.12500"

Temp	Stress	Yield	Modulus	Coef	Poisson	Prim Plus
			x10 ⁶	x10 ⁻⁶	Ratio	Stress
Temp TS T = 330deg.F S = 20000psi	Sy = 33270psi	E = 27.9800psi	V = .300	Sps =		Ops
Temp TFE T = 330deg.F Sfe= 20000psi						
Temp TBS Tt= 330deg.F St = 13400psi	Syt= 0psi	Et = 27.9800psi	Vt= .300			
Temp TBS T = 330deg.F St = 13400psi		Et = 27.9800psi				
Temp CH Tc= 330deg.F Sc = 17100psi	Syc= 30670psi	Ec = 27.9800psi	Vc= .300	SpSC=	61340psi	
Temp SH Ts= 300deg.F Ss = 17100psi	Sys= 31000psi	Es = 28.1000psi	Vs= .300	SpSS=	62000psi	

Mu=0.2500 d*=0.6443" P*=1.18984" Mu*=0.4585 hg'=0.0625" hgs'= 0.0" hrDE= 0.0"
 W* = 135196.1250# Rho s = 1.122362852
 Rho c = 1.122362852 Mts = 0.0In-Lb/In h/p = 1.500000000
 E* = 15270766.00psi v* = 0.304124236 Beta s = 0.0in⁻¹
 Kappa s = 0.0# Lambda s = 0.0psi Delta s = 0.0In³/Lb
 Delta c = 0.0In³/Lb Beta c = 0.0in⁻¹ Kappa c = 0.0#
 Lambda c = 0.0psi Omega s = 0.0in² Omega c = 0.0in²
 K = 1.021097064 F = 0.026619460 M* = 0.0In-Lb/In
 Mp = 0.0In-Lb/In Mo = 0.0In-Lb/In M = 0.0In-Lb/In
 Sigma s,m= 0.0psi Sigma s,b= 0.0psi Sigma s = 0.0psi
 Sigma c,m= 0.0psi Sigma c,b= 0.0psi Sigma c = 0.0psi
 Sigma 0 psi <= 2S 40000 psi [OK]
 Tau 0 psi <= Smax 16000 psi [OK] Smax=Min(0.8S,0.533Sy)

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

[Pressure] [Temperature]						
[Case]	[Pt]	[Ps]	[T_ch]	[T_sh]	[Corr]	[Thermal Expansion]

1	405.0	-15.0	330.0	300.0	Yes	-
2	-15.0	405.0	330.0	300.0	Yes	-
3	405.0	405.0	330.0	300.0	Yes	-
4	-15.0	-15.0	330.0	300.0	Yes	-

////////// Recap of all Cases //////////

(Case Number 1)OK
(Case Number 2)OK
(Case Number 3)OK
(Case Number 4)OK

////////// Tubesheet Stresses //////////

Case#	(Per.Sigma/Allow)	(Sigma)	(Per.Tau/Allow)	(Tau)
[1]	[99]	39482 < 40000	[26]	4147 < 16000
[2]	[99]	39482 < 40000	[26]	4147 < 16000

>>>> UHX-10 (b) Data for Stationary Tubesheet <<<<
Tubesheet Thicknes h = 1.7500
Tubesheet OD = 17.7500
A = 15.1250, at Min. Cylinder Inside Diameter turns
Thickness of Tubesheet at A diameter = 1.7500
Thickness at A diameter not less than Smaller of (0.75h , h-0.375)
(1.3125 , 1.3750)
Thickness at A diameter 1.7500 not less than 1.3125
Tubesheet complies with UHX-10 (b) [[Yes]]

PULLING EYEBOLT CALCULATIONS

BUNDLE WEIGHT = 1400 LBS

1400 X 1.5 = 2100 LBS

IMPACT FACTOR = 1.5

2100 / 2 = 1050 LBS PER PULL BOLT

NO. OF PULL BOLTS = 2

PULL BOLT SIZE = 1/2" DIA. 13-THD SHOULDER EYE BOLT

*WORKING LOAD LIMIT = 2400 LBS. EA. (STRAIGHT PULL)

* ACCORDING TO GRAINGER INDUSTRIAL SUPPLY CATALOG.

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

***** TUBE CALCULATIONS *****

Tube size.....=	0.75000"	Straight or U-Tube.=	U-Tube
Internal Press...=	415.00000psig	External press.....=	390.00000psig
Temperature used.=	330.00000deg.	Tube Matl MT# 34...=	SA-179
Stress Oper.....=	13400.00000psi	Stress Atm.....=	13400.00000psi
Yield.....=	22760.00000psi	Inside Radius.....=	0.29200"
Joint Eff.....=	1.00000	Mill tol...= 0.00% =	0.00000"
Wall Thk. t.....=	0.08300"	Tube gauge.....=	14 BWG Gauge
Mean Rad., R.....=	1.12500"	Tube Length.....=	156.00000"
Corrosion ID.....=	0.00000"	Corrosion OD.....=	0.00000"
Thinning factor..=	1.16667		
tr = PR/SE - .6P =	0.00921"	(tr*TF)+MT+CA.....=	0.01075"
MAWP Internal H/C=	2848.38672psig	MAWP Internal N/C..=	2848.38672psig
MAWP External H/C=	1709.26086psig	MAWP External N/C..=	1745.37158psig

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

**** PRESSURE/TEMPERATURE RATING **** ASME B16.5 2017

---- SHELL NOZZLES -----DESIGN PRESS= 375.0 DESIGN TEMP= 300.0
 NOZ# 1 6.0- 600# MT# FLG= 74 GROUP=1.1 @70deg.=1480.00 @TEMP=1310.00
 NOZ# 2 6.0- 600# MT# FLG= 74 GROUP=1.1 @70deg.=1480.00 @TEMP=1310.00

---- FRONT CHANNEL NOZZLES -----DESIGN PRESS= 400.0 DESIGN TEMP= 330.0
 NOZ#11 3.0- 600# MT# FLG= 74 GROUP=1.1 @70deg.=1480.00 @TEMP=1296.50
 NOZ#12 3.0- 600# MT# FLG= 74 GROUP=1.1 @70deg.=1480.00 @TEMP=1296.50
 NOZ#13 2.0- 300# MT# FLG= 74 GROUP=1.1 @70deg.= 740.00 @TEMP= 649.00
 NOZ#14 2.0- 300# MT# FLG= 74 GROUP=1.1 @70deg.= 740.00 @TEMP= 649.00

/// TEMA PASS PLATE CALCULATIONS ///

Per RCB-9.132

$$t = b \sqrt{\frac{q B}{1.5 S}}$$

TUBE SIDE PRESSURE DROP q = 20.00000

FRONT PASS PLATE THK..... = 0.50000
 MATERIAL..... = SA-516-70
 STRESS OPER..... = 20000.00
 FRONT Chan ID..... = 15.25000
 FRONT Chan OAL..... = 32.50000
 a..... = 30.37500
 b..... = 7.62500
 TABLE RCB-9.132..... = Long sides fixed
 a/b..... = 3.98361
 B..... = 0.50000
 t..... = 0.13921
 Min fillet leg [both sides] = 3/4t = .75 x 0.13921 = 0.10441

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

===== EXCHANGER DATA =====

```

//////// DRY WEIGHTS [Pounds] //////////
EXCHANGER.=      5451.14  ROUGH WT..=      5841.10  BUNDLE....=      1392.92
SHELL.....=      1199.11  FRONT CH..=      727.22  REAR CH...=         0.00
FLTG. HEAD=         0.00  BOLTS.....=      115.75
BOTT SUPTS.=      959.29  TOP SUPTS.=      959.29
FC P-PLS..=       97.56  RC P-PLS..=         0.00  FH P-PLS..=         0.00

```

```

//////// WET WEIGHTS [Pounds] //////////
EXCHANGER FLOODED WITH WATER TUBES AND SHELL SIDE.....=      6654.06
EXCHANGER FLOODED WITH WATER TUBE SIDE.....=      5853.64
EXCHANGER FLOODED WITH WATER SHELL SIDE.....=      6251.56
WTR.TOTAL.=      1202.93  WTR.TUBES.=      402.51  WTR.SHELL.=      800.42

```

```

//////// CENTER OF GRAVITIES [Inches from outline reference] //////////
EXCHANGER DRY.....=      59.36
BUNDLE DRY .....=      73.57
SHELL DRY.....=      74.84
FRONT CHANNEL DRY.....=     -20.59
REAR CHANNEL DRY.....=         0.00
EXCHANGER FLOODED WITH WATER TUBES AND SHELL SIDE.....=      60.36
EXCHANGER FLOODED WITH WATER TUBE SIDE.....=      57.29
EXCHANGER FLOODED WITH WATER SHELL SIDE.....=      62.36

```

```

//////// WEIGHT ON SUPPORTS [Pounds] //////////
EXCH DRY.....[LEFT]=      3854.38 [RIGHT]=      1596.76
EXCH FLOODED W/ WTR TUBES & SHELL.[LEFT]=      4631.31 [RIGHT]=      2022.75
EXCH FLOODED W/ WTR TUBE SIDE....[LEFT]=      4273.80 [RIGHT]=      1579.84
EXCH FLOODED W/ WTR SHELL SIDE....[LEFT]=      4211.89 [RIGHT]=      2039.67

```

```

//////// SURFACE AREAS [Square Feet] //////////
TUBES OUTSIDE GROSS.....=      301.56
TUBES OUTSIDE EFFECTIVE.....=      317.88
EXCHANGER.....=      291.48
SHELL.....=      64.90
FRONT CHANNEL.....=      24.68
REAR CHANNEL.....=         0.00
FRONT TUBESHEET [Tubshts included to shell if fixed tubesheet]=      0.68
BOTTOM SUPPORTS.....=      100.61
TOP SUPPORTS.....=      100.61

```

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

TOP SUPT CALCS BOTTOM UNIT

NOM. SIZE UNIT..... 16.00000
O.D. SHELL..... 16.00000
THK. SHELL..... 0.37500
SUPT TYPE / 1,2or3. 3.00000
SUPT PROJ..... 25.00000
LEVER LOAD..... 2100.0
DEAD LOAD..... 6700.0
LEVER..... 19.46437
bf..... 21.50000
AREA1..... 9.40625
AREA2..... 9.26953
y..... 2.08002
X1..... 1.86127
X2..... 1.88873
C..... 5.41998
I.....104.33306
BASE PL. LENGTH.... 22.00000
BASE PL. WIDTH..... 8.00000
BASE PL. THK..... 0.68750
DIST TO HOLES/SLOTS
FROM INSIDE BASE PL 4.00000
WIDTH TOP..... 7.50000
WIDTH BOTTOM..... 7.50000
BACKING PL. THK.... 0.43750
NO. RIBS..... 3.00000
RIB THK..... 0.43750
DISTANCE TO RIB.... 0.00000
OUTSIDE RIBS 0/1... 1.00000
NO HOLES / SUPT.... 2.00000
HOLE DIA..... 1.25000
SLOT LENGTH..... 2.50000
X-SLOTS Y-HOLES... 1.00000
DIST BETWEEN HOLES. 14.00000
EDGE TO HOLE DIST.. 4.00000
SADDLE PL THK..... 0.31250
SADDLE PL WIDTH.... 13.00000
SADDLE PL LENGTH... 51.43750

REF TO FRONT SUPT.. 33.00000
DIST BETWEEN SUPTS. 81.00000

CONCRETE BEARING...[38.07]
DEAD LOAD STRESS...[342.70]
BENDING STRESS.....[2123.42]

SUPPORTS CALCULATED IN CORRODED CONDITION

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

BOTT. SUPT CALCS BOTTOM UNIT

NOM. SIZE UNIT..... 16.00000
 O.D. SHELL..... 16.00000
 THK. SHELL..... 0.37500
 SUPT TYPE / 1,2or3. 3.00000
 SUPT PROJ..... 27.00000
 LEVER LOAD..... 2100.0
 DEAD LOAD..... 13400.0
 LEVER..... 21.46437
 bf..... 21.50000
 AREA1..... 9.40625
 AREA2..... 9.26953
 y..... 2.08002
 X1..... 1.86127
 X2..... 1.88873
 C..... 5.41998
 I.....104.33306
 BASE PL. LENGTH.... 22.00000
 BASE PL. WIDTH..... 8.00000
 BASE PL. THK..... 0.93750
 DIST TO HOLES/SLOTS
 FROM INSIDE BASE PL 4.00000
 WIDTH TOP..... 7.50000
 WIDTH BOTTOM..... 7.50000
 BACKING PL. THK.... 0.43750
 NO. RIBS..... 3.00000
 RIB THK..... 0.43750
 DISTANCE TO RIB.... 0.00000
 OUTSIDE RIBS 0/1... 1.00000
 NO HOLES / SUPT.... 2.00000
 HOLE DIA..... 1.25000
 SLOT LENGTH..... 2.50000
 X-SLOTS Y-HOLES... 1.00000
 DIST BETWEEN HOLES. 14.00000
 EDGE TO HOLE DIST.. 4.00000
 SADDLE PL THK..... 0.31250
 SADDLE PL WIDTH.... 13.00000
 SADDLE PL LENGTH... 51.43750

 REF TO FRONT SUPT.. 33.00000
 DIST BETWEEN SUPTS. 81.00000

 CONCRETE BEARING...[76.14]
 DEAD LOAD STRESS...[717.51]
 BENDING STRESS.....[2341.60]

SUPPORTS CALCULATED IN CORRODED CONDITION

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

BOTT. SUPT CALCS TOP UNIT

NOM. SIZE UNIT..... 16.00000
 O.D. SHELL..... 16.00000
 THK. SHELL..... 0.37500
 SUPT TYPE / 1,2or3. 3.00000
 SUPT PROJ..... 77.00000
 LEVER LOAD..... 2100.0
 DEAD LOAD..... 6700.0
 LEVER..... 71.46436
 bf..... 21.50000
 AREA1..... 9.40625
 AREA2..... 9.26953
 y..... 2.08002
 X1..... 1.86127
 X2..... 1.88873
 C..... 5.41998
 I..... 104.33306
 BASE PL. LENGTH.... 22.00000
 BASE PL. WIDTH..... 8.00000
 BASE PL. THK..... 0.68750
 DIST TO HOLES/SLOTS
 FROM INSIDE BASE PL 4.00000
 WIDTH TOP..... 7.50000
 WIDTH BOTTOM..... 7.50000
 BACKING PL. THK.... 0.43750
 NO. RIBS..... 3.00000
 RIB THK..... 0.43750
 DISTANCE TO RIB.... 0.00000
 OUTSIDE RIBS 0/1... 1.00000
 NO HOLES / SUPT.... 2.00000
 HOLE DIA..... 1.25000
 SLOT LENGTH..... 2.50000
 X-SLOTS Y-HOLES... 1.00000
 DIST BETWEEN HOLES. 14.00000
 EDGE TO HOLE DIST.. 4.00000
 SADDLE PL THK..... 0.31250
 SADDLE PL WIDTH.... 13.00000
 SADDLE PL LENGTH... 25.68750

REF TO FRONT SUPT.. 33.00000
 DIST BETWEEN SUPTS. 81.00000

CONCRETE BEARING...[38.07]
 DEAD LOAD STRESS...[358.75]
 BENDING STRESS.....[7796.22]

SUPPORTS CALCULATED IN CORRODED CONDITION

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Wind Load Calculation Results:

Input Values:

Wind Design Code	ASCE/SEI 7-16
Wind Load Reduction Scale Factor	0.600
Basic Wind Speed [V]	101 mile/hr
Surface Roughness Category	C: Open Terrain
Importance Factor	1.0 This value cannot be modified for ASCE 7-16
Type of Surface	Moderately Smooth
Base Elevation	0 ft.
Percent Wind for Hydrotest	0.75
Using User defined Wind Press. Vs Elev.	N
Height of Hill or Escarpment H or Hh	0 ft.
Distance Upwind of Crest Lh	0 ft.
Distance from Crest to the Vessel x	0 ft.
Type of Terrain (Hill, Escarpment)	Flat
Damping Factor (Beta) for Wind (Ope)	0.0100
Damping Factor (Beta) for Wind (Empty)	0.0000
Damping Factor (Beta) for Wind (Filled)	0.0000
Site Elevation above Sea Level	0 ft.

Wind Analysis Results

Static Gust-Effect Factor, Operating Case [G]:

$$\begin{aligned} &= \min(0.85, 0.925((1 + 1.7 * g_Q * I_{zbar} * Q)/(1 + 1.7 * g_V * I_{zbar}))) \\ &= \min(0.85, 0.925((1 + 1.7 * 3.4 * 0.228 * 0.992)/(1 + 1.7 * 3.4 * 0.228))) \\ &= \min(0.85, 0.921) \\ &= 0.850 \end{aligned}$$

Natural Frequency of Vessel (Operating)	33.000 Hz
Natural Frequency of Vessel (Empty)	33.000 Hz
Natural Frequency of Vessel (Test)	33.000 Hz

User Entered Importance Factor is	1.000
Force Coefficient [Cf]	0.629
Structure Height to Diameter ratio	12.279

This is classified as a rigid structure. Static analysis performed.

Sample Calculation for the First Element:

Value of [Alpha] and [Zg]:

Exposure Category: C from Table 26.11-1
Alpha = 9.5 : Zg = 900 ft.

Effective Height [z]:

$$\begin{aligned} &= \text{Centroid Height} + \text{Vessel Base Elevation} \\ &= 6.583 + 0 = 6.583 \text{ ft.} \end{aligned}$$

Velocity Pressure coefficient evaluated at height z [Kz]:

$$\begin{aligned} &\text{Because } z(6.583 \text{ ft.}) < 15 \text{ ft.} \\ &= 2.01(15 / Z_g)^{2/\alpha} \\ &= 2.01(15/900)^{2/9.5} \\ &= 0.849 \end{aligned}$$

Type of Hill: No Hill

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Wind Directionality Factor [Kd]:
= 1, per Table 26.6-1

As there is No Hill Present: [Kzt]:
K1 = 0, K2 = 0, K3 = 0

Topographical Factor [Kzt]:
= (1 + K1 * K2 * K3)²
= (1 + 0 * 0 * 0)²
= 1

Velocity Pressure evaluated at height z, Imperial Units [qz]:
= max(16, 0.00256 * Kz * Kzt * Kd * Ke * V(mph)²)
= max(16, 0.00256 * 0.849 * 1 * 1 * 1 * 101²)
= 22.2 psf

Force on the first element [F]:
= qz * G * Cf * WindArea
= 22.17 * 0.85 * 0.629 * 0.632
= 7.5 lb.

Element	Hgt (z) ft.	K1	K2	K3	Kz	Kzt	qz psf
Node 10 to 20	6.6	0.000	0.000	0.000	0.849	1.000	22.168
Node 20 to 30	6.6	0.000	0.000	0.000	0.849	1.000	22.168
Node 30 to 40	6.6	0.000	0.000	0.000	0.849	1.000	22.168

Wind Loads on Masses/Equipment/Piping

ID	Wind Area sq.in.	Elevation ft.	Pressure psf	Force lb.
WGHT:[1 OF 1]	0.00	6.58	22.17	0.00
WGHT:[1 OF 1]	0.00	6.58	22.17	0.00

Wind Load Calculation:

From	To	Wind Height ft.	Wind Diameter ft.	Wind Area sq.in.	Wind Pressure psf	Element Wind Load lb.
10	20	6.58333	1.6	91.0217	22.1682	4.49739
20	30	6.58333	1.6	3597.58	22.1682	177.757
30	40	6.58333	1.6	91.0217	22.1682	4.49739

PV Elite is a trademark of Hexagon AB, 2022, All rights reserved.

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Earthquake Load Calculation Results:

Earthquake Load Calculation:

Input Values:

Seismic Design Code	ASCE/SEI 7-16
Seismic Load Reduction Scale Factor	0.700
Importance Factor	1.500
Table Value Fa	1.000
Table Value Fv	1.721
Max. Mapped Res. Acceleration [Ss]	1.616
Max. Eff. Ground Acceleration [S]	0.579
Force Modification Factor R	2.500
Site Class	D
Component Elevation Ratio z/h	1.000
Amplification Factor Ap	1.000
Force Factor	0.000
Consider Vertical Acceleration	Yes
Minimum Acceleration Multiplier	0.000
User Value of Sds (used if > 0)	1.077
User Value of Sd1 (used if > 0)	0.996
Moment Reduction Factor Tau	1.000

Seismic Analysis Results:

$$\begin{aligned}S_{ms} &= F_a * S_s = 1 * 1.616 = 1.616 \\S_{m1} &= F_v * S_1 = 1.721 * 0.579 = 0.996 \\S_{ds} &= 2/3 * S_{ms} = 2/3 * 1.616 = 1.077\end{aligned}$$

$$\begin{aligned}S_{ds} &= \text{Max}(0.8*S_{ds}, S_{dsUser}) \\&= \text{Max}(0.862, 1.077) \\&= 1.077\end{aligned}$$

$$S_{d1} = 2/3 * S_{m1} = 2/3 * 0.996 = 0.664$$

$$\begin{aligned}S_{d1} &= \text{Max}(0.8*S_{d1}, S_{d1User}) \\&= \text{Max}(0.531, 0.996) \\&= 0.996\end{aligned}$$

Check Approximate Fundamental Period from 12.8-7 [Ta]:
= $C_t * h_n^x$ where $C_t = 0.020$, $x = 0.75$ and h_n = Structural Height (ft.)
= $0.020 * (2.729^{0.75})$
= 0.042 seconds

The Coefficient C_u from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:
= (1/Natural Frequency) = (1/33)
= 0.030

Check the Value of T which is the smaller of $C_u * T_a$ and T:
= Minimum Value of (1.4 * 0.0425, 0.0303) per 12.8.2
= 0.030

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Compute the Seismic Force per equation 13.3-1, [Fp]:

$$= 0.4 * A_p * S_{ds} * W * (1 + 2 * (z/h)) / (R / I_e)$$

$$= 0.4 * 1 * 1.077 * 13752 * (1 + 2 * 1) / (2.5 / 1.5)$$

$$= 10664.067 \text{ lb.}$$

Check the Maximum value of Fp per equation 13.3-2:

$$= 1.6 * S_{ds} * I * W$$

$$= 1.6 * 1.077 * 1.5 * 13752 = 35547 \text{ lb.}$$

Check the Minimum value of Fp per equation 13.3-3:

$$= 0.3 * 1.077 * 1.5 * 13752$$

$$= 6665.042 \text{ lb.}$$

Compute the Total Base Shear V = Fp, [V]:

$$= 10664.067 \text{ lb.}$$

Vertical load per 12.4-4, [Ev]:

$$= 0.2 * S_{ds} * W$$

$$= 0.2 * 1.077 * 13752$$

$$= 2962.2 \text{ lb.}$$

Final Base Shear, V = 7464.85 lb.
 Final Vertical Load, Ev = 2073.57 lb.

Earthquake Load Calculation:

From	To	Earthquake Height ft.	Earthquake Weight lb.	Element Ope Load lb.
10	20	0.63542	2750.46	1492.97
20	Sad1	0.63542	2750.46	1492.97
Sad1	30	0.63542	2750.46	1492.97
20	30	0.63542	2750.46	1492.97
30	40	0.63542	2750.46	1492.97

PV Elite is a trademark of Hexagon AB, 2022, All rights reserved.

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle: TOP UNIT

Horizontal Vessel Stress Calculations : Operating Case

Input and Calculated Values:

Vessel Mean Radius	Rm	7.88	in.
Shell Thickness used in this Case	t	0.375	in.
Stiffened Vessel Length per 4.15.6	L	13.23	ft.
Distance from Saddle to Vessel tangent	a1 or a	34.56	in.
Saddle Width	b1 or b	7.50	in.
Saddle Bearing Angle	delta or theta	138.00	degrees
Wear Plate Width	b2 or b1	13.00	in.
Wear Plate Bearing Angle	delta2 or theta1	180.00	degrees
Wear Plate Thickness	e2 or tr	0.3125	in.
Wear Plate Allowable Stress	fw or Sr	20000.00	psi
Inside Depth of Head	Hi or h2	0.33	ft.
Shell Allowable Stress used in Calculation		17100.00	psi
Head Allowable Stress used in Calculation		17100.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	77.00	in.
Coefficient of Friction	mu	0.00	
Saddle Force Q, Operating Case		35800.73	lb.
Pressure used in Analysis	P	375.000	psig

Horizontal Vessel Analysis Results:	Actual psi	Allowable psi
Long. Stress at Top of Midspan	2957.52	17100.00
Long. Stress at Bottom of Midspan	8854.98	17100.00
Long. Stress at Top of Saddles	11966.83	17100.00
Long. Stress at Bottom of Saddles	-154.33	-27900.00
Long. Stress at Bottom of Saddles	154.33	17100.00
Tangential Shear in Shell	9174.51	13680.00
Circ. Compressive Stress in Shell	1038.21	17100.00
Stiffener Circ. Stress at Shell	2493.12	21375.00
Stiffener Circ. Stress at Tip	671.29	25000.00

Intermediate Results: Saddle Reaction Q due to Wind or Seismic:

Saddle Reaction Force due to Wind Ft [Fwt]:

$$\begin{aligned}
 &= F_{tr} (F_t / \text{Num of Saddles} + Z \text{ Force Load}) * B / E \\
 &= 3 (153.1/2 + 0) * 77/15.52 \\
 &= 1139.0 \text{ lb.}
 \end{aligned}$$

Saddle Reaction Force due to Wind FI [Fwl]:

$$\begin{aligned}
 &= \max (F_l, \text{Sum of X Forces}) * B / L_s \\
 &= \max (26.74, 0) * 77/81 \\
 &= 25.4 \text{ lb.}
 \end{aligned}$$

Page 45 of 148

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Saddle Reaction Force due to Earthquake Fl [Fsl]:

$$= \max(F_l, \text{Sum of X Forces}) * B / L_s$$

$$= \max(4145, 0) * 77/81$$

$$= 3939.9 \text{ lb.}$$

Saddle Reaction Force due to Earthquake Ft [Fst]:

$$= F_{tr}(F_t/\text{Num of Saddles} + Z \text{ Force Load}) * B / E$$

$$= 3(4145/2 + 0) * 77/15.52$$

$$= 30842.7 \text{ lb.}$$

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

$$= \text{Saddle Load} + \max(F_{wl}, F_{wt}, F_{sl}, F_{st})$$

$$= 4958 + \max(25.42, 1139, 3940, 30843)$$

$$= 35800.7 \text{ lb.}$$

Longitudinal Wind Force [Fl]:

$$= \text{WindScalar} * \text{WindPress}(\text{Platform Area} + (\pi/4(OD * \text{WindDiaMult})^2))$$

$$= 0.6 * 22.17(0 + \pi/4(1.333 * 1.2)^2)$$

$$= 26.743 \text{ lbf}$$

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	36207.59	lb.
Transverse Shear Load Saddle	2072.31	lb.
Longitudinal Shear Load Saddle	4144.61	lb.

Formulas and Substitutions for Horizontal Vessel Analysis:

Saddle Dimension [E]:

$$= \min(2(\text{ShellID}/2 + t + \text{WearPadThickness}) \sin(\theta/2), 2 * R_m)$$

$$= \min(2(15.25/2 + 0.375 + 0.312) \sin(138/2), 2 * 7.875)$$

$$= 15.521 \text{ in.}$$

The Computed K values from Table 4.15.1:

K1 = 0.1374	K2 = 0.9229	K3 = 0.6161	K4 = 0.3336
K5 = 0.7024	K6 = 0.0392	K7 = 0.0392	K8 = 0.3195
K9 = 0.2409	K10 = 0.0448	K1* = 0.2426	K6p = 0.0174
K7p = 0.0174			

The suffix 'p' denotes the values for a wear plate if it exists.

Moment per Equation 4.15.1 [M1]:

$$= -Q * a [1 - (1 - a/L + (R_m^2 - h^2)/(2a * L)) / (1 + (4h^2)/3L)]$$

$$= -35801 * 2.88 [1 - (1 - 2.88/13.23 + (0.656^2 - 0.328^2)/(2 * 2.88 * 13.23)) / (1 + (4 * 0.328)/(3 * 13.23))]$$

$$= -24599.4 \text{ ft. lb.}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Moment per Equation 4.15.4 [M2]:

$$\begin{aligned}
 &= Q \cdot L / 4(1 + 2(Rm^2 - h^2) / (L^2)) / (1 + (4h^2) / (3L)) - 4a / L \\
 &= 35801 \cdot 13.23 / 4(1 + 2(0.656^2 - 0.328^2) / (13.23^2)) / (1 + (4 \cdot 0.328) / (3 \cdot 13.23)) - 4 \cdot 2.88 / 13.23 \\
 &= 11968.7 \text{ ft.lb.}
 \end{aligned}$$

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

$$\begin{aligned}
 &= P \cdot Rm / (2t) - M2 / (\pi \cdot Rm^2 \cdot t) \\
 &= 375 \cdot 7.875 / (2 \cdot 0.25) - 143624 / (\pi \cdot 7.875^2 \cdot 0.25) \\
 &= 2957.52 \text{ psi}
 \end{aligned}$$

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

$$\begin{aligned}
 &= P \cdot Rm / (2t) + M2 / (\pi \cdot Rm^2 \cdot t) \\
 &= 375 \cdot 7.875 / (2 \cdot 0.25) + 143624 / (\pi \cdot 7.875^2 \cdot 0.25) \\
 &= 8854.98 \text{ psi}
 \end{aligned}$$

Longitudinal Stress at Top of Shell at Support (4.15.6) [sigma3]:

$$\begin{aligned}
 &= P \cdot Rm / (2t) - M1 / (\pi \cdot Rm^2 \cdot t) \\
 &= 375 \cdot 7.875 / (2 \cdot 0.25) - 295193 / (\pi \cdot 7.875^2 \cdot 0.25) \\
 &= 11966.83 \text{ psi}
 \end{aligned}$$

Longitudinal Stress at bottom of Shell at Support (4.15.7) [sigma4]:

$$\begin{aligned}
 &= P \cdot Rm / (2t) + M1 / (\pi \cdot Rm^2 \cdot t) \\
 &= 375 \cdot 7.875 / (2 \cdot 0.25) + 295193 / (\pi \cdot 7.875^2 \cdot 0.25) \\
 &= -154.33 \text{ psi}
 \end{aligned}$$

Maximum Shear Force in the Saddle (4.15.3) [T]:

$$\begin{aligned}
 &= Q(L - 2a) / (L + (4h^2/3)) \\
 &= 35801(13.23 - 2 \cdot 2.88) / (13.23 + (4 \cdot 0.328^2/3)) \\
 &= 19571.0 \text{ lb.}
 \end{aligned}$$

Shear Stress in the shell with double rings (4.15.12) [tau2]:

$$\begin{aligned}
 &= K2 \cdot T / (Rm \cdot t) \\
 &= 0.923 \cdot 19571 / (7.875 \cdot 0.25) \\
 &= 9174.51 \text{ psi}
 \end{aligned}$$

Decay Length (4.15.20) [x1,x2]:

$$\begin{aligned}
 &= 0.78 \cdot \sqrt{Rm \cdot t} \\
 &= 0.78 \cdot \sqrt{7.875 \cdot 0.25} \\
 &= 1.094 \text{ in.}
 \end{aligned}$$

Circ. Stress in shell w/rings adjacent to Saddle (4.15.37) [sigma6]:

$$\begin{aligned}
 &= -K5 \cdot Q \cdot k / (t(b + 2 \cdot x2)) \\
 &= -0.702 \cdot 35801 \cdot 0.1 / (0.25(7.5 + 2 \cdot 1.094)) \\
 &= -1038.21 \text{ psi}
 \end{aligned}$$

Note: Double Rings adjacent to Saddle Outside the Shell.

Circ. + Bending Stress in shell, rings adjacent to Saddle (4.15.40) [sigma10*]:

$$\begin{aligned}
 &= -K9 \cdot Q/A - K10 \cdot Q \cdot Rm \cdot c1/I \\
 &= -0.241 \cdot 35801 / 7.657 - 0.0448 \cdot 35801 \cdot 7.875 \cdot 2.268 / 20.94 \\
 &= -2493.12 \text{ psi}
 \end{aligned}$$

Circ. + Bending Stress in ring, rings adjacent to Saddle (4.15.41) [sigma11*]:

$$\begin{aligned}
 &= -K9 \cdot Q/A + K10 \cdot Q \cdot Rm \cdot c2/I \\
 &= -0.241 \cdot 35801 / 7.657 + 0.0448 \cdot 35801 \cdot 7.875 \cdot 2.982 / 20.94 \\
 &= 671.29 \text{ psi}
 \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Distance between Saddle Supports [Ls]:
= 81.0 in.

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
= Alpha * Ls(Design Temperature - Ambient Temperature)
= 0.69000E-05 * 81(300 - 70)
= 0.129 in.

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	22.0000	in.
Baseplate Thickness	Bpthk	0.9375	in.
Baseplate Width	Bpwid	8.0000	in.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.4375	in.
Web Thickness	Webtk	0.4375	in.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	18.6	in.
Friction Coefficient	mu	0.000	

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

Inertia of Shell [ShellInertia]:
= ((1.56 * sqrt(R * t) + WearPlateWidth)t³)/12
= ((1.56 * sqrt(7.75 * 0.25) + 13)0.25³)/12
= 0.020 in**4

Resolved Inertia for the Shell [I,shell]:
= ShellInertia + AShell(C1 - Y)²
= 0.0198 + 3.793(34.2 - 0.125)²
= 4403.182 in**4

	B in.	D in.	Y in.	A in ²	AY in. ³	I + AD ² in**4
Shell	15.1714	0.2500	0.1250	3.7929	0.4741	4403.1821
Wearplate	13.0000	0.3125	0.4062	4.0625	1.6504	4638.6875
Web	0.4375	67.7500	34.4375	29.6406	1020.7490	11339.4072
BasePlate	8.0000	0.9375	68.7812	7.5000	515.8594	8971.0156
Totals	...	...	...	44.9960	1538.7329	29352.2969

Distance to Centroid [C1]:
= AY / A
= 1539/45
= 34.197 in.

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 138/2
= 111.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)²)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(111) - 0.5*sin(111)²)/(pi - 1.937 + sin(111)cos(111))
= 0.2367

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.237 * 35801
= 8473.4150 lb.

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Tension Stress, $St = (Fh/As) = 205.6498 \text{ psi}$
 Allowed Stress, $Sa = 0.6 * \text{Yield Str} = 22800.0000 \text{ psi}$

Saddle Splitting Dimension [d]:
 $= B - R * \sin(\theta/2)/(\theta/2 \text{ in radians})$
 $= 77 - 7.75 * \sin(138/2)/1.204$
 $= 70.992 \text{ in.}$

Bending Moment, $M = Fh * d = 50128.7539 \text{ ft.lb.}$

Bending Stress, $Sb = (M * C1 / I) = 700.8347 \text{ psi}$
 Allowed Stress, $Sa = 2/3 * \text{Yield Str} = 25333.3340 \text{ psi}$

Minimum Thickness of Baseplate per Moss:

$= \sqrt{3(Q + \text{Saddle\_Wt}) \text{BasePlateWidth} / (2 * \text{BasePlateLength} * \text{AllStress})}$
 $= \sqrt{3(35801 + 406.9)8 / (2 * 22 * 25333)}$
 $= 0.883 \text{ in.}$

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
 $= 2 * \cos(90 - \text{Saddle Angle}/2)(\text{Inside Radius} + \text{Shell Thk} + \text{Wear Plate Thk})$
 $= 2 * \cos(90 - 138/2)(7.625 + 0.375 + 0.312)$
 $= 15.521 \text{ in.}$

Distance between Ribs [e]:
 $= \text{Web Length} / (\text{Nr ribs} - 1)$
 $= 15.52 / (3 - 1)$
 $= 7.760 \text{ in.}$

Baseplate Pressure Area [Ap]:
 $= e * \text{Bpwid} / 2$
 $= 7.76 * 8/2$
 $= 31.042 \text{ in}^2$

Bearing Pressure [Bp]:
 $= Q / (\text{BasePlateLength} * \text{BasePlateWidth})$
 $= 35801 / (22 * 8)$
 $= 203.413 \text{ lb./in}^2$

Axial Load [P]:
 $= Ap * Bp$
 $= 31.04 * 203.4$
 $= 6314.261 \text{ lb.}$

Area of the Rib and Web [Ar]:
 $= \text{Rib Area} + \text{Web Area}$
 $= 3.09 + 1.698$
 $= 4.787 \text{ in}^2$

Compressive Stress [Sc]:
 $= P/Ar$
 $= 6314/4.787$
 $= 1318.925 \text{ psi}$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.4375	7.0625	3.9688	3.0898	12.2628	18.3065
Web	3.8802	0.4375	0.2188	1.6976	0.3713	9.9711
Totals	...	...	...	4.7874	12.6342	28.2776

Rib dimension [D]:

= Saddle Width - Web Thickness
= 7.5 - 0.438
= 7.062 in.

Distance to Centroid from Datum [ytot]:

= AY / A
= 12.63/4.787
= 2.639 in.

Distance to Centroid [C1]:

= max(ytot, Saddle Width - ytot)
= max(2.639, 7.5 - 2.639)
= 4.861 in.

Radius of Gyration [r]:

= sqrt(Total Inertia / Total Area)
= sqrt(28.28/4.787)
= 2.430 in.

Length of Outer Rib [L]:

= Saddle Height - cos(theta/2)(radius + shlthk + wpdthk) - bpthk
= 77 - cos(138/2)(7.625 + 0.375 + 0.312) - 0.938
= 73.084 in.

Intermediate Term [Cc]:

= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 29000000/38000)
= 122.736

Slenderness ratio [KL/r]:

= KL/r
= 1 * 73.08/2.43
= 30.071

Bending Moment [Rm]:

= F1 / (2 * Bplen) * e * L / 2
= 4145 / (2 * 22) * 7.76 * 73.08/2
= 2225.988 ft.lb.

Compressive Allowable, KL/r < Cc (30.07 < 122.7) per AISC E2-1 [Sca]:

= (1 - (KL/r)² / (2 * Cc²)) Fy / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)³ / (8 * Cc³))
= (1 - (30.07)² / (2 * 122.7²)) 38000 /
(5/3 + 3 * (30.07) / (8 * 122.7) - (30.07³) / (8 * 122.7³))
= 20982 psi

AISC Unity Check of Outside Ribs (must be <= 1)

= Sc/Sca + (Rm * C1 / I) / Sba
= 1319/20982 + (26712 * 4.861/28.28) / 25333
= 0.244

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

AISC Unity Check of Outside Ribs, due to Transverse Force Ft (must be <= 1)

This analysis assumes the entire saddle weight load and load due to transverse forces are concentrated on the outer rib + some portion of the web. This generally would not be the case and as such this analysis is very conservative.

Inertia of Saddle, Outer Ribs - Transverse Direction:

	B	D	Y	A	AY	Io
Rib	7.0625	0.4375	0.2188	3.0898	0.6759	8.2923
Web	0.4375	7.0000	3.5000	3.0625	10.7188	20.8218
Totals	...	...	...	6.1523	11.3947	29.1141

Web dimension [D]:

$$\begin{aligned} &= 16 * \text{Web Thickness} \\ &= 16 * 0.438 \\ &= 7.000 \text{ in.} \end{aligned}$$

Moment at base of outer Rib [Mbase]:

$$\begin{aligned} &= Ft(\text{Centerline dimension B} - \text{Baseplate thickness}) \\ &= 2072(77 - 0.938) \\ &= 157624.719 \text{ in.lbs} \end{aligned}$$

Bending Stress due to Transverse Force [SigmaB,base]:

$$\begin{aligned} &= \text{Bending Moment} / \text{Section Modulus} \\ &= 157625/15.72 \\ &= 10027.232 \text{ psi} \end{aligned}$$

Vertical Load on the Rib due to the Bending Moment [Fv,mom]:

$$\begin{aligned} &= \text{Bending Moment} / \text{Web Length} \\ &= 157625/15.52 \\ &= 10155.726 \text{ lb.} \end{aligned}$$

Total Vertical Load on the Rib [Fv,total]:

$$\begin{aligned} &= Fv,mom + \text{Vertical Load} \\ &= 10156 + 36208 \\ &= 46363.320 \text{ lb.} \end{aligned}$$

Compressive Stress on Outer Rib [Sigma,cr]:

$$\begin{aligned} &= Fv,total / \text{Area} \\ &= 46363/6.152 \\ &= 7535.879 \text{ psi} \end{aligned}$$

Radius of Gyration [r]:

$$\begin{aligned} &= \sqrt{\text{Total Inertia} / \text{Total Area} } \\ &= \sqrt{ 29.11/6.152 } \\ &= 2.175 \text{ in.} \end{aligned}$$

Slenderness ratio [KL/r]:

$$\begin{aligned} &= KL/r \\ &= 1 * 73.08/2.175 \\ &= 33.596 \end{aligned}$$

Compressive Allowable, $KL/r < Cc$ (33.6 < 122.7) per AISC E2-1 [Sca]:

$$\begin{aligned} &= (1 - (KL/r)^2 / (2 * Cc^2)) Fy / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)^3 / (8 * Cc^3)) \\ &= (1 - (33.6)^2 / (2 * 122.7^2)) 38000 / \\ &\quad (5/3 + 3 * (33.6) / (8 * 122.7) - (33.6^3) / (8 * 122.7^3)) \\ &= 20703 \text{ psi} \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Unity Check on Outer Rib [UCheck,outer]:
 = $\text{Sigma},cr / \text{Sca} + \text{SigmaB},base / \text{Sba}$
 = $7536/20703 + 10027/25333$
 = 0.76

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction						
	B	D	Y	A	AY	Io
Rib	0.4375	7.0625	3.9688	3.0898	12.2628	24.7529
Web	7.7604	0.4375	0.2188	3.3952	0.7427	10.8928
Totals	...	...	...	6.4850	13.0055	35.6457

Distance to Centroid from Datum [ytot]:
 = AY / A
 = $13.01/6.485$
 = 2.005 in.

Distance to Centroid [C1]:
 = $\max(ytot, \text{abs}(\text{Saddle Width} - ytot))$
 = $\max(2.005, \text{abs}(7.5 - 2.005))$
 = 5.495 in.

Length of Inner Rib [L]:
 = $\text{Saddle Height} - \text{Outside Radius} - \text{Bpthk}$
 = $77 - \cos(8.312/2) (0.938 + 0 + 0) - 0$
 = 67.750 in.

Radius of Gyration [r]:
 = $\sqrt{ \text{Total Inertia} / \text{Total Area} }$
 = $\sqrt{ 35.65/6.485 }$
 = 2.344 in.

Slenderness ratio [KL/r]:
 = KL/r
 = $1 * 67.75/2.344$
 = 28.898

Unit Force [Force,u]:
 = $F1 / (2 * \text{Baseplate Length})$
 = $4145/(2 * 22)$
 = 94.196 lb./in.

Moment at base of inner Rib [Mbase,c]:
 = $\text{Unit Force} * e * L$
 = $94.2 * 7.76 * 67.75$
 = 49524.906 in.lbs

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
 = $\text{Bending Moment} / \text{Section Modulus}$
 = $49525/6.487$
 = 7633.917 psi

Compressive Allowable, $KL/r < Cc$ ($28.9 < 122.7$) per AISC E2-1 [Sca]:
 = $(1 - (K1r)^2/(2*Cc^2)) Fy / (5/3 + 3*(K1r)/(8*Cc) - (K1r^3)/(8*Cc^3))$
 = $(1 - (28.9)^2/(2 * 122.7^2)) 38000 /$
 $(5/3 + 3*(28.9)/(8* 122.7) - (28.9^3)/(8*122.7^3))$
 = 21072 psi

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

AISC Unity Check of Inside Ribs (must be <= 1)

$$\begin{aligned} &= Sc/Sca + (Mbase,c * C1/I)/Sba \\ &= 2015/21072 +(49525 * 5.495/35.65)/25333 \\ &= 0.397 \end{aligned}$$

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2
Total Number of Bolts in Tension/Baseplate	Nbt	2
Bolt Material Specification	F1554 GR 36	
Bolt Allowable Stress	Stba	21750.00 psi
Bolt Corrosion Allowance	Bca	0.0000 in.
Distance from Bolts to Edge	Edgedis	4.0000 in.
Nominal Bolt Diameter	Bnd	1.0000 in.
Thread Series	Series	UNC
BasePlate Allowable Stress	S	20000.00 psi
Area Available in a Single Bolt	BlArea	0.5510 in²
Saddle Load Q0 (Weight)	Q0	5364.9 lb.
Saddle Load QL (Wind/Seismic contribution)	QL	3939.9 lb.
Maximum Transverse Force	Ft	2072.3 lb.
Maximum Longitudinal Force	F1	4144.6 lb.
Saddle Bolted to Steel Foundation	Yes	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

$$\begin{aligned} &= F1 / (Bolt Area * Number of Bolts) \\ &= 4145/(0.551 * 2) \\ &= 3761.0 \text{ psi. Must be less than } 13050.0 \text{ psi.} \end{aligned}$$

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

$$\begin{aligned} &= Ft / (Bolt Area * Number of Bolts) \\ &= 2072/(0.551 * 2) \\ &= 1880.5 \text{ psi. Must be less than } 13050.0 \text{ psi.} \end{aligned}$$

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

$$= 0.0 \text{ (Q0 > QL --> No Uplift in Longitudinal direction)}$$

Bolt Area due to Shear Load [Bltarears]:

$$\begin{aligned} &= F1 / (BoltShearAllowable * Nbolts) \\ &= 4145/(13050 * 2) \\ &= 0.1588 \text{ in}^2 \end{aligned}$$

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

$$\begin{aligned} &= B * Ft + \text{Sum of X Moments} \\ &= 6.417 * 2072 + 0 \\ &= 13297.29 \text{ ft.lb.} \end{aligned}$$

Eccentricity (e):

$$\begin{aligned} &= Rmom / Q0 \\ &= 159568/5365 \\ &= 29.74 \text{ in. > Bplen/6 --> Uplift in Transverse direction} \end{aligned}$$

$$f = Bplen / 2 - Edgedis$$

$$\begin{aligned} &= 22/2 - 4 \\ &= 7.00 \text{ in.} \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

$$\begin{aligned}
 K1 &= 3 (e - 0.5 * Bplen) \\
 &= 3(29.74 - 0.5*22) \\
 &= 56.23 \text{ in.}
 \end{aligned}$$

$$\begin{aligned}
 K2 &= 6 * n1 * At / Bpwid * (f + e) \\
 &= 6 * 1 * 1.102/8 * (7 + 29.74) \\
 &= 30.37 \text{ in.}^2
 \end{aligned}$$

$$\begin{aligned}
 K3 &= -K2 * (0.5 * Bplen + f) \\
 &= -30.37 *(0.5 * 22 + 7) \\
 &= -546.62 \text{ in.}^3
 \end{aligned}$$

Iteratively Solving for the Effective Bearing Length:

$$\begin{aligned}
 Y^3 + K1 * Y^2 + K2 * Y + K3 &= 0 \\
 Y^3 + 56.23 * Y^2 + 30.37 * Y + -546.6 &= 0 \\
 Y &= 2.80 \text{ in.}
 \end{aligned}$$

$$\begin{aligned}
 Num &= (Bplen / 2 - Y / 3 - e) \\
 &= (22/2 - 2.797/3 - 29.74) \\
 &= -19.68
 \end{aligned}$$

$$\begin{aligned}
 Denom &= (Bplen / 2 - Y / 3 + f) \\
 &= (22/2 - 2.797/3 + 7) \\
 &= 17.07
 \end{aligned}$$

Total Bolt Tension Force [Tforce]:

$$\begin{aligned}
 &= - Q0 * Num / Denom \\
 &= - 5365 * -19.68/17.07 \\
 &= 6184.48 \text{ lb.}
 \end{aligned}$$

Bolt Area Required due to Transverse Load [Bltareart]:

$$\begin{aligned}
 &= Tforce / (Stba * Nbt) \\
 &= 6184/(21750 * 2) \\
 &= 0.1422 \text{ in}^2
 \end{aligned}$$

Required Area of a Single Bolt [Bltarear]:

$$\begin{aligned}
 &= \max[Bltarearl, Bltarears, Bltareart] \\
 &= \max[0, 0.159, 0.142] \\
 &= 0.1588 \text{ in}^2
 \end{aligned}$$

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

$$\begin{aligned}
 &= 2(Q0 + Tforce) / (Y * Bpwid) \\
 &= 2(5365 + 6184)/(2.797 * 8) \\
 &= 1032.39 \text{ psig}
 \end{aligned}$$

Distance from Baseplate Edge to the Web [ADIST]:

$$\begin{aligned}
 &= (Bplen - Weblength) / 2 \\
 &= (22 - 20)/2 \\
 &= 1.0000 \text{ in.}
 \end{aligned}$$

Overturning Moment due To Bolt Tension [Mt]:

$$\begin{aligned}
 &= Tforce * Adist \\
 &= 6184 * 0.0833 \\
 &= 515.37 \text{ ft.lb.}
 \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Equivalent Bearing Pressure (f1):
 $= f_c * (Y - A_{dist}) / Y$
 $= 1032 * (2.797 - 1) / 2.797$
 $= 663.25 \text{ psig}$

Overturning Moment due to Bearing Pressure [Mc]:
 $= (A_{dist}^2 * B_{pwid} / 6) * (f1 + 2 * f_c)$
 $= (0.0833^2 * 0.667 / 6) * (95508 + 2 * 148664)$
 $= 303.11 \text{ ft.lb.}$

Baseplate Required Thickness [Treq]:
 $= \sqrt{6 * \max(M_t, M_c) / (B_{pwid} * S_b)}$
 $= \sqrt{6 * \max(6184, 3637) / (8 * 30000)}$
 $= 0.3932 \text{ in.}$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:**Input and Calculated Values:**

Vessel Mean Radius	Rm	7.88	in.
Shell Thickness used in this Case	t	0.375	in.
Stiffened Vessel Length per 4.15.6	L	13.23	ft.
Distance from Saddle to Vessel tangent	a1 or a	42.50	in.
Saddle Width	b1 or b	7.50	in.
Saddle Bearing Angle	delta or theta	138.00	degrees
Wear Plate Width	b2 or b1	13.00	in.
Wear Plate Bearing Angle	delta2 or theta1	180.00	degrees
Wear Plate Thickness	e2 or tr	0.3125	in.
Wear Plate Allowable Stress	fw or Sr	20000.00	psi
Inside Depth of Head	Hi or h2	0.33	ft.
Shell Allowable Stress used in Calculation		17100.00	psi
Head Allowable Stress used in Calculation		17100.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	77.00	in.
Coefficient of Friction	mu	0.00	
Saddle Force Q, Operating Case		33857.71	lb.
Pressure used in Analysis	P	375.000	psig

Horizontal Vessel Analysis Results:	Actual psi	Allowable psi
-----	-----	-----
Long. Stress at Top of Midspan	8635.16	17100.00
Long. Stress at Bottom of Midspan	3177.34	17100.00
Long. Stress at Top of Saddles	14406.18	17100.00
Long. Stress at Bottom of Saddles	-2593.68	-27900.00
Long. Stress at Bottom of Saddles	2593.68	17100.00
-----	-----	-----
Tangential Shear in Shell	7140.79	13680.00
Circ. Compressive Stress in Shell	981.86	17100.00
Stiffener Circ. Stress at Shell	2357.81	21375.00
Stiffener Circ. Stress at Tip	634.85	25000.00
-----	-----	-----

Intermediate Results: Saddle Reaction Q due to Wind or Seismic:

Saddle Reaction Force due to Wind Ft [Fwt]:
= $F_{tr} (F_t / \text{Num of Saddles} + Z \text{ Force Load}) * B / E$
= $3 (153.1/2 + 0) * 77/15.52$
= 1139.0 lb.

Saddle Reaction Force due to Wind FI [Fwl]:
= $\max(F_l, \text{Sum of X Forces}) * B / L_s$
= $\max(26.74, 0) * 77/81$
= 25.4 lb.

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Saddle Reaction Force due to Earthquake Fl [Fsl]:

$$\begin{aligned} &= \max(F_l, \text{Sum of X Forces}) * B / L_s \\ &= \max(4145, 0) * 77/81 \\ &= 3939.9 \text{ lb.} \end{aligned}$$

Saddle Reaction Force due to Earthquake Ft [Fst]:

$$\begin{aligned} &= F_{tr}(F_t/\text{Num of Saddles} + Z \text{ Force Load}) * B / E \\ &= 3(4145/2 + 0) * 77/15.52 \\ &= 30842.7 \text{ lb.} \end{aligned}$$

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

$$\begin{aligned} &= \text{Saddle Load} + \max(F_{wl}, F_{wt}, F_{sl}, F_{st}) \\ &= 3015 + \max(25.42, 1139, 3940, 30843) \\ &= 33857.7 \text{ lb.} \end{aligned}$$

Longitudinal Wind Force [Fl]:

$$\begin{aligned} &= \text{WindScalar} * \text{WindPress}(\text{Platform Area} + (\pi/4(OD * \text{WindDiaMult})^2)) \\ &= 0.6 * 22.17(0 + \pi/4(1.333 * 1.2)^2) \\ &= 26.743 \text{ lbf} \end{aligned}$$

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	34264.57	lb.
Transverse Shear Load Saddle	2072.31	lb.
Longitudinal Shear Load Saddle	4144.61	lb.

Formulas and Substitutions for Horizontal Vessel Analysis:

Saddle Dimension [E]:

$$\begin{aligned} &= \min(2(\text{ShellID}/2 + t + \text{WearPadThickness}) \sin(\theta/2), 2 * R_m) \\ &= \min(2(15.25/2 + 0.375 + 0.312) \sin(138/2), 2 * 7.875) \\ &= 15.521 \text{ in.} \end{aligned}$$

The Computed K values from Table 4.15.1:

K1 = 0.1374	K2 = 0.9229	K3 = 0.6161	K4 = 0.3336
K5 = 0.7024	K6 = 0.0392	K7 = 0.0392	K8 = 0.3195
K9 = 0.2409	K10 = 0.0448	K1* = 0.2426	K6p = 0.0174
K7p = 0.0174			

The suffix 'p' denotes the values for a wear plate if it exists.

Moment per Equation 4.15.1 [M1]:

$$\begin{aligned} &= -Q * a [1 - (1 - a/L + (R_m^2 - h^2)/(2a * L)) / (1 + (4h^2)/(3L))] \\ &= -33858 * 3.542 [1 - (1 - 3.542/13.23 + (0.656^2 - 0.328^2) / (2 * 3.542 * 13.23)) / (1 + (4 * 0.328) / (3 * 13.23))] \\ &= -34500.5 \text{ ft.lb.} \end{aligned}$$

Moment per Equation 4.15.4 [M2]:

$$\begin{aligned} &= Q * L / 4 (1 + 2(R_m^2 - h^2)/(L^2)) / (1 + (4h^2)/(3L)) - 4a/L \\ &= 33858 * 13.23 / 4 (1 + 2(0.656^2 - 0.328^2)/(13.23^2)) / (1 + (4 * 0.328) / (3 * 13.23)) - 4 * 3.542 / 13.23 \\ &= -11076.4 \text{ ft.lb.} \end{aligned}$$

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

$$\begin{aligned} &= P * R_m / (2t) - M_2 / (\pi * R_m^2 * t) \\ &= 375 * 7.875 / (2 * 0.25) - 132917 / (\pi * 7.875^2 * 0.25) \\ &= 8635.16 \text{ psi} \end{aligned}$$

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

$$\begin{aligned} &= P * R_m / (2t) + M_2 / (\pi * R_m^2 * t) \\ &= 375 * 7.875 / (2 * 0.25) + 132917 / (\pi * 7.875^2 * 0.25) \\ &= 3177.34 \text{ psi} \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Longitudinal Stress at Top of Shell at Support (4.15.6) [sigma3]:

$$\begin{aligned}
 &= P * R_m / (2t) - M_1 / (\pi * R_m^2 * t) \\
 &= 375 * 7.875 / (2 * 0.25) - -414006 / (\pi * 7.875^2 * 0.25) \\
 &= 14406.18 \text{ psi}
 \end{aligned}$$

Longitudinal Stress at bottom of Shell at Support (4.15.7) [sigma4]:

$$\begin{aligned}
 &= P * R_m / (2t) + M_1 / (\pi * R_m^2 * t) \\
 &= 375 * 7.875 / (2 * 0.25) + -414006 / (\pi * 7.875^2 * 0.25) \\
 &= -2593.68 \text{ psi}
 \end{aligned}$$

Maximum Shear Force in the Saddle (4.15.3) [T]:

$$\begin{aligned}
 &= Q(L - 2a) / (L + (4 * h^2 / 3)) \\
 &= 33858(13.23 - 2 * 3.542) / (13.23 + (4 * 0.328 / 3)) \\
 &= 15232.7 \text{ lb.}
 \end{aligned}$$

Shear Stress in the shell with double rings (4.15.12) [tau2]:

$$\begin{aligned}
 &= K_2 * T / (R_m * t) \\
 &= 0.923 * 15233 / (7.875 * 0.25) \\
 &= 7140.79 \text{ psi}
 \end{aligned}$$

Decay Length (4.15.20) [x1,x2]:

$$\begin{aligned}
 &= 0.78 * \sqrt{R_m * t} \\
 &= 0.78 * \sqrt{7.875 * 0.25} \\
 &= 1.094 \text{ in.}
 \end{aligned}$$

Circ. Stress in shell w/rings adjacent to Saddle (4.15.37) [sigma6]:

$$\begin{aligned}
 &= -K_5 * Q * k / (t(b + 2 * x_2)) \\
 &= -0.702 * 33858 * 0.1 / (0.25(7.5 + 2 * 1.094)) \\
 &= -981.86 \text{ psi}
 \end{aligned}$$

Note: Double Rings adjacent to Saddle Outside the Shell.

Circ. + Bending Stress in shell, rings adjacent to Saddle (4.15.40) [sigma10*]:

$$\begin{aligned}
 &= -K_9 * Q/A - K_{10} * Q * R_m * c_1 / I \\
 &= -0.241 * 33858 / 7.657 - 0.0448 * 33858 * 7.875 * 2.268 / 20.94 \\
 &= -2357.81 \text{ psi}
 \end{aligned}$$

Circ. + Bending Stress in ring, rings adjacent to Saddle (4.15.41) [sigma11*]:

$$\begin{aligned}
 &= -K_9 * Q/A + K_{10} * Q * R_m * c_2 / I \\
 &= -0.241 * 33858 / 7.657 + 0.0448 * 33858 * 7.875 * 2.982 / 20.94 \\
 &= 634.85 \text{ psi}
 \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	22.0000	in.
Baseplate Thickness	Bpthk	0.9375	in.
Baseplate Width	Bpwid	8.0000	in.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.4375	in.
Web Thickness	Webtk	0.4375	in.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	18.6	in.
Friction Coefficient	mu	0.000	

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

Inertia of Shell [ShellInertia]:
= ((1.56 * sqrt(R * t) + WearPlateWidth)t³)/12
= ((1.56 * sqrt(7.75 * 0.25) + 13)0.25³)/12
= 0.020 in**4

Resolved Inertia for the Shell [I,shell]:
= ShellInertia + AShell(C1 - Y)²
= 0.0198 + 3.793(34.2 - 0.125)²
= 4403.182 in**4

	B in.	D in.	Y in.	A in ²	AY in. ³	I + AD ² in**4
Shell	15.1714	0.2500	0.1250	3.7929	0.4741	4403.1821
Wearplate	13.0000	0.3125	0.4062	4.0625	1.6504	4638.6875
Web	0.4375	67.7500	34.4375	29.6406	1020.7490	11339.4072
BasePlate	8.0000	0.9375	68.7812	7.5000	515.8594	8971.0156
Totals	...	...	...	44.9960	1538.7329	29352.2969

Distance to Centroid [C1]:
= AY / A
= 1539/45
= 34.197 in.

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 138/2
= 111.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)²)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(111) - 0.5*sin(111)²)/(pi - 1.937 + sin(111)cos(111))
= 0.2367

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.237 * 33858
= 8013.5356 lb.

Tension Stress, St = (Fh/As) = 194.4885 psi
Allowed Stress, Sa = 0.6 * Yield Str = 22800.0000 psi

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Saddle Splitting Dimension [d]:

$$= B - R * \sin(\theta/2)/(\theta/2 \text{ in radians})$$

$$= 77 - 7.75 * \sin(138/2)/1.204$$

$$= 70.992 \text{ in.}$$

Bending Moment, M = Fh * d = 47408.1055 ft.lb.

Bending Stress, Sb = (M * C1 / I) = 662.7981 psi

Allowed Stress, Sa = 2/3 * Yield Str = 25333.3340 psi

Minimum Thickness of Baseplate per Moss:

$$= \sqrt{3(Q + \text{Saddle\_Wt}) \text{BasePlateWidth} / (2 * \text{BasePlateLength} * \text{AllStress})}$$

$$= \sqrt{3(33858 + 406.9)8 / (2 * 22 * 25333)}$$

$$= 0.859 \text{ in.}$$

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:

$$= 2 * \cos(90 - \text{Saddle Angle}/2)(\text{Inside Radius} + \text{Shell Thk} + \text{Wear Plate Thk})$$

$$= 2 * \cos(90 - 138/2)(7.625 + 0.375 + 0.312)$$

$$= 15.521 \text{ in.}$$

Distance between Ribs [e]:

$$= \text{Web Length} / (\text{Nribs} - 1)$$

$$= 15.52 / (3 - 1)$$

$$= 7.760 \text{ in.}$$

Baseplate Pressure Area [Ap]:

$$= e * \text{Bpwid} / 2$$

$$= 7.76 * 8 / 2$$

$$= 31.042 \text{ in}^2$$

Bearing Pressure [Bp]:

$$= Q / (\text{BasePlateLength} * \text{BasePlateWidth})$$

$$= 33858 / (22 * 8)$$

$$= 192.373 \text{ lb./in}^2$$

Axial Load [P]:

$$= \text{Ap} * \text{Bp}$$

$$= 31.04 * 192.4$$

$$= 5971.566 \text{ lb.}$$

Area of the Rib and Web [Ar]:

$$= \text{Rib Area} + \text{Web Area}$$

$$= 3.09 + 1.698$$

$$= 4.787 \text{ in}^2$$

Compressive Stress [Sc]:

$$= P / \text{Ar}$$

$$= 5972 / 4.787$$

$$= 1247.343 \text{ psi}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.4375	7.0625	3.9688	3.0898	12.2628	18.3065
Web	3.8802	0.4375	0.2188	1.6976	0.3713	9.9711
Totals	...	...	...	4.7874	12.6342	28.2776

Rib dimension [D]:

= Saddle Width - Web Thickness
= 7.5 - 0.438
= 7.062 in.

Distance to Centroid from Datum [ytot]:

= AY / A
= 12.63/4.787
= 2.639 in.

Distance to Centroid [C1]:

= max(ytot, Saddle Width - ytot)
= max(2.639, 7.5 - 2.639)
= 4.861 in.

Radius of Gyration [r]:

= sqrt(Total Inertia / Total Area)
= sqrt(28.28/4.787)
= 2.430 in.

Length of Outer Rib [L]:

= Saddle Height - cos(theta/2)(radius + shlthk + wpdthk) - bpthk
= 77 - cos(138/2)(7.625 + 0.375 + 0.312) - 0.938
= 73.084 in.

Intermediate Term [Cc]:

= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 29000000/38000)
= 122.736

Slenderness ratio [KL/r]:

= KL/r
= 1 * 73.08/2.43
= 30.071

Bending Moment [Rm]:

= F1 / (2 * Bplen) * e * L / 2
= 4145 / (2 * 22) * 7.76 * 73.08/2
= 2225.988 ft.lb.

Compressive Allowable, KL/r < Cc(30.07 < 122.7) per AISC E2-1 [Sca]:

= (1 - (KL/r)² / (2 * Cc²)) Fy / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)³ / (8 * Cc³))
= (1 - (30.07)² / (2 * 122.7²)) 38000 /
(5/3 + 3 * (30.07) / (8 * 122.7) - (30.07³) / (8 * 122.7³))
= 20982 psi

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

AISC Unity Check of Outside Ribs (must be <= 1)
 = $S_c/S_{ca} + (R_m * C_1 / I)/S_{ba}$
 = $1247/20982 + (26712 * 4.861/28.28)/25333$
 = 0.241

AISC Unity Check of Outside Ribs, due to Transverse Force Ft (must be <= 1)

This analysis assumes the entire saddle weight load and load due to transverse forces are concentrated on the outer rib + some portion of the web. This generally would not be the case and as such this analysis is very conservative.

Inertia of Saddle, Outer Ribs - Transverse Direction:

	B	D	Y	A	AY	Io
Rib	7.0625	0.4375	0.2188	3.0898	0.6759	8.2923
Web	0.4375	7.0000	3.5000	3.0625	10.7188	20.8218
Totals	...	...	...	6.1523	11.3947	29.1141

Web dimension [D]:
 = 16 * Web Thickness
 = 16 * 0.438
 = 7.000 in.

Moment at base of outer Rib [Mbase]:
 = $F_t(\text{Centerline dimension B} - \text{Baseplate thickness})$
 = $2072(77 - 0.938)$
 = 157624.719 in.lbs

Bending Stress due to Transverse Force [SigmaB,base]:
 = Bending Moment / Section Modulus
 = 157625/15.72
 = 10027.232 psi

Vertical Load on the Rib due to the Bending Moment [Fv,mom]:
 = Bending Moment / Web Length
 = 157625/15.52
 = 10155.726 lb.

Total Vertical Load on the Rib [Fv,total]:
 = Fv,mom + Vertical Load
 = 10156 + 34265
 = 44420.301 lb.

Compressive Stress on Outer Rib [Sigma,cr]:
 = $F_{v,total} / \text{Area}$
 = $44420/6.152$
 = 7220.062 psi

Radius of Gyration [r]:
 = $\text{sqrt}(\text{Total Inertia} / \text{Total Area})$
 = $\text{sqrt}(29.11/6.152)$
 = 2.175 in.

Slenderness ratio [KL/r]:
 = KL/r
 = $1 * 73.08/2.175$
 = 33.596

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Compressive Allowable, $KL/r < Cc$ ($33.6 < 122.7$) per AISC E2-1 [Sca]:

$$= (1 - (KL/r)^2 / (2 * Cc^2)) F_y / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)^3 / (8 * Cc^3))$$

$$= (1 - (33.6)^2 / (2 * 122.7^2)) 38000 / (5/3 + 3 * (33.6) / (8 * 122.7) - (33.6^3) / (8 * 122.7^3))$$

$$= 20703 \text{ psi}$$

Unity Check on Outer Rib [Ucheck,outer]:

$$= \text{Sigma}_{cr} / S_{ca} + \text{Sigma}_{B,base} / S_{ba}$$

$$= 7220/20703 + 10027/25333$$

$$= 0.745$$

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.4375	7.0625	3.9688	3.0898	12.2628	24.7529
Web	7.7604	0.4375	0.2188	3.3952	0.7427	10.8928
Totals	...	...	...	6.4850	13.0055	35.6457

Distance to Centroid from Datum [ytot]:

$$= AY / A$$

$$= 13.01/6.485$$

$$= 2.005 \text{ in.}$$

Distance to Centroid [C1]:

$$= \max(y_{tot}, \text{abs}(\text{Saddle Width} - y_{tot}))$$

$$= \max(2.005, \text{abs}(7.5 - 2.005))$$

$$= 5.495 \text{ in.}$$

Length of Inner Rib [L]:

$$= \text{Saddle Height} - \text{Outside Radius} - B_{pthk}$$

$$= 77 - \cos(8.312/2) (0.938 + 0 + 0) - 0$$

$$= 67.750 \text{ in.}$$

Radius of Gyration [r]:

$$= \sqrt{ \text{Total Inertia} / \text{Total Area} }$$

$$= \sqrt{ 35.65/6.485 }$$

$$= 2.344 \text{ in.}$$

Slenderness ratio [KL/r]:

$$= KL/r$$

$$= 1 * 67.75/2.344$$

$$= 28.898$$

Unit Force [Force,u]:

$$= F_1 / (2 * \text{Baseplate Length})$$

$$= 4145 / (2 * 22)$$

$$= 94.196 \text{ lb./in.}$$

Moment at base of inner Rib [Mbase,c]:

$$= \text{Unit Force} * e * L$$

$$= 94.2 * 7.76 * 67.75$$

$$= 49524.906 \text{ in.lbs}$$

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

$$= \text{Bending Moment} / \text{Section Modulus}$$

$$= 49525/6.487$$

$$= 7633.917 \text{ psi}$$

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Compressive Allowable, $KL/r < Cc$ ($28.9 < 122.7$) per AISC E2-1 [Sca]:

$$= (1 - (KL/r)^2 / (2 * Cc^2)) F_y / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)^3 / (8 * Cc^3))$$

$$= (1 - (28.9)^2 / (2 * 122.7^2)) 38000 / (5/3 + 3 * (28.9) / (8 * 122.7) - (28.9^3) / (8 * 122.7^3))$$

$$= 21072 \text{ psi}$$

AISC Unity Check of Inside Ribs (must be <= 1)

$$= S_c / S_{ca} + (M_{base,c} * C_1 / I) / S_{ba}$$

$$= 1906 / 21072 + (49525 * 5.495 / 35.65) / 25333$$

$$= 0.392$$

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2
Total Number of Bolts in Tension/Baseplate	Nbt	2
Bolt Material Specification		F1554 GR 36
Bolt Allowable Stress	Stba	21750.00 psi
Bolt Corrosion Allowance	Bca	0.0000 in.
Distance from Bolts to Edge	Edgedis	4.0000 in.
Nominal Bolt Diameter	Bnd	1.0000 in.
Thread Series	Series	UNC
BasePlate Allowable Stress	S	20000.00 psi
Area Available in a Single Bolt	BltArea	0.5510 in²
Saddle Load Q0 (Weight)	Q0	3421.9 lb.
Saddle Load QL (Wind/Seismic contribution)	QL	3939.9 lb.
Maximum Transverse Force	Ft	2072.3 lb.
Maximum Longitudinal Force	F1	4144.6 lb.
Saddle Bolted to Steel Foundation		Yes

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

$$= F_1 / (\text{ Bolt Area } * \text{ Number of Bolts })$$

$$= 4145 / (0.551 * 2)$$

$$= 3761.0 \text{ psi. Must be less than } 13050.0 \text{ psi.}$$

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

$$= F_t / (\text{ Bolt Area } * \text{ Number of Bolts })$$

$$= 2072 / (0.551 * 2)$$

$$= 1880.5 \text{ psi. Must be less than } 13050.0 \text{ psi.}$$

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

$$= (Q_L - Q_0) / (St_{ba} * R_{nbolts})$$

$$= (3940 - 3422) / (21750 * 2)$$

$$= 0.0119 \text{ in}^2$$

Bolt Area due to Shear Load [Bltarears]:

$$= F_1 / (\text{ BoltShearAllowable } * N_{bolts})$$

$$= 4145 / (13050 * 2)$$

$$= 0.1588 \text{ in}^2$$

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6”-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

$$\begin{aligned} &= B * Ft + \text{Sum of X Moments} \\ &= 6.417 * 2072 + 0 \\ &= 13297.29 \text{ ft.lb.} \end{aligned}$$

Eccentricity (e):

$$\begin{aligned} &= Rmom / Q0 \\ &= 159568/3422 \\ &= 46.63 \text{ in.} > Bplen/6 \rightarrow \text{Uplift in Transverse direction} \end{aligned}$$

f = Bplen / 2 - Edgedis

$$\begin{aligned} &= 22/2 - 4 \\ &= 7.00 \text{ in.} \end{aligned}$$

K1 = 3 (e - 0.5 * Bplen)

$$\begin{aligned} &= 3(46.63 - 0.5*22) \\ &= 106.89 \text{ in.} \end{aligned}$$

K2 = 6 * n1 * At / Bpwid * (f + e)

$$\begin{aligned} &= 6 * 1 * 1.102/8 * (7 + 46.63) \\ &= 44.33 \text{ in.}^2 \end{aligned}$$

K3 = -K2 * (0.5 * Bplen + f)

$$\begin{aligned} &= -44.33 * (0.5 * 22 + 7) \\ &= -797.88 \text{ in.}^3 \end{aligned}$$

Iteratively Solving for the Effective Bearing Length:

$$Y^3 + K1 * Y^2 + K2 * Y + K3 = 0$$

$$Y^3 + 106.9 * Y^2 + 44.33 * Y + -797.9 = 0$$

$$Y = 2.51 \text{ in.}$$

Num = (Bplen / 2 - Y / 3 - e)

$$\begin{aligned} &= (22/2 - 2.506/3 - 46.63) \\ &= -36.47 \end{aligned}$$

Denom = (Bplen / 2 - Y / 3 + f)

$$\begin{aligned} &= (22/2 - 2.506/3 + 7) \\ &= 17.16 \end{aligned}$$

Total Bolt Tension Force [Tforce]:

$$\begin{aligned} &= - Q0 * Num / Denom \\ &= - 3422 * -36.47/17.16 \\ &= 7269.80 \text{ lb.} \end{aligned}$$

Bolt Area Required due to Transverse Load [Bltareart]:

$$\begin{aligned} &= Tforce / (Stba * Nbt) \\ &= 7270 / (21750 * 2) \\ &= 0.1671 \text{ in}^2 \end{aligned}$$

Required Area of a Single Bolt [Bltarear]:

$$\begin{aligned} &= \max[Bltarearl, Bltarears, Bltareart] \\ &= \max[0.0119, 0.159, 0.167] \\ &= 0.1671 \text{ in}^2 \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
= $2(Q_0 + T_{force}) / (Y * B_{pwid})$
= $2(3422 + 7270) / (2.506 * 8)$
= 1066.78 psig

Distance from Baseplate Edge to the Web [ADIST]:
= $(B_{plen} - Web_{length}) / 2$
= $(22 - 20) / 2$
= 1.0000 in.

Overturning Moment due To Bolt Tension [Mt]:
= $T_{force} * A_{dist}$
= $7270 * 0.0833$
= 605.82 ft.lb.

Equivalent Bearing Pressure (f1):
= $f_c * (Y - A_{dist}) / Y$
= $1067 * (2.506 - 1) / 2.506$
= 641.02 psig

Overturning Moment due to Bearing Pressure [Mc]:
= $(A_{dist}^2 * B_{pwid} / 6) * (f_1 + 2 * f_c)$
= $(0.0833^2 * 0.667 / 6) * (92307 + 2 * 153617)$
= 308.29 ft.lb.

Baseplate Required Thickness [Treq]:
= $\sqrt{6 * \max(M_t, M_c) / (B_{pwid} * S_{ba})}$
= $\sqrt{6 * \max(7270, 3699) / (8 * 30000)}$
= 0.4263 in.

MDMT Calculations for: SdI 2 Fr20, Saddle to Wearplate Junction, Curve: B

Govrn. thk, tg = 0.312, c = 0.125 in., $E^* = 1$
Thickness Ratio = $tr * E^* / (tg - c) = 0.487$, Temp. Reduction = 61 °F
Attachment governing, Attachment stress = Shell stress per Code

Min Metal Temp. w/o impact per UCS-66, Curve B	-20 °F
Min Metal Temp. at Required thickness (UCS 66.1)	-55 °F

PV Elite is a trademark of Hexagon AB, 2022, All rights reserved.

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Wind Load Calculation Results: BOTTOM UNIT

Input Values:

Wind Design Code	ASCE/SEI 7-16
Wind Load Reduction Scale Factor	0.600
Basic Wind Speed	101 mile/hr
Surface Roughness Category	C: Open Terrain
Importance Factor	1.0 This value cannot be modified w/ ASCE 7-16
Type of Surface	Moderately Smooth
Base Elevation	2.9166 ft.
Percent Wind for Hydrotest	0.75
Using User defined Wind Press. Vs Elev.	N
Height of Hill or Escarpment H or Hh	0 ft.
Distance Upwind of Crest Lh	0 ft.
Distance from Crest to the Vessel x	0 ft.
Type of Terrain (Hill, Escarpment)	Flat
Damping Factor (Beta) for Wind (Ope)	0.0100
Damping Factor (Beta) for Wind (Empty)	0.0000
Damping Factor (Beta) for Wind (Filled)	0.0000
Site Elevation above Sea Level	78 ft.

Wind Analysis Results

Static Gust-Effect Factor, Operating Case [G]:

$$\begin{aligned}
 &= \min(0.85, 0.925((1 + 1.7 * g_Q * I_{zbar} * Q)/(1 + 1.7 * g_V * I_{zbar}))) \\
 &= \min(0.85, 0.925((1+1.7*3.4*0.228*0.983)/(1+1.7*3.4*0.228))) \\
 &= \min(0.85, 0.916) \\
 &= 0.850
 \end{aligned}$$

Natural Frequency of Vessel (Operating)	33.000 Hz
Natural Frequency of Vessel (Empty)	33.000 Hz
Natural Frequency of Vessel (Test)	33.000 Hz

User Entered Importance Factor is	1.000
Force Coefficient	[Cf] 0.629
Structure Height to Diameter ratio	12.279

This is classified as a rigid structure. Static analysis performed.

Sample Calculation for the First Element:

Value of [Alpha] and [Zg]:

Exposure Category: C from Table 26.11-1

Alpha = 9.5 : Zg = 900 ft.

Effective Height [z]:

$$\begin{aligned}
 &= \text{Centroid Height} + \text{Vessel Base Elevation} \\
 &= 2.417 + 2.917 = 5.333 \text{ ft.}
 \end{aligned}$$

Velocity Pressure coefficient evaluated at height z [Kz]:

$$\begin{aligned}
 &\text{Because } z(5.333 \text{ ft.}) < 15 \text{ ft.} \\
 &= 2.01(15 / Z_g)^{2/\text{Alpha}} \\
 &= 2.01(15/900)^{2/9.5} \\
 &= 0.849
 \end{aligned}$$

Type of Hill: No Hill

Wind Directionality Factor [Kd]:

= 1, per Table 26.6-1

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

As there is No Hill Present: [Kzt]:
K1 = 0, K2 = 0, K3 = 0

Topographical Factor [Kzt]:
= (1 + K1 * K2 * K3)²
= (1 + 0 * 0 * 0)²
= 1

Velocity Pressure evaluated at height z, Imperial Units [qz]:
= max(16, 0.00256 * Kz * Kzt * Kd * Ke * V(mph)²)
= max(16, 0.00256 * 0.849 * 1 * 1 * 0.997 * 101²)
= 22.1 psf

Force on the first element [F]:
= qz * G * Cf * WindArea
= 22.1 * 0.85 * 0.629 * 0.632
= 7.5 lb.

Element	Hgt (z) ft.	K1	K2	K3	Kz	Kzt	qz psf
Node 10 to 20	5.3	0.000	0.000	0.000	0.849	1.000	22.099
Node 20 to 30	5.3	0.000	0.000	0.000	0.849	1.000	22.099
Node 30 to 40	5.3	0.000	0.000	0.000	0.849	1.000	22.099

Wind Loads on Masses/Equipment/Piping

ID	Wind Area sq.in.	Elevation ft.	Pressure psf	Force lb.
WGHT:[1 OF 1]	0.00	5.33	22.10	0.00
WGHT:[1 OF 1]	0.00	5.33	22.10	0.00

Wind Load Calculation:

From	To	Wind Height ft.	Wind Diameter ft.	Wind Area sq.in.	Wind Pressure psf	Element Wind Load lb.
10	20	5.33327	1.6	91.0217	22.0991	4.48336
20	30	5.33327	1.6	3597.58	22.0991	177.202
30	40	5.33327	1.6	91.0217	22.0991	4.48336

PV Elite is a trademark of Hexagon AB, 2022, All rights reserved.

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Earthquake Load Calculation Results: BOTTOM UNIT

Earthquake Load Calculation:

Input Values:

Seismic Design Code	ASCE/SEI 7-16
Seismic Load Reduction Scale Factor	0.700
Importance Factor	1.500
Table Value Fa	1.000
Table Value Fv	1.721
Max. Mapped Res. Acceleration [Ss]	1.616
Max. Eff. Ground Acceleration [S]	0.579
Force Modification Factor R	2.500
Site Class	D
Component Elevation Ratio z/h	1.000
Amplification Factor Ap	1.000
Force Factor	0.000
Consider Vertical Acceleration	Yes
Minimum Acceleration Multiplier	0.000
User Value of Sds (used if > 0)	1.077
User Value of Sd1 (used if > 0)	0.996
Moment Reduction Factor Tau	1.000

Seismic Analysis Results:

$$S_{ms} = F_a * S_s = 1 * 1.616 = 1.616$$

$$S_{m1} = F_v * S_1 = 1.721 * 0.579 = 0.996$$

$$S_{ds} = 2/3 * S_{ms} = 2/3 * 1.616 = 1.077$$

$$S_{ds} = \text{Max}(0.8 * S_{ds}, S_{dsUser})$$

$$= \text{Max}(0.862, 1.077)$$

$$= 1.077$$

$$S_{d1} = 2/3 * S_{m1} = 2/3 * 0.996 = 0.664$$

$$S_{d1} = \text{Max}(0.8 * S_{d1}, S_{d1User})$$

$$= \text{Max}(0.531, 0.996)$$

$$= 0.996$$

Check Approximate Fundamental Period from 12.8-7 [Ta]:

$$= C_t * h_n^x \text{ where } C_t = 0.020, x = 0.75 \text{ and } h_n = \text{Structural Height (ft.)}$$

$$= 0.020 * (2.885^{0.75})$$

$$= 0.044 \text{ seconds}$$

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

$$= (1/\text{Natural Frequency}) = (1/33)$$

$$= 0.030$$

Check the Value of T which is the smaller of Cu*Ta and T:

$$= \text{Minimum Value of}(1.4 * 0.0443, 0.0303) \text{ per 12.8.2}$$

$$= 0.030$$

Compute the Seismic Force per equation 13.3-1, [Fp]:

$$= 0.4 * A_p * S_{ds} * W * (1 + 2 * (z/h)) / (R / I_e)$$

$$= 0.4 * 1 * 1.077 * 13504 * (1 + 2 * 1) / (2.5/1.5)$$

$$= 10471.567 \text{ lb.}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Check the Maximum value of Fp per equation 13.3-2:
 = 1.6 * Sds * I * W
 = 1.6 * 1.077 * 1.5 * 13504 = 34905 lb.

Check the Minimum value of Fp per equation 13.3-3:
 = 0.3 * 1.077 * 1.5 * 13504
 = 6544.729 lb.

Compute the Total Base Shear V = Fp, [V]:
 = 10471.567 lb.

Vertical load per 12.4-4, [Ev]:
 = 0.2 * Sds * W
 = 0.2 * 1.077 * 13504
 = 2908.8 lb.

Final Base Shear, V = 7330.10 lb.
 Final Vertical Load, Ev = 2036.14 lb.

Earthquake Load Calculation:

From	To	Earthquake Height ft.	Earthquake Weight lb.	Element Ope Load lb.
10	20	0.63542	2700.81	1466.02
20	Sad1	0.63542	2700.81	1466.02
Sad1	30	0.63542	2700.81	1466.02
20	30	0.63542	2700.81	1466.02
30	40	0.63542	2700.81	1466.02

PV Elite is a trademark of Hexagon AB, 2022, All rights reserved.

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6”-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

**ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:
BOTTOM UNIT**

Horizontal Vessel Stress Calculations : Operating Case

Input and Calculated Values:

Vessel Mean Radius	Rm	7.88	in.
Shell Thickness used in this Case	t	0.375	in.
Stiffened Vessel Length per 4.15.6	L	13.23	ft.
Distance from Saddle to Vessel tangent	a1 or a	34.56	in.
Saddle Width	b1 or b	7.50	in.
Saddle Bearing Angle	delta or theta	138.00	degrees
Wear Plate Width	b2 or b1	13.00	in.
Wear Plate Bearing Angle	delta2 or theta1	180.00	degrees
Wear Plate Thickness	e2 or tr	0.3125	in.
Wear Plate Allowable Stress	fw or Sr	20000.00	psi
Inside Depth of Head	Hi or h2	0.33	ft.
Shell Allowable Stress used in Calculation		17100.00	psi
Head Allowable Stress used in Calculation		17100.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	27.00	in.
Coefficient of Friction	mu	0.00	
Saddle Force Q, Operating Case		29524.05	lb.
Pressure used in Analysis	P	375.000	psig
Horizontal Vessel Analysis Results:	Actual Allowable		
	psi psi		
-----	-----		
Long. Stress at Top of Midspan	3474.50	17100.00	
Long. Stress at Bottom of Midspan	8338.00	17100.00	
Long. Stress at Top of Saddles	10904.28	17100.00	
Long. Stress at Bottom of Saddles	908.22	17100.00	
-----	-----		
Tangential Shear in Shell	7566.01	13680.00	
Circ. Compressive Stress in Shell	856.19	17100.00	
Stiffener Circ. Stress at Shell	2056.02	21375.00	
Stiffener Circ. Stress at Tip	553.59	25000.00	
-----	-----		

Intermediate Results: Saddle Reaction Q due to Wind or Seismic:

Saddle Reaction Force due to Wind Ft [Fwt]:

$$\begin{aligned}
 &= F_{tr} (F_t / \text{Num of Saddles} + Z \text{ Force Load}) * B / E \\
 &= 3 (153.1/2 + 0) * 27/15.52 \\
 &= 399.4 \text{ lb.}
 \end{aligned}$$

Saddle Reaction Force due to Wind FI [FWI]:

$$\begin{aligned}
 &= \max (F_I, \text{Sum of X Forces}) * B / L_s \\
 &= \max (26.74, 0) * 27/81 \\
 &= 8.9 \text{ lb.}
 \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Saddle Reaction Force due to Earthquake Fl [Fsl]:

$$\begin{aligned} &= \max(F_l, \text{Sum of X Forces}) * B / L_s \\ &= \max(7474, 0) * 27/81 \\ &= 2491.4 \text{ lb.} \end{aligned}$$

Saddle Reaction Force due to Earthquake Ft [Fst]:

$$\begin{aligned} &= F_{tr}(F_t/\text{Num of Saddles} + Z \text{ Force Load}) * B / E \\ &= 3(7474/2 + 0) * 27/15.52 \\ &= 19503.6 \text{ lb.} \end{aligned}$$

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

$$\begin{aligned} &= \text{Saddle Load} + \max(F_{wl}, F_{wt}, F_{sl}, F_{st}) \\ &= 10020 + \max(8.914, 399.4, 2491, 19504) \\ &= 29524.0 \text{ lb.} \end{aligned}$$

Longitudinal Wind Force [Fl]:

$$\begin{aligned} &= \text{WindScalar} * \text{WindPress}(\text{Platform Area} + (\pi/4(OD * \text{WindDiaMult})^2)) \\ &= 0.6 * 22.17(0 + \pi/4(1.333 * 1.2)^2) \\ &= 26.743 \text{ lbf} \end{aligned}$$

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	29698.04	lb.
Transverse Shear Load Saddle	3737.16	lb.
Longitudinal Shear Load Saddle	7474.33	lb.

Formulas and Substitutions for Horizontal Vessel Analysis:

Saddle Dimension [E]:

$$\begin{aligned} &= \min(2(\text{ShellID}/2 + t + \text{WearPadThickness}) \sin(\theta/2), 2 * R_m) \\ &= \min(2(15.25/2 + 0.375 + 0.312) \sin(138/2), 2 * 7.875) \\ &= 15.521 \text{ in.} \end{aligned}$$

The Computed K values from Table 4.15.1:

K1 = 0.1374	K2 = 0.9229	K3 = 0.6161	K4 = 0.3336
K5 = 0.7024	K6 = 0.0392	K7 = 0.0392	K8 = 0.3195
K9 = 0.2409	K10 = 0.0448	K1* = 0.2426	K6p = 0.0174
K7p = 0.0174			

The suffix 'p' denotes the values for a wear plate if it exists.

Moment per Equation 4.15.1 [M1]:

$$\begin{aligned} &= -Q * a [1 - (1 - a/L + (R_m^2 - h^2)/(2a * L)) / (1 + (4h^2)/3L)] \\ &= -29524 * 2.88 [1 - (1 - 2.88/13.23 + (0.656^2 - 0.328^2) / (2 * 2.88 * 13.23)) / (1 + (4 * 0.328) / (3 * 13.23))] \\ &= -20286.6 \text{ ft.lb.} \end{aligned}$$

Moment per Equation 4.15.4 [M2]:

$$\begin{aligned} &= Q * L / 4 (1 + 2(R_m^2 - h^2)/(L^2)) / (1 + (4h^2)/(3L)) - 4a/L \\ &= 29524 * 13.23 / 4 (1 + 2(0.656^2 - 0.328^2)/(13.23^2)) / (1 + (4 * 0.328) / (3 * 13.23)) - 4 * 2.88 / 13.23 \\ &= 9870.3 \text{ ft.lb.} \end{aligned}$$

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

$$\begin{aligned} &= P * R_m / (2t) - M_2 / (\pi * R_m^2 t) \\ &= 375 * 7.875 / (2 * 0.25) - 118443 / (\pi * 7.875^2 * 0.25) \\ &= 3474.50 \text{ psi} \end{aligned}$$

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

$$\begin{aligned} &= P * R_m / (2t) + M_2 / (\pi * R_m^2 * t) \\ &= 375 * 7.875 / (2 * 0.25) + 118443 / (\pi * 7.875^2 * 0.25) \\ &= 8338.00 \text{ psi} \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Longitudinal Stress at Top of Shell at Support (4.15.6) [sigma3]:

$$= P * R_m / (2t) - M_1 / (\pi * R_m^2 * t)$$

$$= 375 * 7.875 / (2 * 0.25) - -243439 / (\pi * 7.875^2 * 0.25)$$

$$= 10904.28 \text{ psi}$$

Longitudinal Stress at bottom of Shell at Support (4.15.7) [sigma4]:

$$= P * R_m / (2t) + M_1 / (\pi * R_m^2 * t)$$

$$= 375 * 7.875 / (2 * 0.25) + -243439 / (\pi * 7.875^2 * 0.25)$$

$$= 908.22 \text{ psi}$$

Maximum Shear Force in the Saddle (4.15.3) [T]:

$$= Q(L - 2a) / (L + (4 * h^2 / 3))$$

$$= 29524(13.23 - 2 * 2.88) / (13.23 + (4 * 0.328^2 / 3))$$

$$= 16139.8 \text{ lb.}$$

Shear Stress in the shell with double rings (4.15.12) [tau2]:

$$= K_2 * T / (R_m * t)$$

$$= 0.923 * 16140 / (7.875 * 0.25)$$

$$= 7566.01 \text{ psi}$$

Decay Length (4.15.20) [x1,x2]:

$$= 0.78 * \sqrt{R_m * t}$$

$$= 0.78 * \sqrt{7.875 * 0.25}$$

$$= 1.094 \text{ in.}$$

Circ. Stress in shell w/rings adjacent to Saddle (4.15.37) [sigma6]:

$$= -K_5 * Q * k / (t(b + 2 * x^2))$$

$$= -0.702 * 29524 * 0.1 / (0.25(7.5 + 2 * 1.094^2))$$

$$= -856.19 \text{ psi}$$

Note: Double Rings adjacent to Saddle Outside the Shell.

Circ. + Bending Stress in shell, rings adjacent to Saddle (4.15.40) [sigma10*]:

$$= -K_9 * Q/A - K_{10} * Q * R_m * c_1/I$$

$$= -0.241 * 29524 / 7.657 - 0.0448 * 29524 * 7.875 * 2.268 / 20.94$$

$$= -2056.02 \text{ psi}$$

Circ. + Bending Stress in ring, rings adjacent to Saddle (4.15.41) [sigma11*]:

$$= -K_9 * Q/A + K_{10} * Q * R_m * c_2/I$$

$$= -0.241 * 29524 / 7.657 + 0.0448 * 29524 * 7.875 * 2.982 / 20.94$$

$$= 553.59 \text{ psi}$$

Distance between Saddle Supports [Ls]:

$$= 81.0 \text{ in.}$$

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

$$= \alpha * L_s (\text{Design Temperature} - \text{Ambient Temperature})$$

$$= 0.69000E-05 * 81(300 - 70)$$

$$= 0.129 \text{ in.}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	22.0000	in.
Baseplate Thickness	Bpthk	0.9375	in.
Baseplate Width	Bpwid	8.0000	in.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.4375	in.
Web Thickness	Webtk	0.4375	in.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	18.6	in.
Friction Coefficient	mu	0.000	

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

Inertia of Shell [ShellInertia]:
= ((1.56 * sqrt(R * t) + WearPlateWidth)t³)/12
= ((1.56 * sqrt(7.75 * 0.25) + 13)0.25³)/12
= 0.020 in**4

Resolved Inertia for the Shell [I,shell]:
= ShellInertia + AShell(C1 - Y)²
= 0.0198 + 3.793(9.354 - 0.125)²
= 323.069 in**4

	B in.	D in.	Y in.	A in ²	AY in. ³	I + AD ² in**4
Shell	15.1714	0.2500	0.1250	3.7929	0.4741	323.0690
Wearplate	13.0000	0.3125	0.4062	4.0625	1.6504	325.2805
Web	0.4375	17.7500	9.4375	7.7656	73.2881	203.9424
BasePlate	8.0000	0.9375	18.7812	7.5000	140.8594	667.1077
Totals	...	...	...	23.1210	216.2720	1519.3995

Distance to Centroid [C1]:
= AY / A
= 216.3/23.12
= 9.354 in.

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 138/2
= 111.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)²)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(111) - 0.5*sin(111)²)/(pi - 1.937 + sin(111)cos(111))
= 0.2367

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.237 * 29524
= 6987.8330 lb.

Tension Stress, St = (Fh/As) = 361.5370 psi
Allowed Stress, Sa = 0.6 * Yield Str = 22800.0000 psi

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Saddle Splitting Dimension [d]:

$$\begin{aligned} &= B - R * \sin(\theta/2)/(\theta/2 \text{ in radians}) \\ &= 27 - 7.75 * \sin(138/2)/1.204 \\ &= 20.992 \text{ in.} \end{aligned}$$

$$\text{Bending Moment, } M = F_h * d = 12224.0732 \text{ ft.lb.}$$

$$\text{Bending Stress, } S_b = (M * C_1 / I) = 903.0652 \text{ psi}$$

$$\text{Allowed Stress, } S_a = 2/3 * \text{Yield Str} = 25333.3340 \text{ psi}$$

Minimum Thickness of Baseplate per Moss:

$$\begin{aligned} &= \sqrt{3(Q + \text{Saddle\_Wt}) \text{BasePlateWidth} / (2 * \text{BasePlateLength} * \text{AllStress})} \\ &= \sqrt{3(29524 + 174)8/(2 * 22 * 25333)} \\ &= 0.800 \text{ in.} \end{aligned}$$

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:

$$\begin{aligned} &= 2 * \cos(90 - \text{Saddle Angle}/2)(\text{Inside Radius} + \text{Shell Thk} + \text{Wear Plate Thk}) \\ &= 2 * \cos(90 - 138/2)(7.625 + 0.375 + 0.312) \\ &= 15.521 \text{ in.} \end{aligned}$$

Distance between Ribs [e]:

$$\begin{aligned} &= \text{Web Length} / (\text{Nribs} - 1) \\ &= 15.52/(3 - 1) \\ &= 7.760 \text{ in.} \end{aligned}$$

Baseplate Pressure Area [Ap]:

$$\begin{aligned} &= e * \text{Bpwid} / 2 \\ &= 7.76 * 8/2 \\ &= 31.042 \text{ in}^2 \end{aligned}$$

Bearing Pressure [Bp]:

$$\begin{aligned} &= Q / (\text{BasePlateLength} * \text{BasePlateWidth}) \\ &= 29524/(22 * 8) \\ &= 167.750 \text{ lb./in}^2 \end{aligned}$$

Axial Load [P]:

$$\begin{aligned} &= A_p * B_p \\ &= 31.04 * 167.8 \\ &= 5207.228 \text{ lb.} \end{aligned}$$

Area of the Rib and Web [Ar]:

$$\begin{aligned} &= \text{Rib Area} + \text{Web Area} \\ &= 3.09 + 1.698 \\ &= 4.787 \text{ in}^2 \end{aligned}$$

Compressive Stress [Sc]:

$$\begin{aligned} &= P/A_r \\ &= 5207/4.787 \\ &= 1087.688 \text{ psi} \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.4375	7.0625	3.9688	3.0898	12.2628	18.3065
Web	3.8802	0.4375	0.2188	1.6976	0.3713	9.9711
Totals	...	...	...	4.7874	12.6342	28.2776

Rib dimension [D]:

= Saddle Width - Web Thickness
= 7.5 - 0.438
= 7.062 in.

Distance to Centroid from Datum [ytot]:

= AY / A
= 12.63/4.787
= 2.639 in.

Distance to Centroid [C1]:

= max(ytot, Saddle Width - ytot)
= max(2.639, 7.5 - 2.639)
= 4.861 in.

Radius of Gyration [r]:

= sqrt(Total Inertia / Total Area)
= sqrt(28.28/4.787)
= 2.430 in.

Length of Outer Rib [L]:

= Saddle Height - cos(theta/2)(radius + shlthk + wpdthk) - bpthk
= 27 - cos(138/2)(7.625 + 0.375 + 0.312) - 0.938
= 23.084 in.

Intermediate Term [Cc]:

= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 29000000/38000)
= 122.736

Slenderness ratio [KL/r]:

= KL/r
= 1 * 23.08/2.43
= 9.498

Bending Moment [Rm]:

= F1 / (2 * Bplen) * e * L / 2
= 7474 / (2 * 22) * 7.76 * 23.08/2
= 1267.928 ft.lb.

Compressive Allowable, KL/r < Cc(9.498 < 122.7) per AISC E2-1 [Sca]:

= (1 - (KL/r)² / (2 * Cc²)) Fy / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)³ / (8 * Cc³))
= (1 - (9.498)² / (2 * 122.7²)) 38000 /
(5/3 + 3 * (9.498) / (8 * 122.7) - (9.498³) / (8 * 122.7³))
= 22343 psi

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

AISC Unity Check of Outside Ribs (must be <= 1)

$$\begin{aligned}
&= S_c/S_{ca} + (R_m * C_1 / I)/S_{ba} \\
&= 1088/22343 + (15215 * 4.861/28.28)/25333 \\
&= 0.152
\end{aligned}$$

AISC Unity Check of Outside Ribs, due to Transverse Force Ft (must be <= 1)

This analysis assumes the entire saddle weight load and load due to transverse forces are concentrated on the outer rib + some portion of the web. This generally would not be the case and as such this analysis is very conservative.

Inertia of Saddle, Outer Ribs - Transverse Direction:

	B	D	Y	A	AY	Io
Rib	7.0625	0.4375	0.2188	3.0898	0.6759	8.2923
Web	0.4375	7.0000	3.5000	3.0625	10.7188	20.8218
Totals	...	...	...	6.1523	11.3947	29.1141

Web dimension [D]:

$$\begin{aligned}
&= 16 * \text{Web Thickness} \\
&= 16 * 0.438 \\
&= 7.000 \text{ in.}
\end{aligned}$$

Moment at base of outer Rib [Mbase]:

$$\begin{aligned}
&= F_t (\text{Centerline dimension B} - \text{Baseplate thickness}) \\
&= 3737 (27 - 0.938) \\
&= 97399.828 \text{ in.lbs}
\end{aligned}$$

Bending Stress due to Transverse Force [SigmaB,base]:

$$\begin{aligned}
&= \text{Bending Moment} / \text{Section Modulus} \\
&= 97400/15.72 \\
&= 6196.051 \text{ psi}
\end{aligned}$$

Vertical Load on the Rib due to the Bending Moment [Fv,mom]:

$$\begin{aligned}
&= \text{Bending Moment} / \text{Web Length} \\
&= 97400/15.52 \\
&= 6275.449 \text{ lb.}
\end{aligned}$$

Total Vertical Load on the Rib [Fv,total]:

$$\begin{aligned}
&= F_{v,mom} + \text{Vertical Load} \\
&= 6275 + 29698 \\
&= 35973.484 \text{ lb.}
\end{aligned}$$

Compressive Stress on Outer Rib [Sigma,cr]:

$$\begin{aligned}
&= F_{v,total} / \text{Area} \\
&= 35973/6.152 \\
&= 5847.119 \text{ psi}
\end{aligned}$$

Radius of Gyration [r]:

$$\begin{aligned}
&= \sqrt{ \text{Total Inertia} / \text{Total Area} } \\
&= \sqrt{ 29.11/6.152 } \\
&= 2.175 \text{ in.}
\end{aligned}$$

Slenderness ratio [KL/r]:

$$\begin{aligned}
&= KL/r \\
&= 1 * 23.08/2.175 \\
&= 10.611
\end{aligned}$$

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Compressive Allowable, $KL/r < Cc$ (10.61 < 122.7) per AISC E2-1 [Sca]:

$$= (1 - (KL/r)^2 / (2 * Cc^2)) F_y / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)^3 / (8 * Cc^3))$$

$$= (1 - (10.61)^2 / (2 * 122.7^2)) 38000 / (5/3 + 3 * (10.61) / (8 * 122.7) - (10.61^3) / (8 * 122.7^3))$$

$$= 22282 \text{ psi}$$

Unity Check on Outer Rib [UCheck,outer]:

$$= \text{Sigma}_{cr} / S_{ca} + \text{Sigma}_{B,base} / S_{ba}$$

$$= 5847/22282 + 6196/25333$$

$$= 0.507$$

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.4375	7.0625	3.9688	3.0898	12.2628	24.7529
Web	7.7604	0.4375	0.2188	3.3952	0.7427	10.8928
Totals	...	...	...	6.4850	13.0055	35.6457

Distance to Centroid from Datum [ytot]:

$$= AY / A$$

$$= 13.01/6.485$$

$$= 2.005 \text{ in.}$$

Distance to Centroid [C1]:

$$= \max(ytot, \text{abs}(\text{Saddle Width} - ytot))$$

$$= \max(2.005, \text{abs}(7.5 - 2.005))$$

$$= 5.495 \text{ in.}$$

Length of Inner Rib [L]:

$$= \text{Saddle Height} - \text{Outside Radius} - B_{pthk}$$

$$= 27 - \cos(8.312/2) (0.938 + 0 + 0) - 0$$

$$= 17.750 \text{ in.}$$

Radius of Gyration [r]:

$$= \sqrt{ \text{Total Inertia} / \text{Total Area} }$$

$$= \sqrt{ 35.65/6.485 }$$

$$= 2.344 \text{ in.}$$

Slenderness ratio [KL/r]:

$$= KL/r$$

$$= 1 * 17.75/2.344$$

$$= 7.571$$

Unit Force [Force,u]:

$$= F_1 / (2 * \text{Baseplate Length})$$

$$= 7474 / (2 * 22)$$

$$= 169.871 \text{ lb./in.}$$

Moment at base of inner Rib [Mbase,c]:

$$= \text{Unit Force} * e * L$$

$$= 169.9 * 7.76 * 17.75$$

$$= 23399.207 \text{ in.lbs}$$

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

$$= \text{Bending Moment} / \text{Section Modulus}$$

$$= 23399/6.487$$

$$= 3606.823 \text{ psi}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Compressive Allowable, $KL/r < Cc$ ($7.571 < 122.7$) per AISC E2-1 [Sca]:

$$= (1 - (KL/r)^2 / (2 * Cc^2)) F_y / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)^3 / (8 * Cc^3))$$

$$= (1 - (7.571)^2 / (2 * 122.7^2)) 38000 / (5/3 + 3 * (7.571) / (8 * 122.7) - (7.571^3) / (8 * 122.7^3))$$

$$= 22445 \text{ psi}$$

AISC Unity Check of Inside Ribs (must be <= 1)

$$= S_c / S_{ca} + (M_{base,c} * C_1 / I) / S_{ba}$$

$$= 1662 / 22445 + (23399 * 5.495 / 35.65) / 25333$$

$$= 0.216$$

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2
Total Number of Bolts in Tension/Baseplate	Nbt	2
Bolt Material Specification		F1554 GR 36
Bolt Allowable Stress	Stba	21750.00 psi
Bolt Corrosion Allowance	Bca	0.0000 in.
Distance from Bolts to Edge	Edgedis	4.0000 in.
Nominal Bolt Diameter	Bnd	1.0000 in.
Thread Series	Series	UNC
BasePlate Allowable Stress	S	20000.00 psi
Area Available in a Single Bolt	BltArea	0.5510 in²
Saddle Load Q0 (Weight)	Q0	10194.5 lb.
Saddle Load QL (Wind/Seismic contribution)	QL	2491.4 lb.
Maximum Transverse Force	Ft	3737.2 lb.
Maximum Longitudinal Force	F1	7474.3 lb.
Saddle Bolted to Steel Foundation		Yes

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

$$= F_1 / (\text{Bolt Area} * \text{Number of Bolts})$$

$$= 7474 / (0.551 * 2)$$

$$= 6782.5 \text{ psi. Must be less than } 13050.0 \text{ psi.}$$

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

$$= F_t / (\text{Bolt Area} * \text{Number of Bolts})$$

$$= 3737 / (0.551 * 2)$$

$$= 3391.3 \text{ psi. Must be less than } 13050.0 \text{ psi.}$$

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

$$= 0.0 \text{ (} Q_0 > Q_L \text{ --> No Uplift in Longitudinal direction)}$$

Bolt Area due to Shear Load [Bltarears]:

$$= F_1 / (\text{BoltShearAllowable} * \text{Nbolts})$$

$$= 7474 / (13050 * 2)$$

$$= 0.2864 \text{ in}^2$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

$$\begin{aligned} &= B * Ft + \text{Sum of X Moments} \\ &= 2.25 * 3737 + 0 \\ &= 8408.62 \text{ ft.lb.} \end{aligned}$$

Eccentricity (e):

$$\begin{aligned} &= Rmom / Q0 \\ &= 100903/10194 \\ &= 9.90 \text{ in.} > Bplen/6 \rightarrow \text{Uplift in Transverse direction} \end{aligned}$$

f = Bplen / 2 - Edgedis

$$\begin{aligned} &= 22/2 - 4 \\ &= 7.00 \text{ in.} \end{aligned}$$

K1 = 3 (e - 0.5 * Bplen)

$$\begin{aligned} &= 3(9.898 - 0.5*22) \\ &= -3.31 \text{ in.} \end{aligned}$$

K2 = 6 * n1 * At / Bpwid * (f + e)

$$\begin{aligned} &= 6 * 1 * 1.102/8 * (7 + 9.898) \\ &= 13.97 \text{ in.}^2 \end{aligned}$$

K3 = -K2 * (0.5 * Bplen + f)

$$\begin{aligned} &= -13.97 * (0.5 * 22 + 7) \\ &= -251.39 \text{ in.}^3 \end{aligned}$$

Iteratively Solving for the Effective Bearing Length:

$$Y^3 + K1 * Y^2 + K2 * Y + K3 = 0$$

$$Y^3 + -3.306 * Y^2 + 13.97 * Y + -251.4 = 0$$

$$Y = 6.75 \text{ in.}$$

Num = (Bplen / 2 - Y / 3 - e)

$$\begin{aligned} &= (22/2 - 6.752/3 - 9.898) \\ &= -1.15 \end{aligned}$$

Denom = (Bplen / 2 - Y / 3 + f)

$$\begin{aligned} &= (22/2 - 6.752/3 + 7) \\ &= 15.75 \end{aligned}$$

Total Bolt Tension Force [Tforce]:

$$\begin{aligned} &= - Q0 * Num / Denom \\ &= - 10194 * -1.149/15.75 \\ &= 743.45 \text{ lb.} \end{aligned}$$

Bolt Area Required due to Transverse Load [Bltareart]:

$$\begin{aligned} &= Tforce / (Stba * Nbt) \\ &= 743.5 / (21750 * 2) \\ &= 0.0171 \text{ in}^2 \end{aligned}$$

Required Area of a Single Bolt [Bltarear]:

$$\begin{aligned} &= \max[Bltarearl, Bltarears, Bltareart] \\ &= \max[0, 0.286, 0.0171] \\ &= 0.2864 \text{ in}^2 \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

$$\begin{aligned} &= 2(Q_0 + T_{\text{force}}) / (Y * B_{\text{pwid}}) \\ &= 2(10194 + 743.5) / (6.752 * 8) \\ &= 404.98 \text{ psig} \end{aligned}$$

Distance from Baseplate Edge to the Web [ADIST]:

$$\begin{aligned} &= (B_{\text{plen}} - W_{\text{blength}}) / 2 \\ &= (22 - 20) / 2 \\ &= 1.0000 \text{ in.} \end{aligned}$$

Overturning Moment due To Bolt Tension [Mt]:

$$\begin{aligned} &= T_{\text{force}} * A_{\text{dist}} \\ &= 743.5 * 0.0833 \\ &= 61.95 \text{ ft.lb.} \end{aligned}$$

Equivalent Bearing Pressure (f1):

$$\begin{aligned} &= f_c * (Y - A_{\text{dist}}) / Y \\ &= 405 * (6.752 - 1) / 6.752 \\ &= 345.00 \text{ psig} \end{aligned}$$

Overturning Moment due to Bearing Pressure [Mc]:

$$\begin{aligned} &= (A_{\text{dist}}^2 * B_{\text{pwid}} / 6) * (f_1 + 2 * f_c) \\ &= (0.0833^2 * 0.667 / 6) * (49681 + 2 * 58318) \\ &= 128.33 \text{ ft.lb.} \end{aligned}$$

Baseplate Required Thickness [Treq]:

$$\begin{aligned} &= \sqrt{6 * \max(M_t, M_c) / (B_{\text{pwid}} * S_{\text{ba}})} \\ &= \sqrt{6 * \max(743.5, 1540) / (8 * 30000)} \\ &= 0.1962 \text{ in.} \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

Input and Calculated Values:

Vessel Mean Radius	Rm	7.88	in.
Shell Thickness used in this Case	t	0.375	in.
Stiffened Vessel Length per 4.15.6	L	13.23	ft.
Distance from Saddle to Vessel tangent	a1 or a	42.50	in.
Saddle Width	b1 or b	7.50	in.
Saddle Bearing Angle	delta or theta	138.00	degrees
Wear Plate Width	b2 or b1	13.00	in.
Wear Plate Bearing Angle	delta2 or theta1	180.00	degrees
Wear Plate Thickness	e2 or tr	0.3125	in.
Wear Plate Allowable Stress	fw or Sr	20000.00	psi
Inside Depth of Head	Hi or h2	0.33	ft.
Shell Allowable Stress used in Calculation		17100.00	psi
Head Allowable Stress used in Calculation		17100.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	27.00	in.
Coefficient of Friction	mu	0.00	
Saddle Force Q, Operating Case		24981.03	lb.
Pressure used in Analysis	P	375.000	psig
Horizontal Vessel Analysis Results:	Actual psi	Allowable psi	
Long. Stress at Top of Midspan	7919.70	17100.00	
Long. Stress at Bottom of Midspan	3892.80	17100.00	
Long. Stress at Top of Saddles	12177.70	17100.00	
Long. Stress at Bottom of Saddles	-365.20	-27900.00	
Long. Stress at Bottom of Saddles	365.20	17100.00	
Tangential Shear in Shell	5268.64	13680.00	
Circ. Compressive Stress in Shell	724.44	17100.00	
Stiffener Circ. Stress at Shell	1739.65	21375.00	
Stiffener Circ. Stress at Tip	468.41	25000.00	

Intermediate Results: Saddle Reaction Q due to Wind or Seismic:

Saddle Reaction Force due to Wind Ft [Fwt]:

$$\begin{aligned} &= F_{tr} (F_t / \text{Num of Saddles} + Z \text{ Force Load}) * B / E \\ &= 3 (153.1/2 + 0) * 27/15.52 \\ &= 399.4 \text{ lb.} \end{aligned}$$

Saddle Reaction Force due to Wind FI [Fwl]:

$$\begin{aligned} &= \max(F_l, \text{Sum of X Forces}) * B / L_s \\ &= \max(26.74, 0) * 27/81 \\ &= 8.9 \text{ lb.} \end{aligned}$$

Saddle Reaction Force due to Earthquake FI [Fsl]:

$$\begin{aligned} &= \max(F_l, \text{Sum of X Forces}) * B / L_s \\ &= \max(7474, 0) * 27/81 \\ &= 2491.4 \text{ lb.} \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Saddle Reaction Force due to Earthquake Ft [Fst]:
 = Ftr(Ft/Num of Saddles + Z Force Load) * B / E
 = 3(7474/2 + 0) * 27/15.52
 = 19503.6 lb.

Load Combination Results for Q + Wind or Seismic [Q]:
 = Saddle Load + max(Fw1, Fwt, Fsl, Fst)
 = 5477 + max(8.914, 399.4, 2491, 19504)
 = 24981.0 lb.

Longitudinal Wind Force [F]:
 = WindScalar * WindPress(Platform Area + (pi/4(OD * WindDiaMult)²))
 = 0.6 * 22.17(0 + pi/4(1.333 * 1.2)²)
 = 26.743 lbf

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	25155.02 lb.
Transverse Shear Load Saddle	3737.16 lb.
Longitudinal Shear Load Saddle	7474.33 lb.

Formulas and Substitutions for Horizontal Vessel Analysis:

Saddle Dimension [E]:
 = min(2(ShellID/2 + t + WearPadThickness)sin(θ/2), 2*Rm)
 = min(2(15.25/2 + 0.375 + 0.312)sin(138/2), 2*7.875)
 = 15.521 in.

The Computed K values from Table 4.15.1:

K1 = 0.1374	K2 = 0.9229	K3 = 0.6161	K4 = 0.3336
K5 = 0.7024	K6 = 0.0392	K7 = 0.0392	K8 = 0.3195
K9 = 0.2409	K10 = 0.0448	K1* = 0.2426	K6p = 0.0174
K7p = 0.0174			

The suffix 'p' denotes the values for a wear plate if it exists.

Moment per Equation 4.15.1 [M1]:
 = -Q*a [1 - (1- a/L + (Rm²-h²)/(2a*L))/(1+(4h²)/3L)]
 = -24981*3.542[1-(1-3.542/13.23+(0.656²-0.328²)/
 (2*3.542*13.23))/(1+(4*0.328)/(3*13.23))]]
 = -25455.3 ft.lb.

Moment per Equation 4.15.4 [M2]:
 = Q*L/4(1+2(Rm²-h²)/(L²))/(1+(4h²)/(3L))-4a/L
 = 24981*13.23/4(1+2(0.656²-0.328²)/(13.23²))/(1+(4*0.328)/
 (3*13.23))-4*3.542/13.23
 = -8172.4 ft.lb.

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
 = P * Rm/(2t) - M2/(pi*Rm²t)
 = 375 * 7.875/(2*0.25) - -98069/(pi*7.875²*0.25)
 = 7919.70 psi

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
 = P * Rm/(2t) + M2/(pi * Rm² * t)
 = 375 * 7.875/(2 * 0.25) + -98069/(pi * 7.875² * 0.25)
 = 3892.80 psi

Longitudinal Stress at Top of Shell at Support (4.15.6) [sigma3]:
 = P * Rm/(2t) - M1/(pi * Rm² * t)
 = 375 * 7.875/(2 * 0.25) - -305463/(pi * 7.875² * 0.25)
 = 12177.70 psi

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Longitudinal Stress at bottom of Shell at Support (4.15.7) [sigma4]:
 = $P * R_m / (2t) + M1 / (\pi * R_m^2 t)$
 = $375 * 7.875 / (2 * 0.25) + -305463 / (\pi * 7.875^2 * 0.25)$
 = -365.20 psi

Maximum Shear Force in the Saddle (4.15.3) [T]:
 = $Q(L - 2a) / (L + (4 * h^2 / 3))$
 = $24981(13.23 - 2 * 3.542) / (13.23 + (4 * 0.328 / 3))$
 = 11239.0 lb.

Shear Stress in the shell with double rings (4.15.12) [tau2]:
 = $K2 * T / (R_m * t)$
 = $0.923 * 11239 / (7.875 * 0.25)$
 = 5268.64 psi

Decay Length (4.15.20) [x1,x2]:
 = $0.78 * \sqrt{R_m * t}$
 = $0.78 * \sqrt{7.875 * 0.25}$
 = 1.094 in.

Circ. Stress in shell w/rings adjacent to Saddle (4.15.37) [sigma6]:
 = $-K5 * Q * k / (t(b + 2 * x2))$
 = $-0.702 * 24981 * 0.1 / (0.25(7.5 + 2 * 1.094))$
 = -724.44 psi

Note: Double Rings adjacent to Saddle Outside the Shell.

Circ. + Bending Stress in shell, rings adjacent to Saddle (4.15.40) [sigma10*]:
 = $-K9 * Q/A - K10 * Q * R_m * c1/I$
 = $-0.241 * 24981 / 7.657 - 0.0448 * 24981 * 7.875 * 2.268 / 20.94$
 = -1739.65 psi

Circ. + Bending Stress in ring, rings adjacent to Saddle (4.15.41) [sigma11*]:
 = $-K9 * Q/A + K10 * Q * R_m * c2/I$
 = $-0.241 * 24981 / 7.657 + 0.0448 * 24981 * 7.875 * 2.982 / 20.94$
 = 468.41 psi

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	22.0000	in.
Baseplate Thickness	Bpthk	0.9375	in.
Baseplate Width	Bpwid	8.0000	in.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.4375	in.
Web Thickness	Webtk	0.4375	in.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	18.6	in.
Friction Coefficient	mu	0.000	

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

Inertia of Shell [ShellInertia]:
 = $((1.56 * \sqrt{R * t} + \text{WearPlateWidth})t^3) / 12$
 = $((1.56 * \sqrt{7.75 * 0.25} + 13)0.25^3) / 12$
 = 0.020 in**4

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Resolved Inertia for the Shell [I,shell]:

$$\begin{aligned} &= \text{ShellInertia} + A_{\text{Shell}} (C1 - Y)^2 \\ &= 0.0198 + 3.793 (9.354 - 0.125)^2 \\ &= 323.069 \text{ in}^4 \end{aligned}$$

	B in.	D in.	Y in.	A in ²	AY in. ³	I + AD ² in ⁴
Shell	15.1714	0.2500	0.1250	3.7929	0.4741	323.0690
Wearplate	13.0000	0.3125	0.4062	4.0625	1.6504	325.2805
Web	0.4375	17.7500	9.4375	7.7656	73.2881	203.9424
BasePlate	8.0000	0.9375	18.7812	7.5000	140.8594	667.1077
Totals	...	...	...	23.1210	216.2720	1519.3995

Distance to Centroid [C1]:

$$\begin{aligned} &= AY / A \\ &= 216.3/23.12 \\ &= 9.354 \text{ in.} \end{aligned}$$

Angle [beta]:

$$\begin{aligned} &= 180 - \text{Saddle Angle}/2 \\ &= 180 - 138/2 \\ &= 111.0 \end{aligned}$$

Saddle Splitting Coefficient [K1]:

$$\begin{aligned} &= (1 + \cos(\text{beta}) - 0.5 \sin(\text{beta})^2) / (\pi - \text{beta} + \sin(\text{beta}) \cos(\text{beta})) \\ &= (1 + \cos(111) - 0.5 \sin(111)^2) / (\pi - 1.937 + \sin(111) \cos(111)) \\ &= 0.2367 \end{aligned}$$

Saddle Splitting Force [Fh]:

$$\begin{aligned} &= K1 * Q \\ &= 0.237 * 24981 \\ &= 5912.5796 \text{ lb.} \end{aligned}$$

$$\begin{aligned} \text{Tension Stress, } St &= (Fh/As) = 305.9055 \text{ psi} \\ \text{Allowed Stress, } Sa &= 0.6 * \text{Yield Str} = 22800.0000 \text{ psi} \end{aligned}$$

Saddle Splitting Dimension [d]:

$$\begin{aligned} &= B - R * \sin(\text{theta}/2) / (\text{theta}/2 \text{ in radians}) \\ &= 27 - 7.75 * \sin(138/2) / 1.204 \\ &= 20.992 \text{ in.} \end{aligned}$$

$$\text{Bending Moment, } M = Fh * d = 10343.0928 \text{ ft.lb.}$$

$$\begin{aligned} \text{Bending Stress, } Sb &= (M * C1 / I) = 764.1060 \text{ psi} \\ \text{Allowed Stress, } Sa &= 2/3 * \text{Yield Str} = 25333.3340 \text{ psi} \end{aligned}$$

Minimum Thickness of Baseplate per Moss:

$$\begin{aligned} &= \sqrt[3]{(Q + \text{Saddle\_Wt}) \text{BasePlateWidth} / (2 * \text{BasePlateLength} * \text{AllStress})} \\ &= \sqrt[3]{(3(24981 + 174)8 / (2 * 22 * 25333))} \\ &= 0.736 \text{ in.} \end{aligned}$$

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:

$$\begin{aligned} &= 2 * \cos(90 - \text{Saddle Angle}/2) (\text{Inside Radius} + \text{Shell Thk} + \text{Wear Plate Thk}) \\ &= 2 * \cos(90 - 138/2) (7.625 + 0.375 + 0.312) \\ &= 15.521 \text{ in.} \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Distance between Ribs [e]:
 = Web Length / (Nribs - 1)
 = 15.52/(3 - 1)
 = 7.760 in.

Baseplate Pressure Area [Ap]:
 = e * Bpwid / 2
 = 7.76 * 8/2
 = 31.042 in²

Bearing Pressure [Bp]:
 = Q / (BasePlateLength * BasePlateWidth)
 = 24981/(22 * 8)
 = 141.938 lb./in²

Axial Load [P]:
 = Ap * Bp
 = 31.04 * 141.9
 = 4405.965 lb.

Area of the Rib and Web [Ar]:
 = Rib Area + Web Area
 = 3.09 + 1.698
 = 4.787 in²

Compressive Stress [Sc]:
 = P/Ar
 = 4406/4.787
 = 920.320 psi

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.4375	7.0625	3.9688	3.0898	12.2628	18.3065
Web	3.8802	0.4375	0.2188	1.6976	0.3713	9.9711
Totals	...	...	...	4.7874	12.6342	28.2776

Rib dimension [D]:
 = Saddle Width - Web Thickness
 = 7.5 - 0.438
 = 7.062 in.

Distance to Centroid from Datum [ytot]:
 = AY / A
 = 12.63/4.787
 = 2.639 in.

Distance to Centroid [C1]:
 = max(ytot, Saddle Width - ytot)
 = max(2.639, 7.5 - 2.639)
 = 4.861 in.

Radius of Gyration [r]:
 = sqrt(Total Inertia / Total Area)
 = sqrt(28.28/4.787)
 = 2.430 in.

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Length of Outer Rib [L]:

$$= \text{Saddle Height} - \cos(\theta/2)(\text{radius} + \text{shlthk} + \text{wpdthk}) - \text{bpthk}$$

$$= 27 - \cos(138/2)(7.625 + 0.375 + 0.312) - 0.938$$

$$= 23.084 \text{ in.}$$

Intermediate Term [Cc]:

$$= \sqrt{2 * \pi^2 * \text{Elastic Modulus} / \text{Yield Stress}}$$

$$= \sqrt{2 * \pi^2 * 29000000 / 38000}$$

$$= 122.736$$

Slenderness ratio [KL/r]:

$$= KL/r$$

$$= 1 * 23.08 / 2.43$$

$$= 9.498$$

Bending Moment [Rm]:

$$= F1 / (2 * Bpln) * e * L / 2$$

$$= 7474 / (2 * 22) * 7.76 * 23.08 / 2$$

$$= 1267.928 \text{ ft.lb.}$$

Compressive Allowable, $KL/r < Cc$ ($9.498 < 122.7$) per AISC E2-1 [Sca]:

$$= (1 - (KL/r)^2 / (2 * Cc^2)) Fy / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)^3 / (8 * Cc^3))$$

$$= (1 - (9.498)^2 / (2 * 122.7^2)) 38000 / (5/3 + 3 * (9.498) / (8 * 122.7) - (9.498^3) / (8 * 122.7^3))$$

$$= 22343 \text{ psi}$$

AISC Unity Check of Outside Ribs (must be <= 1)

$$= Sc/Sca + (Rm * C1 / I) / Sba$$

$$= 920.3 / 22343 + (15215 * 4.861 / 28.28) / 25333$$

$$= 0.144$$

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

AISC Unity Check of Outside Ribs, due to Transverse Force Ft (must be <= 1)

This analysis assumes the entire saddle weight load and load due to transverse forces are concentrated on the outer rib + some portion of the web. This generally would not be the case and as such this analysis is very conservative.

Inertia of Saddle, Outer Ribs - Transverse Direction:

	B	D	Y	A	AY	Io
Rib	7.0625	0.4375	0.2188	3.0898	0.6759	8.2923
Web	0.4375	7.0000	3.5000	3.0625	10.7188	20.8218
Totals	...	...	...	6.1523	11.3947	29.1141

Web dimension [D]:
= 16 * Web Thickness
= 16 * 0.438
= 7.000 in.

Moment at base of outer Rib [Mbase]:
= Ft(Centerline dimension B - Baseplate thickness)
= 3737(27 - 0.938)
= 97399.828 in.lbs

Bending Stress due to Transverse Force [SigmaB,base]:
= Bending Moment / Section Modulus
= 97400/15.72
= 6196.051 psi

Vertical Load on the Rib due to the Bending Moment [Fv,mom]:
= Bending Moment / Web Length
= 97400/15.52
= 6275.449 lb.

Total Vertical Load on the Rib [Fv,total]:
= Fv,mom + Vertical Load
= 6275 + 25155
= 31430.469 lb.

Compressive Stress on Outer Rib [Sigma,cr]:
= Fv,total / Area
= 31430/6.152
= 5108.698 psi

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(29.11/6.152)
= 2.175 in.

Slenderness ratio [KL/r]:
= KL/r
= 1 * 23.08/2.175
= 10.611

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Compressive Allowable, $KL/r < C_c$ (10.61 < 122.7) per AISC E2-1 [Sca]:

$$= (1 - (KL/r)^2 / (2 * C_c^2)) F_y / (5/3 + 3 * (KL/r) / (8 * C_c) - (KL/r)^3 / (8 * C_c^3))$$

$$= (1 - (10.61)^2 / (2 * 122.7^2)) 38000 / (5/3 + 3 * (10.61) / (8 * 122.7) - (10.61^3) / (8 * 122.7^3))$$

$$= 22282 \text{ psi}$$

Unity Check on Outer Rib [UCheck,outer]:

$$= \text{Sigma}_{cr} / S_{ca} + \text{Sigma}_{B,base} / S_{ba}$$

$$= 5109/22282 + 6196/25333$$

$$= 0.474$$

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.4375	7.0625	3.9688	3.0898	12.2628	24.7529
Web	7.7604	0.4375	0.2188	3.3952	0.7427	10.8928
Totals	...	...	...	6.4850	13.0055	35.6457

Distance to Centroid from Datum [ytot]:

$$= AY / A$$

$$= 13.01/6.485$$

$$= 2.005 \text{ in.}$$

Distance to Centroid [C1]:

$$= \max(y_{tot}, \text{abs}(\text{Saddle Width} - y_{tot}))$$

$$= \max(2.005, \text{abs}(7.5 - 2.005))$$

$$= 5.495 \text{ in.}$$

Length of Inner Rib [L]:

$$= \text{Saddle Height} - \text{Outside Radius} - B_{pthk}$$

$$= 27 - \cos(8.312/2) (0.938 + 0 + 0) - 0$$

$$= 17.750 \text{ in.}$$

Radius of Gyration [r]:

$$= \sqrt{ \text{Total Inertia} / \text{Total Area} }$$

$$= \sqrt{ 35.65/6.485 }$$

$$= 2.344 \text{ in.}$$

Slenderness ratio [KL/r]:

$$= KL/r$$

$$= 1 * 17.75/2.344$$

$$= 7.571$$

Unit Force [Force,u]:

$$= F_1 / (2 * \text{Baseplate Length})$$

$$= 7474 / (2 * 22)$$

$$= 169.871 \text{ lb./in.}$$

Moment at base of inner Rib [Mbase,c]:

$$= \text{Unit Force} * e * L$$

$$= 169.9 * 7.76 * 17.75$$

$$= 23399.207 \text{ in.lbs}$$

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

$$= \text{Bending Moment} / \text{Section Modulus}$$

$$= 23399/6.487$$

$$= 3606.823 \text{ psi}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Compressive Allowable, $KL/r < Cc$ ($7.571 < 122.7$) per AISC E2-1 [Sca]:

$$= (1 - (KL/r)^2 / (2 * Cc^2)) F_y / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)^3 / (8 * Cc^3))$$

$$= (1 - (7.571)^2 / (2 * 122.7^2)) 38000 / (5/3 + 3 * (7.571) / (8 * 122.7) - (7.571^3) / (8 * 122.7^3))$$

$$= 22445 \text{ psi}$$

AISC Unity Check of Inside Ribs (must be <= 1)

$$= S_c / S_{ca} + (M_{base,c} * C_1 / I) / S_{ba}$$

$$= 1406 / 22445 + (23399 * 5.495 / 35.65) / 25333$$

$$= 0.205$$

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		F1554 GR 36	
Bolt Allowable Stress	Stba	21750.00	psi
Bolt Corrosion Allowance	Bca	0.0000	in.
Distance from Bolts to Edge	Edgedis	4.0000	in.
Nominal Bolt Diameter	Bnd	1.0000	in.
Thread Series	Series	UNC	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	0.5510	in ²
Saddle Load Q0 (Weight)	Q0	5651.5	lb.
Saddle Load QL (Wind/Seismic contribution)	QL	2491.4	lb.
Maximum Transverse Force	Ft	3737.2	lb.
Maximum Longitudinal Force	F1	7474.3	lb.
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

$$= F_1 / (\text{Bolt Area} * \text{Number of Bolts})$$

$$= 7474 / (0.551 * 2)$$

$$= 6782.5 \text{ psi. Must be less than } 13050.0 \text{ psi.}$$

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

$$= F_t / (\text{Bolt Area} * \text{Number of Bolts})$$

$$= 3737 / (0.551 * 2)$$

$$= 3391.3 \text{ psi. Must be less than } 13050.0 \text{ psi.}$$

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

$$= 0.0 \text{ (} Q_0 > Q_L \text{ --> No Uplift in Longitudinal direction)}$$

Bolt Area due to Shear Load [Bltarears]:

$$= F_1 / (\text{BoltShearAllowable} * \text{Nbolts})$$

$$= 7474 / (13050 * 2)$$

$$= 0.2864 \text{ in}^2$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

$$\begin{aligned} &= B * Ft + \text{Sum of X Moments} \\ &= 2.25 * 3737 + 0 \\ &= 8408.62 \text{ ft.lb.} \end{aligned}$$

Eccentricity (e):

$$\begin{aligned} &= Rmom / Q0 \\ &= 100903/5651 \\ &= 17.85 \text{ in.} > Bplen/6 \rightarrow \text{Uplift in Transverse direction} \end{aligned}$$

$$\begin{aligned} f &= Bplen / 2 - Edgedis \\ &= 22/2 - 4 \\ &= 7.00 \text{ in.} \end{aligned}$$

$$\begin{aligned} K1 &= 3 (e - 0.5 * Bplen) \\ &= 3(17.85 - 0.5*22) \\ &= 20.56 \text{ in.} \end{aligned}$$

$$\begin{aligned} K2 &= 6 * n1 * At / Bpwid * (f + e) \\ &= 6 * 1 * 1.102/8 * (7 + 17.85) \\ &= 20.54 \text{ in.}^2 \end{aligned}$$

$$\begin{aligned} K3 &= -K2 * (0.5 * Bplen + f) \\ &= -20.54 * (0.5 * 22 + 7) \\ &= -369.76 \text{ in.}^3 \end{aligned}$$

Iteratively Solving for the Effective Bearing Length:

$$\begin{aligned} Y^3 + K1 * Y^2 + K2 * Y + K3 &= 0 \\ Y^3 + 20.56 * Y^2 + 20.54 * Y + -369.8 &= 0 \\ Y &= 3.52 \text{ in.} \end{aligned}$$

$$\begin{aligned} \text{Num} &= (Bplen / 2 - Y / 3 - e) \\ &= (22/2 - 3.515/3 - 17.85) \\ &= -8.03 \end{aligned}$$

$$\begin{aligned} \text{Denom} &= (Bplen / 2 - Y / 3 + f) \\ &= (22/2 - 3.515/3 + 7) \\ &= 16.83 \end{aligned}$$

Total Bolt Tension Force [Tforce]:

$$\begin{aligned} &= - Q0 * \text{Num} / \text{Denom} \\ &= - 5651 * -8.026/16.83 \\ &= 2695.44 \text{ lb.} \end{aligned}$$

Bolt Area Required due to Transverse Load [Bltareart]:

$$\begin{aligned} &= Tforce / (Stba * Nbt) \\ &= 2695/(21750 * 2) \\ &= 0.0620 \text{ in}^2 \end{aligned}$$

Required Area of a Single Bolt [Bltarear]:

$$\begin{aligned} &= \max[\text{Bltarearl}, \text{Bltarears}, \text{Bltareart}] \\ &= \max[0, 0.286, 0.062] \\ &= 0.2864 \text{ in}^2 \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
= $2(Q_0 + T_{force}) / (Y * B_{pwid})$
= $2(5651 + 2695) / (3.515 * 8)$
= 593.61 psig

Distance from Baseplate Edge to the Web [ADIST]:
= $(B_{plen} - Weblength) / 2$
= $(22 - 20) / 2$
= 1.0000 in.

Overturning Moment due To Bolt Tension [Mt]:
= $T_{force} * A_{dist}$
= $2695 * 0.0833$
= 224.62 ft.lb.

Equivalent Bearing Pressure (f1):
= $f_c * (Y - A_{dist}) / Y$
= $593.6 * (3.515 - 1) / 3.515$
= 424.75 psig

Overturning Moment due to Bearing Pressure [Mc]:
= $(A_{dist}^2 * B_{pwid} / 6) * (f_1 + 2 * f_c)$
= $(0.0833^2 * 0.667 / 6) * (61164 + 2 * 85480)$
= 179.11 ft.lb.

Baseplate Required Thickness [Treq]:
= $\sqrt{6 * \max(M_t, M_c) / (B_{pwid} * S_{ba})}$
= $\sqrt{6 * \max(2695, 2149) / (8 * 30000)}$
= 0.2596 in.

PV Elite is a trademark of Hexagon AB, 2022, All rights reserved.

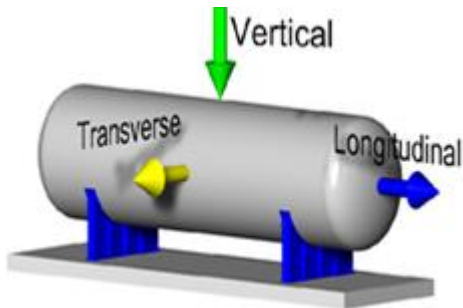
Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Road Transport

Input and Calculated Values:

Vessel Mean Radius	Rm	7.81	in.
Shell Thickness used in this Case	t	0.375	in.
Stiffened Vessel Length per 4.15.6	L	13.58	ft.
Distance from Saddle to Vessel tangent	a1 or a	37.50	in.
Saddle Width	b1 or b	7.50	in.
Saddle Bearing Angle	delta or theta	138.00	degrees
Wear Plate Width	b2 or b1	13.00	in.
Wear Plate Bearing Angle	delta2 or theta1	180.00	degrees
Wear Plate Thickness	e2 or tr	0.3125	in.
Wear Plate Allowable Stress	fw or Sr	20000.00	psi
Inside Depth of Head	Hi or h2	0.33	ft.
Shell Allowable Stress used in Calculation		17100.00	psi
Head Allowable Stress used in Calculation		17100.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	27.00	in.
Coefficient of Friction	mu	0.00	
Saddle Force Q for this Transportation Case		16786.85	lb.
Shipping Longitudinal Acceleration	gx	1.50	g
Shipping Transverse Acceleration	gz	1.50	g
Shipping Vertical Acceleration	gy	2.24	g
Vertical Acceleration Acting with Transverse	gw	2.24	g
Internal Pressure during Transport		0.00	psig
Transportation Wind Load Scalar Factor	wlsf	1.00	
Transportation Wind Velocity	wv	101.0	mile/hr



Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Horizontal Vessel Analysis Results:	Actual psi	Allowable psi

Long. Stress at Top of Midspan	-493.47	-33250.00
Long. Stress at Top of Midspan	493.47	17100.00
Long. Stress at Bottom of Midspan	493.47	17100.00
Long. Stress at Top of Saddles	2192.85	17100.00
Long. Stress at Bottom of Saddles	-2192.85	-33250.00
Long. Stress at Bottom of Saddles	2192.85	17100.00

Tangential Shear in Shell	2765.89	13680.00
Circ. Compressive Stress in Shell	309.18	17100.00
Stiffener Circ. Stress at Shell	943.94	17100.00
Stiffener Circ. Stress at Tip	277.52	20000.00

Intermediate Results: Saddle Reaction Q due to Road Transport Load:

Transverse Force due to Wind during Transport [Ft_w]:

$$\begin{aligned}
 &= \text{Transverse Area} * 0.00256 * wv^2 * wlsf \\
 &= 22.46 * 0.00256 * 101^2 * 1 \\
 &= 586.6 \text{ lbf}
 \end{aligned}$$

Longitudinal Force due to Wind during Transport [Fl_w]:

$$\begin{aligned}
 &= \pi * D^2/4 * 0.00256 * wv^2 * wlsf * \text{Wind Dia. Mult} \\
 &= \pi * 1.333^2/4 * 0.00256 * 101^2 * 1 * 1.2 \\
 &= 43.8 \text{ lbf}
 \end{aligned}$$

Transverse Force due to Lateral Acceleration [Ft]:

$$\begin{aligned}
 &= gz * \text{saddle Load} * gw + Ft_w \\
 &= 1.5 * 4150 * 2.24 + 586.6 \\
 &= 14529.0 \text{ lb.}
 \end{aligned}$$

Longitudinal Force due to Axial Acceleration [Fl]:

$$\begin{aligned}
 &= gx * \text{saddle Load} * gw + Fl_w \\
 &= 1.5 * 4150 * 2.24 + 43.76 \\
 &= 13986.1 \text{ lb.}
 \end{aligned}$$

Transverse Saddle Reaction Force due to Lateral Acceleration [Fwt]:

$$\begin{aligned}
 &= Ft/\text{Num of Saddles} * B / E \\
 &= 14529/2 * 27/15.52 \\
 &= 12637.3 \text{ lb.}
 \end{aligned}$$

Saddle Reaction Force due to Transport Load [Fwl]:

$$\begin{aligned}
 &= Fl * B / Ls \\
 &= 13986 * 27/81 \\
 &= 4662.0 \text{ lb.}
 \end{aligned}$$

Saddle Reaction Force due to Vertical Transportation Acceleration [Fsl]:

$$\begin{aligned}
 &= \text{Saddle Load} * gy \\
 &= 4150 * 2.24 \\
 &= 9294.896 \text{ lb.}
 \end{aligned}$$

Load Combination Results due to Transport Loading [Q]:

$$\begin{aligned}
 &= \text{Saddle Load} + \max(Fwl, Fwt, Fsl) \\
 &= 4150 + \max(4662, 12637, 9295) \\
 &= 16786.8 \text{ lb.}
 \end{aligned}$$

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	16974.85	lb.
Transverse Shear Load Saddle	12637.34	lb.
Longitudinal Shear Load Saddle	13986.10	lb.

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

$$\begin{aligned} &= \min(2(\text{ShellID}/2 + t + \text{WearPadThickness}) \sin(\theta/2), 2 * R_m) \\ &= \min(2(15.25/2 + 0.375 + 0.312) \sin(138/2), 2 * 7.812) \\ &= 15.521 \text{ in.} \end{aligned}$$

The Computed K values from Table 4.15.1:

K1 = 0.1374	K2 = 0.9229	K3 = 0.6161	K4 = 0.3336
K5 = 0.7024	K6 = 0.0392	K7 = 0.0392	K8 = 0.3195
K9 = 0.2409	K10 = 0.0448	K1* = 0.2426	K6p = 0.0174
K7p = 0.0174			

The suffix 'p' denotes the values for a wear plate if it exists.

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

Moment per Equation 4.15.1 [M1]:

$$\begin{aligned} &= -Q * a [1 - (1 - a/L + (R_m^2 - h^2)/(2a * L)) / (1 + (4h^2)/3L)] \\ &= -16787 * 3.125 [1 - (1 - 3.125/13.58 + (0.651^2 - 0.328^2) / (2 * 3.125 * 13.58)) / (1 + (4 * 0.328) / (3 * 13.58))] \\ &= -13139.8 \text{ ft.lb.} \end{aligned}$$

Moment per Equation 4.15.4 [M2]:

$$\begin{aligned} &= Q * L / 4 (1 + 2(R_m^2 - h^2)/(L^2)) / (1 + (4h^2)/(3L)) - 4a/L \\ &= 16787 * 13.58 / 4 (1 + 2(0.651^2 - 0.328^2)/(13.58^2)) / (1 + (4 * 0.328) / (3 * 13.58)) - 4 * 3.125 / 13.58 \\ &= 2957.0 \text{ ft.lb.} \end{aligned}$$

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

$$\begin{aligned} &= P * R_m / (2t) - M2 / (\pi * R_m^2 * t) \\ &= 0 * 7.812 / (2 * 0.375) - 35483 / (\pi * 7.812^2 * 0.375) \\ &= -493.47 \text{ psi} \end{aligned}$$

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

$$\begin{aligned} &= P * R_m / (2t) + M2 / (\pi * R_m^2 * t) \\ &= 0 * 7.812 / (2 * 0.375) + 35483 / (\pi * 7.812^2 * 0.375) \\ &= 493.47 \text{ psi} \end{aligned}$$

Longitudinal Stress at Top of Shell at Support (4.15.6) [sigma3]:

$$\begin{aligned} &= P * R_m / (2t) - M1 / (\pi * R_m^2 * t) \\ &= 0 * 7.812 / (2 * 0.375) - 157678 / (\pi * 7.812^2 * 0.375) \\ &= 2192.85 \text{ psi} \end{aligned}$$

Longitudinal Stress at bottom of Shell at Support (4.15.7) [sigma4]:

$$\begin{aligned} &= P * R_m / (2t) + M1 / (\pi * R_m^2 * t) \\ &= 0 * 7.812 / (2 * 0.375) + 157678 / (\pi * 7.812^2 * 0.375) \\ &= -2192.85 \text{ psi} \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Maximum Shear Force in the Saddle (4.15.3) [T]:

$$= Q(L-2a)/(L+(4*h^2/3))$$

$$= 16787(13.58 - 2 * 3.125)/(13.58 +(4 * 0.328/3))$$

$$= 8780.0 \text{ lb.}$$

Shear Stress in the shell with double rings (4.15.12) [tau2]:

$$= K2 * T / (Rm * t)$$

$$= 0.923 * 8780/(7.812 * 0.375)$$

$$= 2765.89 \text{ psi}$$

Decay Length (4.15.20) [x1,x2]:

$$= 0.78 * \text{sqrt}(Rm * t)$$

$$= 0.78 * \text{sqrt}(7.812 * 0.375)$$

$$= 1.335 \text{ in.}$$

Circ. Stress in shell w/rings adjacent to Saddle (4.15.37) [sigma6]:

$$= -K5 * Q * k/(t(b + 2 * x2))$$

$$= -0.702 * 16787 * 0.1/(0.375(7.5 + 2 * 1.335))$$

$$= -309.18 \text{ psi}$$

Note: Double Rings adjacent to Saddle Outside the Shell.

Circ. + Bending Stress in shell, rings adjacent to Saddle (4.15.40) [sigma10*]:

$$= -K9 * Q/A - K10 * Q * Rm * c1/I$$

$$= -0.241*16787/8.721-0.0448*16787*7.812*2.113/25.84$$

$$= -943.94 \text{ psi}$$

Circ. + Bending Stress in ring, rings adjacent to Saddle (4.15.41) [sigma11*]:

$$= -K9 * Q/A + K10 * Q * Rm * c2/I$$

$$= -0.241*16787/8.721+0.0448*16787*7.812*3.262/25.84$$

$$= 277.52 \text{ psi}$$

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	22.0000	in.
Baseplate Thickness	Bpthk	0.9375	in.
Baseplate Width	Bpwid	8.0000	in.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5000	in.
Web Thickness	Webtk	0.5000	in.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	18.6	in.
Friction Coefficient	mu	0.000	

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

Inertia of Shell [ShellInertia]:

$$= ((1.56 * \text{sqrt}(R * t) + \text{WearPlateWidth})t^3)/12$$

$$= ((1.56 * \text{sqrt}(7.625 * 0.375) + 13)0.375^3)/12$$

$$= 0.069 \text{ in**4}$$

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6”-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Resolved Inertia for the Shell [I,shell]:

$$\begin{aligned} &= \text{ShellInertia} + A_{\text{Shell}}(C1 - Y)^2 \\ &= 0.0687 + 5.864(8.742 - 0.188)^2 \\ &= 429.179 \text{ in}^4 \end{aligned}$$

	B in.	D in.	Y in.	A in ²	AY in. ³	I + AD ² in ⁴
Shell	15.6379	0.3750	0.1875	5.8642	1.0995	429.1793
Wearplate	13.0000	0.3125	0.5312	4.0625	2.1582	273.8925
Web	0.5000	17.7500	9.5625	8.8750	84.8672	238.9941
BasePlate	8.0000	0.9375	18.9062	7.5000	141.7969	775.4343
Totals	...	...	...	26.3017	229.9218	1717.5000

Distance to Centroid [C1]:

$$\begin{aligned} &= AY / A \\ &= 229.9/26.3 \\ &= 8.742 \text{ in.} \end{aligned}$$

Angle [beta]:

$$\begin{aligned} &= 180 - \text{Saddle Angle}/2 \\ &= 180 - 138/2 \\ &= 111.0 \end{aligned}$$

Saddle Splitting Coefficient [K1]:

$$\begin{aligned} &= (1 + \cos(\text{beta}) - 0.5 \sin(\text{beta})^2) / (\pi - \text{beta} + \sin(\text{beta}) \cos(\text{beta})) \\ &= (1 + \cos(111) - 0.5 \sin(111)^2) / (\pi - 1.937 + \sin(111) \cos(111)) \\ &= 0.2367 \end{aligned}$$

Saddle Splitting Force [Fh]:

$$\begin{aligned} &= K1 * Q \\ &= 0.237 * 16787 \\ &= 3973.1575 \text{ lb.} \end{aligned}$$

$$\begin{aligned} \text{Tension Stress, } St &= (Fh/As) = 194.4053 \text{ psi} \\ \text{Allowed Stress, } Sa &= 0.6 * \text{Yield Str} = 22800.0000 \text{ psi} \end{aligned}$$

Saddle Splitting Dimension [d]:

$$\begin{aligned} &= B - R * \sin(\text{theta}/2) / (\text{theta}/2 \text{ in radians}) \\ &= 27 - 7.625 * \sin(138/2) / 1.204 \\ &= 21.089 \text{ in.} \end{aligned}$$

$$\text{Bending Moment, } M = Fh * d = 6982.4746 \text{ ft.lb.}$$

$$\begin{aligned} \text{Bending Stress, } Sb &= (M * C1 / I) = 426.4714 \text{ psi} \\ \text{Allowed Stress, } Sa &= 2/3 * \text{Yield Str} = 25333.3340 \text{ psi} \end{aligned}$$

Minimum Thickness of Baseplate per Moss:

$$\begin{aligned} &= \sqrt{3(Q + \text{Saddle\_Wt}) \text{BasePlateWidth} / (2 * \text{BasePlateLength} * \text{AllStress})} \\ &= \sqrt{3(16787 + 188)8 / (2 * 22 * 25333)} \\ &= 0.605 \text{ in.} \end{aligned}$$

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:

$$\begin{aligned} &= 2 * \cos(90 - \text{Saddle Angle}/2) (\text{Inside Radius} + \text{Shell Thk} + \text{Wear Plate Thk}) \\ &= 2 * \cos(90 - 138/2) (7.625 + 0.375 + 0.312) \\ &= 15.521 \text{ in.} \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Distance between Ribs [e]:
= Web Length / (Nribs - 1)
= 15.52/(3 - 1)
= 7.760 in.

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2
= 7.76 * 8/2
= 31.042 in²

Bearing Pressure [Bp]:
= Q / (BasePlateLength * BasePlateWidth)
= 16787/(22 * 8)
= 95.380 lb./in²

Axial Load [P]:
= Ap * Bp
= 31.04 * 95.38
= 2960.737 lb.

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 3.5 + 1.94
= 5.440 in²

Compressive Stress [Sc]:
= P/Ar
= 2961/5.44
= 544.243 psi

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5000	7.0000	4.0000	3.5000	14.0000	20.5515
Web	3.8802	0.5000	0.2500	1.9401	0.4850	11.3334
Totals	...	...	...	5.4401	14.4850	31.8849

Rib dimension [D]:
= Saddle Width - Web Thickness
= 7.5 - 0.5
= 7.000 in.

Distance to Centroid from Datum [ytot]:
= AY / A
= 14.49/5.44
= 2.663 in.

Distance to Centroid [C1]:
= max(ytot, Saddle Width - ytot)
= max(2.663, 7.5 - 2.663)
= 4.837 in.

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(31.88/5.44)
= 2.421 in.

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Length of Outer Rib [L]:

$$= \text{Saddle Height} - \cos(\theta/2)(\text{radius} + \text{shlthk} + \text{wpdthk}) - \text{bpthk}$$

$$= 27 - \cos(138/2)(7.625 + 0.375 + 0.312) - 0.938$$

$$= 23.084 \text{ in.}$$

Intermediate Term [Cc]:

$$= \sqrt{2 \cdot \pi^2 \cdot \text{Elastic Modulus} / \text{Yield Stress}}$$

$$= \sqrt{2 \cdot \pi^2 \cdot 29000000 / 38000}$$

$$= 122.736$$

Slenderness ratio [KL/r]:

$$= KL/r$$

$$= 1 \cdot 23.08 / 2.421$$

$$= 9.535$$

Bending Moment [Rm]:

$$= F1 / (2 \cdot B_{\text{plen}}) \cdot e \cdot L / 2$$

$$= 13986 / (2 \cdot 22) \cdot 7.76 \cdot 23.08 / 2$$

$$= 2372.570 \text{ ft.lb.}$$

Compressive Allowable, $KL/r < Cc$ ($9.535 < 122.7$) per AISC E2-1 [Sca]:

$$= (1 - (KL/r)^2 / (2 \cdot Cc^2)) F_y / (5/3 + 3 \cdot (KL/r) / (8 \cdot Cc) - (KL/r)^3 / (8 \cdot Cc^3))$$

$$= (1 - (9.535)^2 / (2 \cdot 122.7^2)) 38000 / (5/3 + 3 \cdot (9.535) / (8 \cdot 122.7) - (9.535^3) / (8 \cdot 122.7^3))$$

$$= 22341 \text{ psi}$$

AISC Unity Check of Outside Ribs (must be <= 1)

$$= S_c / S_{ca} + (R_m \cdot C_1 / I) / S_{ba}$$

$$= 544.2 / 22341 + (28471 \cdot 4.837 / 31.88) / 25333$$

$$= 0.195$$

AISC Unity Check of Outside Ribs, due to Transverse Force Ft (must be <= 1)

This analysis assumes the entire saddle weight load and load due to transverse forces are concentrated on the outer rib + some portion of the web. This generally would not be the case and as such this analysis is very conservative.

Inertia of Saddle, Outer Ribs - Transverse Direction:

	B	D	Y	A	AY	Io
Rib	7.0000	0.5000	0.2500	3.5000	0.8750	14.0729
Web	0.5000	8.0000	4.0000	4.0000	16.0000	33.5833
Totals	...	...	...	7.5000	16.8750	47.6563

Web dimension [D]:

$$= 16 \cdot \text{Web Thickness}$$

$$= 16 \cdot 0.5$$

$$= 8.000 \text{ in.}$$

Moment at base of outer Rib [Mbase]:

$$= F_t(\text{Centerline dimension B} - \text{Baseplate thickness})$$

$$= 0(27 - 0.938)$$

$$= 0.000 \text{ in.lbs}$$

Bending Stress due to Transverse Force [SigmaB,base]:

$$= \text{Bending Moment} / \text{Section Modulus}$$

$$= 0 / 21.18$$

$$= 0.000 \text{ psi}$$

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Vertical Load on the Rib due to the Bending Moment [Fv,mom]:

$$= \text{Bending Moment} / \text{Web Length}$$

$$= 0/15.52$$

$$= 0.000 \text{ lb.}$$

Total Vertical Load on the Rib [Fv,total]:

$$= F_{v,mom} + \text{Vertical Load}$$

$$= 0 + 0$$

$$= 0.000 \text{ lb.}$$

Compressive Stress on Outer Rib [Sigma,cr]:

$$= F_{v,total} / \text{Area}$$

$$= 0/7.5$$

$$= 0.000 \text{ psi}$$

Radius of Gyration [r]:

$$= \sqrt{\text{Total Inertia} / \text{Total Area}}$$

$$= \sqrt{47.66/7.5}$$

$$= 2.521 \text{ in.}$$

Slenderness ratio [KL/r]:

$$= KL/r$$

$$= 1 * 23.08/2.521$$

$$= 9.157$$

Compressive Allowable, $KL/r < C_c$ ($9.157 < 122.7$) per AISC E2-1 [Sca]:

$$= (1 - (KL/r)^2 / (2 * C_c^2)) F_y / (5/3 + 3 * (KL/r) / (8 * C_c) - (KL/r)^3 / (8 * C_c^3))$$

$$= (1 - (9.157)^2 / (2 * 122.7^2)) 38000 / (5/3 + 3 * (9.157) / (8 * 122.7) - (9.157^3) / (8 * 122.7^3))$$

$$= 22362 \text{ psi}$$

Unity Check on Outer Rib [UCheck,outer]:

$$= \text{Sigma}_{cr} / S_{ca} + \text{Sigma}_{B,base} / S_{ba}$$

$$= 0/22362 + 0/25333$$

$$= 0$$

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5000	7.0000	4.0000	3.5000	14.0000	27.8968
Web	7.7604	0.5000	0.2500	3.8802	0.9700	12.3529
Totals	...	...	...	7.3802	14.9700	40.2496

Distance to Centroid from Datum [ytot]:

$$= AY / A$$

$$= 14.97/7.38$$

$$= 2.028 \text{ in.}$$

Distance to Centroid [C1]:

$$= \max(y_{tot}, \text{abs}(\text{Saddle Width} - y_{tot}))$$

$$= \max(2.028, \text{abs}(7.5 - 2.028))$$

$$= 5.472 \text{ in.}$$

Length of Inner Rib [L]:

$$= \text{Saddle Height} - \text{Outside Radius} - B_{pthk}$$

$$= 27 - \cos(8.312/2) (0.938 + 0 + 0) - 0$$

$$= 17.750 \text{ in.}$$

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Radius of Gyration [r]:
 = $\sqrt{\text{Total Inertia} / \text{Total Area}}$
 = $\sqrt{40.25/7.38}$
 = 2.335 in.

Slenderness ratio [KL/r]:
 = KL/r
 = $1 * 17.75/2.335$
 = 7.601

Unit Force [Force,u]:
 = $F1 / (2 * \text{Baseplate Length})$
 = $13986/(2 * 22)$
 = 317.866 lb./in.

Moment at base of inner Rib [Mbase,c]:
 = Unit Force * e * L
 = $317.9 * 7.76 * 17.75$
 = 43785.035 in.lbs

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
 = Bending Moment / Section Modulus
 = $43785/7.356$
 = 5952.198 psi

Compressive Allowable, KL/r < Cc (7.601 < 122.7) per AISC E2-1 [Sca]:
 = $(1 - (KL/r)^2 / (2 * Cc^2)) Fy / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r^3) / (8 * Cc^3))$
 = $(1 - (7.601)^2 / (2 * 122.7^2)) 38000 / (5/3 + 3 * (7.601) / (8 * 122.7) - (7.601^3) / (8 * 122.7^3))$
 = 22444 psi

AISC Unity Check of Inside Ribs (must be <= 1)
 = $S_c / S_{ca} + (M_{base,c} * C1/I) / S_{ba}$
 = $830.5/22444 + (43785 * 5.472/40.25) / 25333$
 = 0.272

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

Input and Calculated Values:

Vessel Mean Radius	Rm	7.81	in.
Shell Thickness used in this Case	t	0.375	in.
Stiffened Vessel Length per 4.15.6	L	13.58	ft.
Distance from Saddle to Vessel tangent	a1 or a	40.50	in.
Saddle Width	b1 or b	7.50	in.
Saddle Bearing Angle	delta or theta	138.00	degrees
Wear Plate Width	b2 or b1	13.00	in.
Wear Plate Bearing Angle	delta2 or theta1	180.00	degrees
Wear Plate Thickness	e2 or tr	0.3125	in.
Wear Plate Allowable Stress	fw or Sr	20000.00	psi
Inside Depth of Head	Hi or h2	0.33	ft.
Shell Allowable Stress used in Calculation		17100.00	psi
Head Allowable Stress used in Calculation		17100.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	27.00	in.
Coefficient of Friction	mu	0.00	
Saddle Force Q for this Transportation Case		11034.00	lb.
Shipping Longitudinal Acceleration	gx	1.50	g
Shipping Transverse Acceleration	gz	1.50	g
Shipping Vertical Acceleration	gy	2.24	g
Vertical Acceleration Acting with Transverse	gw	2.24	g
Internal Pressure during Transport		0.00	psig
Transportation Wind Load Scalar Factor	wlsf	1.00	
Transportation Wind Velocity	wv	101.0	mile/hr

Horizontal Vessel Analysis Results:	Actual psi	Allowable psi
Long. Stress at Top of Midspan	135.99	17100.00
Long. Stress at Bottom of Midspan	-135.99	-33250.00
Long. Stress at Bottom of Midspan	135.99	17100.00
Long. Stress at Top of Saddles	1669.14	17100.00
Long. Stress at Bottom of Saddles	-1669.14	-33250.00
Long. Stress at Bottom of Saddles	1669.14	17100.00
Tangential Shear in Shell	1694.07	13680.00
Circ. Compressive Stress in Shell	203.23	17100.00
Stiffener Circ. Stress at Shell	620.45	17100.00
Stiffener Circ. Stress at Tip	182.41	20000.00

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Intermediate Results: Saddle Reaction Q due to Road Transport Load:

Transverse Force due to Wind during Transport [Ft_w]:

$$\begin{aligned} &= \text{Transverse Area} * 0.00256 * wv^2 * wlsf \\ &= 22.46 * 0.00256 * 101^2 * 1 \\ &= 586.6 \text{ lbf} \end{aligned}$$

Longitudinal Force due to Wind during Transport [Fl_w]:

$$\begin{aligned} &= \pi * D^2/4 * 0.00256 * wv^2 * wlsf * \text{Wind Dia. Mult} \\ &= \pi * 1.333^2/4 * 0.00256 * 101^2 * 1 * 1.2 \\ &= 43.8 \text{ lbf} \end{aligned}$$

Transverse Force due to Lateral Acceleration [Ft]:

$$\begin{aligned} &= gz * \text{saddle Load} * gw + Ft_w \\ &= 1.5 * 2683 * 2.24 + 586.6 \\ &= 9601.2 \text{ lb.} \end{aligned}$$

Longitudinal Force due to Axial Acceleration [Fl]:

$$\begin{aligned} &= gx * \text{saddle Load} * gw + Fl_w \\ &= 1.5 * 2683 * 2.24 + 43.76 \\ &= 9058.3 \text{ lb.} \end{aligned}$$

Transverse Saddle Reaction Force due to Lateral Acceleration [Fwt]:

$$\begin{aligned} &= Ft/\text{Num of Saddles} * B / E \\ &= 9601/2 * 27/15.52 \\ &= 8351.1 \text{ lb.} \end{aligned}$$

Saddle Reaction Force due to Transport Load [Fwl]:

$$\begin{aligned} &= Fl * B / Ls \\ &= 9058 * 27/81 \\ &= 3019.4 \text{ lb.} \end{aligned}$$

Saddle Reaction Force due to Vertical Transportation Acceleration [Fsl]:

$$\begin{aligned} &= \text{Saddle Load} * gy \\ &= 2683 * 2.24 \\ &= 6009.679 \text{ lb.} \end{aligned}$$

Load Combination Results due to Transport Loading [Q]:

$$\begin{aligned} &= \text{Saddle Load} + \max(Fwl, Fwt, Fsl) \\ &= 2683 + \max(3019, 8351, 6010) \\ &= 11034.0 \text{ lb.} \end{aligned}$$

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	11222.00	lb.
Transverse Shear Load Saddle	8351.11	lb.
Longitudinal Shear Load Saddle	9058.28	lb.

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

$$\begin{aligned} &= \min(2(\text{ShellID}/2 + t + \text{WearPadThickness}) \sin(\theta/2), 2*Rm) \\ &= \min(2(15.25/2 + 0.375 + 0.312) \sin(138/2), 2*7.812) \\ &= 15.521 \text{ in.} \end{aligned}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

The Computed K values from Table 4.15.1:

K1 = 0.1374 K2 = 0.9229 K3 = 0.6161 K4 = 0.3336
 K5 = 0.7024 K6 = 0.0392 K7 = 0.0392 K8 = 0.3195
 K9 = 0.2409 K10 = 0.0448 K1* = 0.2426 K6p = 0.0174
 K7p = 0.0174

The suffix 'p' denotes the values for a wear plate if it exists.

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

Moment per Equation 4.15.1 [M1]:

$$= -Q \cdot a \left[1 - \left(1 - \frac{a}{L} + \frac{(R_m^2 - h^2)}{(2a \cdot L)} \right) / \left(1 + \frac{(4h^2)}{3L} \right) \right]$$

$$= -11034 \cdot 3.375 \left[1 - \left(1 - \frac{3.375}{13.58} + \frac{(0.651^2 - 0.328^2)}{(2 \cdot 3.375 \cdot 13.58)} \right) / \left(1 + \frac{(4 \cdot 0.328^2)}{3 \cdot 13.58} \right) \right]$$

$$= -10001.7 \text{ ft.lb.}$$

Moment per Equation 4.15.4 [M2]:

$$= Q \cdot L / 4 \left(1 + 2 \frac{(R_m^2 - h^2)}{(L^2)} \right) / \left(1 + \frac{(4h^2)}{3L} \right) - 4a/L$$

$$= 11034 \cdot 13.58 / 4 \left(1 + 2 \frac{(0.651^2 - 0.328^2)}{(13.58^2)} \right) / \left(1 + \frac{(4 \cdot 0.328^2)}{3 \cdot 13.58} \right) - 4 \cdot 3.375 / 13.58$$

$$= -814.9 \text{ ft.lb.}$$

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

$$= P \cdot R_m / (2t) - M_2 / (\pi \cdot R_m^2 \cdot t)$$

$$= 0 \cdot 7.812 / (2 \cdot 0.375) - -9779 / (\pi \cdot 7.812^2 \cdot 0.375)$$

$$= 135.99 \text{ psi}$$

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

$$= P \cdot R_m / (2t) + M_2 / (\pi \cdot R_m^2 \cdot t)$$

$$= 0 \cdot 7.812 / (2 \cdot 0.375) + -9779 / (\pi \cdot 7.812^2 \cdot 0.375)$$

$$= -135.99 \text{ psi}$$

Longitudinal Stress at Top of Shell at Support (4.15.6) [sigma3]:

$$= P \cdot R_m / (2t) - M_1 / (\pi \cdot R_m^2 \cdot t)$$

$$= 0 \cdot 7.812 / (2 \cdot 0.375) - -120020 / (\pi \cdot 7.812^2 \cdot 0.375)$$

$$= 1669.14 \text{ psi}$$

Longitudinal Stress at bottom of Shell at Support (4.15.7) [sigma4]:

$$= P \cdot R_m / (2t) + M_1 / (\pi \cdot R_m^2 \cdot t)$$

$$= 0 \cdot 7.812 / (2 \cdot 0.375) + -120020 / (\pi \cdot 7.812^2 \cdot 0.375)$$

$$= -1669.14 \text{ psi}$$

Maximum Shear Force in the Saddle (4.15.3) [T]:

$$= Q(L - 2a) / (L + (4 \cdot h^2 / 3))$$

$$= 11034(13.58 - 2 \cdot 3.375) / (13.58 + (4 \cdot 0.328^2 / 3))$$

$$= 5377.6 \text{ lb.}$$

Shear Stress in the shell with double rings (4.15.12) [tau2]:

$$= K_2 \cdot T / (R_m \cdot t)$$

$$= 0.923 \cdot 5378 / (7.812 \cdot 0.375)$$

$$= 1694.07 \text{ psi}$$

Decay Length (4.15.20) [x1,x2]:

$$= 0.78 \cdot \sqrt{R_m \cdot t}$$

$$= 0.78 \cdot \sqrt{7.812 \cdot 0.375}$$

$$= 1.335 \text{ in.}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Circ. Stress in shell w/rings adjacent to Saddle (4.15.37) [sigma6]:

= -K5 * Q * k/(t(b + 2 * x2))

= -0.702 * 11034 * 0.1/(0.375(7.5 + 2 * 1.335))

= -203.23 psi

Note: Double Rings adjacent to Saddle Outside the Shell.

Circ. + Bending Stress in shell, rings adjacent to Saddle (4.15.40) [sigma10*]:

= -K9 * Q/A - K10 * Q * Rm * c1/I

= -0.241*11034/8.721-0.0448*11034*7.812*2.113/25.84

= -620.45 psi

Circ. + Bending Stress in ring, rings adjacent to Saddle (4.15.41) [sigma11*]:

= -K9 * Q/A + K10 * Q * Rm * c2/I

= -0.241*11034/8.721+0.0448*11034*7.812*3.262/25.84

= 182.41 psi

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	22.0000	in.
Baseplate Thickness	Bpthk	0.9375	in.
Baseplate Width	Bpwid	8.0000	in.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5000	in.
Web Thickness	Webtk	0.5000	in.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	18.6	in.
Friction Coefficient	mu	0.000	

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

Inertia of Shell [ShellInertia]:

= ((1.56 * sqrt(R * t) + WearPlateWidth)t³)/12

= ((1.56 * sqrt(7.625 * 0.375) + 13)0.375³)/12

= 0.069 in**4

Resolved Inertia for the Shell [I,shell]:

= ShellInertia + AShell(C1 - Y)²

= 0.0687 + 5.864(8.742 - 0.188)²

= 429.179 in**4

	B in.	D in.	Y in.	A in²	AY in.³	I + AD² in**4
Shell	15.6379	0.3750	0.1875	5.8642	1.0995	429.1793
Wearplate	13.0000	0.3125	0.5312	4.0625	2.1582	273.8925
Web	0.5000	17.7500	9.5625	8.8750	84.8672	238.9941
BasePlate	8.0000	0.9375	18.9062	7.5000	141.7969	775.4343
Totals	...	...	...	26.3017	229.9218	1717.5000

Distance to Centroid [C1]:

= AY / A

= 229.9/26.3

= 8.742 in.

Angle [beta]:

= 180 - Saddle Angle/2

= 180 - 138/2

= 111.0

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Saddle Splitting Coefficient [K1]:

$$= (1 + \cos(\beta) - 0.5 \sin(\beta)^2) / (\pi - \beta + \sin(\beta) \cos(\beta))$$

$$= (1 + \cos(111) - 0.5 \sin(111)^2) / (\pi - 1.937 + \sin(111) \cos(111))$$

$$= 0.2367$$

Saddle Splitting Force [Fh]:

$$= K1 * Q$$

$$= 0.237 * 11034$$

$$= 2611.5581 \text{ lb.}$$

$$\text{Tension Stress, } St = (Fh / As) = 127.7827 \text{ psi}$$

$$\text{Allowed Stress, } Sa = 0.6 * \text{Yield Str} = 22800.0000 \text{ psi}$$

Saddle Splitting Dimension [d]:

$$= B - R * \sin(\theta/2) / (\theta/2 \text{ in radians})$$

$$= 27 - 7.625 * \sin(138/2) / 1.204$$

$$= 21.089 \text{ in.}$$

$$\text{Bending Moment, } M = Fh * d = 4589.5835 \text{ ft.lb.}$$

$$\text{Bending Stress, } Sb = (M * C1 / I) = 280.3199 \text{ psi}$$

$$\text{Allowed Stress, } Sa = 2/3 * \text{Yield Str} = 25333.3340 \text{ psi}$$

Minimum Thickness of Baseplate per Moss:

$$= \sqrt{3(Q + \text{Saddle\_Wt}) \text{BasePlateWidth} / (2 * \text{BasePlateLength} * \text{AllStress})}$$

$$= \sqrt{3(11034 + 188)8 / (2 * 22 * 25333)}$$

$$= 0.492 \text{ in.}$$

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:

$$= 2 * \cos(90 - \text{Saddle Angle}/2) (\text{Inside Radius} + \text{Shell Thk} + \text{Wear Plate Thk})$$

$$= 2 * \cos(90 - 138/2) (7.625 + 0.375 + 0.312)$$

$$= 15.521 \text{ in.}$$

Distance between Ribs [e]:

$$= \text{Web Length} / (\text{Nr ribs} - 1)$$

$$= 15.52 / (3 - 1)$$

$$= 7.760 \text{ in.}$$

Baseplate Pressure Area [Ap]:

$$= e * \text{Bpwid} / 2$$

$$= 7.76 * 8 / 2$$

$$= 31.042 \text{ in}^2$$

Bearing Pressure [Bp]:

$$= Q / (\text{BasePlateLength} * \text{BasePlateWidth})$$

$$= 11034 / (22 * 8)$$

$$= 62.693 \text{ lb./in}^2$$

Axial Load [P]:

$$= Ap * Bp$$

$$= 31.04 * 62.69$$

$$= 1946.094 \text{ lb.}$$

Area of the Rib and Web [Ar]:

$$= \text{Rib Area} + \text{Web Area}$$

$$= 3.5 + 1.94$$

$$= 5.440 \text{ in}^2$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Compressive Stress [Sc]:

= P/Ar
= 1946/5.44
= 357.731 psi

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5000	7.0000	4.0000	3.5000	14.0000	20.5515
Web	3.8802	0.5000	0.2500	1.9401	0.4850	11.3334
Totals	...	...	...	5.4401	14.4850	31.8849

Rib dimension [D]:

= Saddle Width - Web Thickness
= 7.5 - 0.5
= 7.000 in.

Distance to Centroid from Datum [ytot]:

= AY / A
= 14.49/5.44
= 2.663 in.

Distance to Centroid [C1]:

= max(ytot, Saddle Width - ytot)
= max(2.663, 7.5 - 2.663)
= 4.837 in.

Radius of Gyration [r]:

= sqrt(Total Inertia / Total Area)
= sqrt(31.88/5.44)
= 2.421 in.

Length of Outer Rib [L]:

= Saddle Height - cos(theta/2)(radius + shlthk + wpdthk) - bpthk
= 27 - cos(138/2)(7.625 + 0.375 + 0.312) - 0.938
= 23.084 in.

Intermediate Term [Cc]:

= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 29000000/38000)
= 122.736

Slenderness ratio [KL/r]:

= KL/r
= 1 * 23.08/2.421
= 9.535

Bending Moment [Rm]:

= F1 / (2 * Bplen) * e * L / 2
= 9058 / (2 * 22) * 7.76 * 23.08/2
= 1536.625 ft.lb.

Compressive Allowable, KL/r < Cc(9.535 < 122.7) per AISC E2-1 [Sca]:

= (1 - (K1r)² / (2 * Cc²)) Fy / (5/3 + 3 * (K1r) / (8 * Cc) - (K1r³) / (8 * Cc³))
= (1 - (9.535)² / (2 * 122.7²)) 38000 /
(5/3 + 3 * (9.535) / (8 * 122.7) - (9.535³) / (8 * 122.7³))
= 22341 psi

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

AISC Unity Check of Outside Ribs (must be <= 1)

$$= S_c/S_{ca} + (R_m * C_1 / I)/S_{ba}$$

$$= 357.7/22341 + (18440 * 4.837/31.88)/25333$$

$$= 0.126$$

AISC Unity Check of Outside Ribs, due to Transverse Force Ft (must be <= 1)

This analysis assumes the entire saddle weight load and load due to transverse forces are concentrated on the outer rib + some portion of the web. This generally would not be the case and as such this analysis is very conservative.

Inertia of Saddle, Outer Ribs - Transverse Direction:

	B	D	Y	A	AY	Io
Rib	7.0000	0.5000	0.2500	3.5000	0.8750	14.0729
Web	0.5000	8.0000	4.0000	4.0000	16.0000	33.5833
Totals	...	...	...	7.5000	16.8750	47.6563

Web dimension [D]:

$$= 16 * \text{Web Thickness}$$

$$= 16 * 0.5$$

$$= 8.000 \text{ in.}$$

Moment at base of outer Rib [Mbase]:

$$= F_t(\text{Centerline dimension B} - \text{Baseplate thickness})$$

$$= 0(27 - 0.938)$$

$$= 0.000 \text{ in.lbs}$$

Bending Stress due to Transverse Force [SigmaB,base]:

$$= \text{Bending Moment} / \text{Section Modulus}$$

$$= 0/21.18$$

$$= 0.000 \text{ psi}$$

Vertical Load on the Rib due to the Bending Moment [Fv,mom]:

$$= \text{Bending Moment} / \text{Web Length}$$

$$= 0/15.52$$

$$= 0.000 \text{ lb.}$$

Total Vertical Load on the Rib [Fv,total]:

$$= F_{v,mom} + \text{Vertical Load}$$

$$= 0 + 0$$

$$= 0.000 \text{ lb.}$$

Compressive Stress on Outer Rib [Sigma,cr]:

$$= F_{v,total} / \text{Area}$$

$$= 0/7.5$$

$$= 0.000 \text{ psi}$$

Radius of Gyration [r]:

$$= \sqrt{ \text{Total Inertia} / \text{Total Area} }$$

$$= \sqrt{ 47.66/7.5 }$$

$$= 2.521 \text{ in.}$$

Slenderness ratio [KL/r]:

$$= KL/r$$

$$= 1 * 23.08/2.521$$

$$= 9.157$$

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Compressive Allowable, $KL/r < Cc$ (9.157 < 122.7) per AISC E2-1 [Sca]:

$$= (1 - (KL/r)^2 / (2 * Cc^2)) F_y / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)^3 / (8 * Cc^3))$$

$$= (1 - (9.157)^2 / (2 * 122.7^2)) 38000 / (5/3 + 3 * (9.157) / (8 * 122.7) - (9.157^3) / (8 * 122.7^3))$$

$$= 22362 \text{ psi}$$

Unity Check on Outer Rib [UCheck,outer]:

$$= \text{Sigma}_{cr} / S_{ca} + \text{Sigma}_{B,base} / S_{ba}$$

$$= 0/22362 + 0/25333$$

$$= 0$$

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5000	7.0000	4.0000	3.5000	14.0000	27.8968
Web	7.7604	0.5000	0.2500	3.8802	0.9700	12.3529
Totals	...	...	...	7.3802	14.9700	40.2496

Distance to Centroid from Datum [ytot]:

$$= AY / A$$

$$= 14.97/7.38$$

$$= 2.028 \text{ in.}$$

Distance to Centroid [C1]:

$$= \max(ytot, \text{abs}(\text{Saddle Width} - ytot))$$

$$= \max(2.028, \text{abs}(7.5 - 2.028))$$

$$= 5.472 \text{ in.}$$

Length of Inner Rib [L]:

$$= \text{Saddle Height} - \text{Outside Radius} - \text{Bpthk}$$

$$= 27 - \cos(8.312/2) (0.938 + 0 + 0) - 0$$

$$= 17.750 \text{ in.}$$

Radius of Gyration [r]:

$$= \sqrt{ \text{Total Inertia} / \text{Total Area} }$$

$$= \sqrt{ 40.25/7.38 }$$

$$= 2.335 \text{ in.}$$

Slenderness ratio [KL/r]:

$$= KL/r$$

$$= 1 * 17.75/2.335$$

$$= 7.601$$

Unit Force [Force,u]:

$$= F1 / (2 * \text{Baseplate Length})$$

$$= 9058 / (2 * 22)$$

$$= 205.870 \text{ lb./in.}$$

Moment at base of inner Rib [Mbase,c]:

$$= \text{Unit Force} * e * L$$

$$= 205.9 * 7.76 * 17.75$$

$$= 28357.932 \text{ in.lbs}$$

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

$$= \text{Bending Moment} / \text{Section Modulus}$$

$$= 28358/7.356$$

$$= 3855.016 \text{ psi}$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Compressive Allowable, $KL/r < Cc$ ($7.601 < 122.7$) per AISC E2-1 [Sca]:

$$= \left(1 - \frac{(KL/r)^2}{(2 * Cc^2)} \right) F_y / \left(\frac{5}{3} + 3 * \frac{(KL/r)}{(8 * Cc)} - \frac{(KL/r)^3}{(8 * Cc^3)} \right)$$

$$= \left(1 - \frac{(7.601)^2}{(2 * 122.7^2)} \right) 38000 / \left(\frac{5}{3} + 3 * \frac{(7.601)}{(8 * 122.7)} - \frac{(7.601^3)}{(8 * 122.7^3)} \right)$$

$$= 22444 \text{ psi}$$

AISC Unity Check of Inside Ribs (must be ≤ 1)

$$= S_c / S_{ca} + (M_{base,c} * C_1 / I) / S_{ba}$$

$$= 545.9 / 22444 + (28358 * 5.472 / 40.25) / 25333$$

$$= 0.176$$

PV Elite is a trademark of Hexagon AB, 2022, All rights reserved.

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

LIFTING LUG STANDARD
DESIGN CALCULATIONS

FABSCO JOB NO. S21-13258-9/10
ITEM NO. 18-X-372A/B
P.O. NO. 4505600057

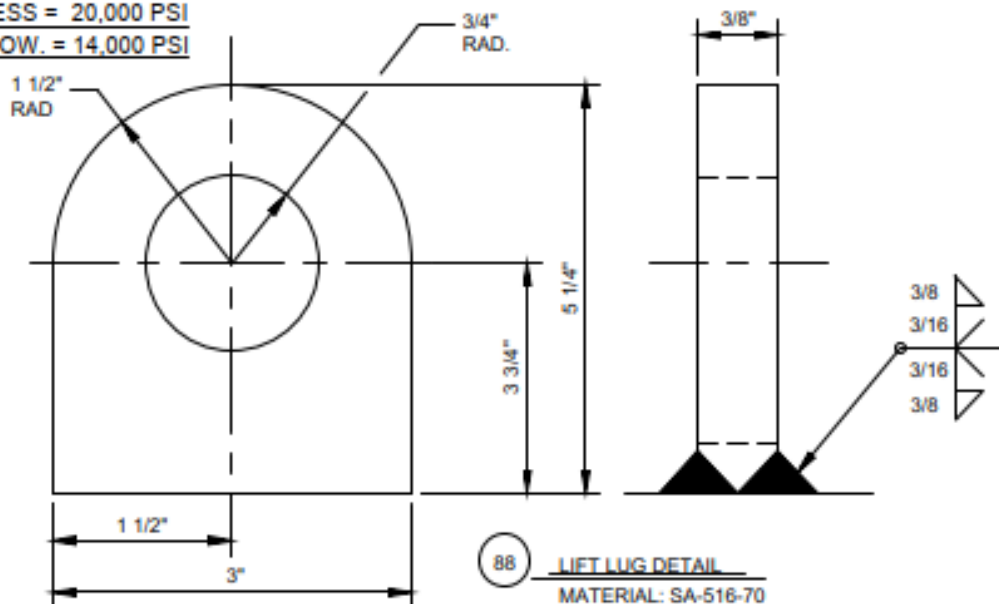
900

IMPACT FACTOR = 2

DESIGN LOAD = (P x I) 1800 LBS

ALLOW. STRESS = 20,000 PSI

USE 70% ALLOW. = 14,000 PSI



T = REQUIRED THICKNESS OF LUG, INCHES

S = ALLOWABLE STRESS OF LUG, PSI

L = WIDTH OF LUG, INCHES

H = DISTANCE, CENTERLINE OF HOLE TO COMPONENT, INCHES

P = LOAD PER LUG, LB

I = IMPACT FACTOR

R = RADIUS OF LUG, INCHES

D = DIAMETER OF HOLE, INCHES

W = ACTUAL WELD STRESS, PSI

WELD STRESS FOR 3/8" FILLET

$$W = \frac{.707 (P \times I)}{.375 (L \times 2)} \text{ , PSI}$$

$$W = \frac{.707 \times 1800}{.375 \times 6} = 565 \text{ PSI}$$

(12,700 PSI = MAX. ALLOWABLE WELD STRESS)

REQUIRED THICKNESS FOR SHEAR

$$T = \frac{(P \times I)}{(S) (R - D/2)} \text{ , INCHES}$$

REQUIRED THICKNESS FOR SHEAR

$$T = \frac{1800}{14,000 \times (1.5 - .75)} = 0.171"$$

REQUIRED THICKNESS FOR BENDING

$$T = \frac{6 (P \times I) H}{S (L)^2} \text{ , INCHES}$$

REQUIRED THICKNESS FOR BENDING

$$T = \frac{6 \times 1800 \times 3.75}{14,000 \times 3^2} = 0.321"$$

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

**Input Echo, 107/537 Item 1, Description: New WRC 107/537
3"-600# RF LWN CHANNEL IN & OUT (T1/T2)**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	0.1250	in.
Vessel Diameter	Dv	15.375	in.
Vessel Thickness	Tv	0.375	in.

Design Temperature		330.00	F
Vessel Material		SA-106B	
Vessel UNS Number		K03006	
Vessel Cold S.I. Allowable	Smc	20000.00	psi
Vessel Hot S.I. Allowable	Smh	20000.00	psi

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	0.1250	in.
Nozzle Diameter	Dn	4.625	in.
Nozzle Thickness	Tn	0.812	in.
Nozzle Material		SA-350LF2CL1	
Nozzle Cold S.I. Allowable	SNmc	17100.00	psi
Nozzle Hot S.I. Allowable	SNmh	17100.00	psi

Thickness of Reinforcing Pad	Tpad	0.500	in.
Diameter of Reinforcing Pad	Dpad	8.625	in.

Design Internal Pressure	Dp	400.000	psig
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	-1590.0	lb.
Longitudinal Shear (SUS)	VL	1340.0	lb.
Circumferential Shear (SUS)	Vc	1340.0	lb.
Circumferential Moment (SUS)	Mc	1080.0	ft.lb.
Longitudinal Moment (SUS)	ML	1360.0	ft.lb.
Torsional Moment (SUS)	Mt	1720.0	ft.lb.

Use Interactive Control	No
WRC107 Version	Version March 1979 (B1 & B2)

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

= NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
 = 4.625 + 2 * 1.65 * sqrt(7.938 (0.375 - 0.125))
 = 9.274 in.

WRC 107 Stress Calculation for SUSained loads:

Radial Load	P	-1590.0	lb.
Circumferential Shear	VC	1340.0	lb.
Longitudinal Shear	VL	1340.0	lb.
Circumferential Moment	MC	1080.0	ft.lb.
Longitudinal Moment	ML	1360.0	ft.lb.
Torsional Moment	MT	1720.0	ft.lb.
Dimensionless Parameters used : Gamma = 10.92			

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979 B1/B2	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.247	4C	1.777	(A,B)
N(PHI) / (P/Rm)	0.247	3C	1.437	(C,D)
M(PHI) / (P)	0.247	2C1	0.063	(A,B)
M(PHI) / (P)	0.247	1C	0.089	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.247	3A	0.390	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.247	1A	0.091	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.247	3B	1.293	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.247	1B1	0.039	(A,B,C,D)
N(x) / (P/Rm)	0.247	3C	1.437	(A,B)
N(x) / (P/Rm)	0.247	4C	1.777	(C,D)
M(x) / (P)	0.247	1C1	0.092	(A,B)
M(x) / (P)	0.247	2C	0.062	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.247	4A	0.678	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.247	2A	0.050	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.247	4B	0.392	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.247	2B1	0.063	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (psi)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		460	460	460	460	372	372	372	372
Circ. Bend. P		1061	-1061	1061	-1061	1507	-1507	1507	-1507
Circ. Memb. MC		0	0	0	0	-407	-407	407	407
Circ. Bend. MC		0	0	0	0	-6233	6233	6233	-6233
Circ. Memb. ML		-1697	-1697	1697	1697	0	0	0	0
Circ. Bend. ML		-3369	3369	3369	-3369	0	0	0	0
Tot. Circ. Str.		-3545	1070	6588	-2272	-4761	4691	8520	-6961
Long. Memb. P		372	372	372	372	460	460	460	460
Long. Bend. P		1552	-1552	1552	-1552	1049	-1049	1049	-1049
Long. Memb. MC		0	0	0	0	-707	-707	707	707
Long. Bend. MC		0	0	0	0	-3439	3439	3439	-3439
Long. Memb. ML		-514	-514	514	514	0	0	0	0
Long. Bend. ML		-5435	5435	5435	-5435	0	0	0	0
Tot. Long. Str.		-4024	3739	7874	-6101	-2637	2142	5656	-3321
Shear VC		245	245	-245	-245	0	0	0	0
Shear VL		0	0	0	0	-245	-245	245	245
Shear MT		819	819	819	819	819	819	819	819
Tot. Shear		1064	1064	573	573	573	573	1064	1064
Str. Int.		4876	4112	8093	6185	4906	4813	8873	7250

Dimensionless Parameters used : Gamma = 31.75

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979 B1/B2	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.475	4C	2.577	(A,B)
N(PHI) / (P/Rm)	0.475	3C	1.039	(C,D)
M(PHI) / (P)	0.475	2C1	0.008	(A,B)
M(PHI) / (P)	0.475	1C !	0.061	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.475	3A	0.840	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.475	1A	0.063	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.475	3B	1.415	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.475	1B1	0.010	(A,B,C,D)
N(x) / (P/Rm)	0.475	3C	1.039	(A,B)
N(x) / (P/Rm)	0.475	4C	2.577	(C,D)
M(x) / (P)	0.475	1C1	0.019	(A,B)
M(x) / (P)	0.475	2C !	0.031	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.475	4A	3.112	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.475	2A	0.026	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.475	4B	0.828	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.475	2B1	0.019	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (psi)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		2064	2064	2064	2064	832	832	832	832
Circ. Bend. P		1216	-1216	1216	-1216	9250	-9250	9250	-9250
Circ. Memb. MC		0	0	0	0	-1454	-1454	1454	1454
Circ. Bend. MC		0	0	0	0	-20717	20717	20717	-20717
Circ. Memb. ML		-3084	-3084	3084	3084	0	0	0	0
Circ. Bend. ML		-3978	3978	3978	-3978	0	0	0	0
Tot. Circ. Str.		-3782	1742	10344	-44	-12088	10845	32255	-27681
Long. Memb. P		832	832	832	832	2064	2064	2064	2064
Long. Bend. P		2848	-2848	2848	-2848	4733	-4733	4733	-4733
Long. Memb. MC		0	0	0	0	-5386	-5386	5386	5386
Long. Bend. MC		0	0	0	0	-8562	8562	8562	-8562
Long. Memb. ML		-1803	-1803	1803	1803	0	0	0	0
Long. Bend. ML		-7870	7870	7870	-7870	0	0	0	0
Tot. Long. Str.		-5993	4051	13355	-8082	-7150	507	20746	-5844
Shear VC		395	395	-395	-395	0	0	0	0
Shear VL		0	0	0	0	-395	-395	395	395
Shear MT		706	706	706	706	706	706	706	706
Tot. Shear		1102	1102	310	310	310	310	1102	1102
Str. Int.		6448	4492	13386	8094	12107	10854	32360	27737

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (psi)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		3975	4375	3975	4375	3975	4375	3975	4375
Circ. Pl (SUS)		-1237	-1237	2158	2158	-35	-35	779	779
Circ. Q (SUS)		-2307	2307	4430	-4430	-4726	4726	7741	-7741
Long. Pm (SUS)		1987	1987	1987	1987	1987	1987	1987	1987
Long. Pl (SUS)		-142	-142	886	886	-247	-247	1167	1167
Long. Q (SUS)		-3882	3882	6987	-6987	-2390	2390	4488	-4488
Shear Pm (SUS)		0	0	0	0	0	0	0	0
Shear Pl (SUS)		245	245	-245	-245	-245	-245	245	245
Shear Q (SUS)		819	819	819	819	819	819	819	819
Pm (SUS)		3975	4375	3975	4375	3975	4375	3975	4375
Pm+Pl (SUS)		2801	3183	6152	6550	3967	4363	4792	5185
Pm+Pl+Q (Total)		3259	6660	10885	6320	1294	9132	12719	3194

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	4375	20000	Passed
Pm+Pl (SUS)	6550	30000	Passed
Pm+Pl+Q (TOTAL)	12719	60000	Passed

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (psi)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		12303	12703	12303	12703	12303	12703	12303	12703
Circ. Pl (SUS)		-1020	-1020	5149	5149	-621	-621	2287	2287
Circ. Q (SUS)		-2762	2762	5194	-5194	-11466	11466	29968	-29968
Long. Pm (SUS)		6151	6151	6151	6151	6151	6151	6151	6151
Long. Pl (SUS)		-970	-970	2636	2636	-3321	-3321	7451	7451
Long. Q (SUS)		-5022	5022	10718	-10718	-3828	3828	13295	-13295
Shear Pm (SUS)		0	0	0	0	0	0	0	0
Shear Pl (SUS)		395	395	-395	-395	-395	-395	395	395
Shear Q (SUS)		706	706	706	706	706	706	706	706
Pm (SUS)		12303	12703	12303	12703	12303	12703	12303	12703
Pm+Pl (SUS)		11308	11707	17470	17870	11699	12098	14729	15095
Pm+Pl+Q (Total)		8663	14714	22678	14602	1363	23554	44627	15443

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	12703	20000	Passed
Pm+Pl (SUS)	17870	30000	Passed
Pm+Pl+Q (TOTAL)	44627	60000	Passed

PV Elite is a trademark of Hexagon AB, 2021, All rights reserved.

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

6"-600 # RF WN SHELLSIDE INLET & OUTLET NOZZLE PRO/FEA ANALYSIS

Tabular Results

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

Model Notes

Model Notes

Input Echo:

Model Type : Cylindrical Shell

Parent Geometry

Parent Outside Diam. : 16.000 in.
 Thickness : 0.203 in.
 Fillet Along Shell : 0.375 in.

Parent Properties:

Cold Allowable : 17100.0 psi
 Hot Allowable : 17100.0 psi
 Material DB # 1009922.
 Ultimate Tensile (Amb) : 60000.0 psi
 Yield Strength (Amb) : 35000.0 psi
 Yield Strength (Hot) : 31000.0 psi
 Elastic Modulus (Amb) : 29400000.0 psi
 Poissons Ratio : 0.300
 Expansion Coefficient : 0.6900E-05 in./in./deg.
 Weight Density : 0.0000E+00 lb./cu.in. (NOT USED)

Nozzle Geometry

Nozzle Outside Diam. : 6.625 in.
 Thickness : 0.307 in.
 Length : 11.000 in.
 Nozzle Weld Length : 0.375 in.
 RePad Width : 3.500 in.
 RePad Thickness : 0.500 in.
 RePad Weld Leg : 0.500 in.
 Nozzle Tilt Angle : 0.000 deg.
 Distance from Top : 45.000 in.
 Distance from Bottom : 45.000 in.

Nozzle Properties

Cold Allowable : 17100.0 psi
 Hot Allowable : 17100.0 psi
 Material DB # 1009922.
 Ultimate Tensile (Amb) : 60000.0 psi
 Yield Strength (Amb) : 35000.0 psi
 Yield Strength (Hot) : 31000.0 psi
 Elastic Modulus (Amb) : 29400000.0 psi
 Poissons Ratio : 0.300

Expansion Coefficient : 0.6900E-05 in./in./deg.
 Weight Density : 0.0000E+00 lb./cu.in. (NOT USED)

Page 117 of 148

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Design Operating Cycles : 7000.
Ambient Temperature (Deg.) : 69.98

Uniform thermal expansion produces no stress in this geometry.
Any thermal loads will come through operating forces and moments applied through the nozzle.

Nozzle Inside Temperature : 300.00 deg.
Nozzle Outside Temperature : 300.00 deg.
Vessel Inside Temperature : 300.00 deg.
Vessel Outside Temperature : 300.00 deg.

Nozzle Pressure : 375.0 psi
Vessel Pressure : 375.0 psi

Operating Pressure : 285.0 psi

The operating pressure is used for secondary and peak stress cases. The design pressure is used for primary cases. The ratio of the operating/design pressure = 0.760

User Defined Load Input Echo for the ATTACHMENT:
Loads are given at the Nozzle/Header Junction
Loads are defined in Global Coordinates

Forces(lb.) Moments (ft-lb)

Load Case	FX	FY	FZ	MX	MYMZ
WEIGHT:	2625.0	-2100.0	2625.0	4005.0	6465.0 5070.0

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

Forces(lb.) Moments (ft-lb)

Load Case	FX	FY	FZ	MX	MYMZ
WEIGHT:	2625.0	-2100.0	2625.0	1598.8	6465.0 7476.2

The "top" or "positive" end of this model is "free" in the axial and translational directions.

Stresses ARE nodally AVERAGED.

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

[Table of Contents](#)

Load Case Report
FEPipe Version 15.0 Jobname: NOZZLE \$P
Released Jan. 2021 2:08pm JAN 16,2023

Load Case Report \$X

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

THE 9 LOAD CASES ANALYZED ARE:

1 WEIGHT ONLY (Wgt Only)

Weight ONLY case run to get the stress range between the installed and the operating states.

/----- Loads in Case 1
Loads due to Weight

Page 118 of 148

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

2 SUSTAINED (Wgt+Pr)

Sustained case run to satisfy local primary
membrane and bending stress limits.

/----- Loads in Case 2
 Loads due to Weight
 Pressure Case 1

3 OPERATING

Case run to compute the operating stresses used in
secondary, peak and range calculations as needed.

/----- Loads in Case 3
 Pressure Case 1
 Loads from (Operating)

4 RANGE (Fatigue Calc Performed)

Case run to get the RANGE of stresses.

as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

/----- Combinations in Range Case 4
 Plus Stress Results from CASE 3
 Minus Stress Results from CASE 1

5 Program Generated -- Force Only

Case run to compute sif's and flexibilities.

/----- Loads in Case 5
 Loads from (Axial)

6 Program Generated -- Force Only

Case run to compute sif's and flexibilities.

/----- Loads in Case 6
 Loads from (Inplane)

7 Program Generated -- Force Only

Case run to compute sif's and flexibilities.

/----- Loads in Case 7
 Loads from (Outplane)

8 Program Generated -- Force Only

Case run to compute sif's and flexibilities.

/----- Loads in Case 8
 Loads from (Torsion)

9 Program Generated -- Force Only

Case run to compute sif's and flexibilities.

/----- Loads in Case 9
 Pressure Case 1

Solution Data
 FEPipe Version 15.0 Jobname: NOZZLE \$P
 Released Jan. 2021 2:08pm JAN 16,2023

Solution Data

Maximum Solution Row Size = 1008
 Number of Nodes = 2328
 Number of Elements = 768
 Number of Solution Cases =8

Summation of Loads per Case

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Case #	FX	FY	FZ
1	2625.	-2100.	2625.
2	76125.	-3215.	2625.
3	73500.	-1115.	0.
4	0.	121870.	0.
5	0.	0.	0.
6	0.	0.	0.
7	0.	0.	0.
8	73500.	-1115.	0.

[Table of Contents](#)

ASME Code Stress Output Plots
 FEPipe Version 15.0 Jobname: NOZZLE \$P
 Released Jan. 2021 2:09pm JAN 16,2023

ASME Code Stress Output Plots \$X

- 1) Pl < SPL (SUS,Membrane) Case 2
- 2) Qb < SPS (SUS,Bending) Case 2
- 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
- 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
- 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
- 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
- 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
- 8) Membrane < User (OPE,Membrane) Case 3
- 9) Bending < User (OPE,Bending) Case 3
- 10) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 5
- 11) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 6
- 12) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 7
- 13) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 8
- 14) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 9
- 15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
- 16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
- 17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
- 18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Stress Results - Notes
 FEPipe Version 15.0 Jobname: NOZZLE \$P
 Released Jan. 2021 2:09pm JAN 16,2023

Stress Results - Notes

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

- Results in this analysis were generated using the finite element solution method.
- Using 2019 ASME Section VIII Division 2
- Use Polished Bar fatigue curve.
- Ratio between Operating and Design Pressure = 0.7600000
Range cases use operating pressure. Primary cases use design pressure.
- Assume free end displacements of attached pipe (e.g. thermal loads) are secondary loads.
- Primary bending stresses at discontinuities are treated like secondary stresses. (Pb=0)
- Use Equivalent Stress (Von Mises).
- TRIAXIAL Stress Guidelines:
S1+S2+S3 evaluation omitted from operating stress.
Include S1+S2+S3 evaluation in primary case evaluation.
Bending stress NOT included for all S1+S2+S3 calculations.
- Use local tensor values for averaged and not averaged stresses.

ASME Overstressed Areas Jobname: NOZZLE \$P
 FEPipe Version 15.0 2:09pm JAN 16,2023
 Released Jan. 2021

ASME Overstressed Areas \$X

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

Highest Primary Stress Ratios \$P
 FEPipe Version 15.0 Jobname: NOZZLE \$P
 Released Jan. 2021 2:09pm JAN 16,2023

Highest Primary Stress Ratios \$X

Pad/Header at Junction

Pl	SPL	Primary Membrane Load Case 2
18,011	31,000	Min Prin. Stress = -15927. (69% Neg, 5% NegHi)
psi	psi	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
58%		

Branch at Junction

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
61,705	66,000	Min Prin. Stress = -47599. (90% Neg, 32% NegHi)
psi	psi	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
93%		

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Branch Transition

Pl SPL Primary Membrane Load Case 2
17,470 31,000 Min Prin. Stress = -15064. (86% Neg, 16% NegHi)
psi psi Plot Reference:
1) Pl < SPL (SUS,Membrane) Case 2
56%

Pad Outer Edge Weld

Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2
60,242 66,000 Min Prin. Stress = -8469. (40% Neg, 0% NegHi)
psi psi Plot Reference:
4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
91%

Header Outside Pad Area

Pl SPL Primary Membrane Load Case 2
15,644 31,000 Min Prin. Stress = -3881. (61% Neg, 0% NegHi)
psi psi Plot Reference:
1) Pl < SPL (SUS,Membrane) Case 2
50%

Branch removed from Junction

Pl SPL Primary Membrane Load Case 2
17,867 31,000 Min Prin. Stress = -15400. (93% Neg, 42% NegHi)
psi psi Plot Reference:
1) Pl < SPL (SUS,Membrane) Case 2
57%

Highest Secondary Stress Ratios

FEPipe Version 15.0 Jobname: NOZZLE \$P
Released Jan. 2021 2:09pm JAN 16,2023

Highest Secondary Stress Ratios

\$X

In combination case 4 the max range stress divided
by the max component stress is 1.98. The case tensor components
are in some directions additive and so the combination
case will have HIGHER stresses than the largest of any
of the individual cases by more than 50%.

Load Case	Combined/Max (Inside)	Combined/Max (Outside)
4	1.984	1.969

Pad/Header at Junction

Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2
33,360 66,000 Min Prin. Stress = -15927. (69% Neg, 5% NegHi)
psi psi Plot Reference:
3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
50%

Branch at Junction

Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2
61,705 66,000 Min Prin. Stress = -47599. (90% Neg, 32% NegHi)
psi psi Plot Reference:
4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
93%

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Branch Transition

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
20,208	66,000	Min Prin. Stress = -15064. (86% Neg, 16% NegHi)
psi	psi	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
30%		

Pad Outer Edge Weld

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 4
60,806	66,000	Min Prin. Stress = -5978. (51% Neg, 0% NegHi)
psi	psi	Plot Reference:
		16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
92%		

Header Outside Pad Area

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
27,664	66,000	Min Prin. Stress = -3881. (61% Neg, 0% NegHi)
psi	psi	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
41%		

Branch removed from Junction

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
19,097	66,000	Min Prin. Stress = -15400. (93% Neg, 42% NegHi)
psi	psi	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
28%		

Highest Fatigue Stress Ratios

FEPipe Version 15.0 Jobname: NOZZLE \$P
Released Jan. 2021 2:09pm JAN 16,2023

Highest Fatigue Stress Ratios

\$X

Pad/Header at Junction

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 4
30,870	0.028 Life	Stress Concentration Factor = 1.350
psi	0.368 Stress	Strain Concentration Factor = 1.000
Allowable		Cycles Allowed for this Stress = 247,334.
83,994		"B31" Fatigue Stress Allowable = 85500.0
psi		Mark1 Fatigue Stress Allowable = 83402.0
		WRC 474 Mean Cycles to Failure = 1,122,861.
36%		WRC 474 99% Probability Cycles = 260,856.
		WRC 474 95% Probability Cycles = 362,170.
		BS5500 Allowed Cycles(Curve F) = 176,818.
		Membrane-to-Bending Ratio = 0.258
		Bending-to-PL+PB+Q Ratio = 0.795
		Plot Reference:
		18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Branch at Junction

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4
 59,768 0.333 Life Stress Concentration Factor = 1.350
 psi 0.712 Stress Strain Concentration Factor = 1.000
 Cycles Allowed for this Stress = 21,037.
 Allowable "B31" Fatigue Stress Allowable = 85500.0
 83,994 Markl Fatigue Stress Allowable = 83402.0
 psi WRC 474 Mean Cycles to Failure = 247,918.
 WRC 474 99% Probability Cycles = 57,595.
 71% WRC 474 95% Probability Cycles = 79,964.
 BS5500 Allowed Cycles(Curve F) = 24,363.
 Membrane-to-Bending Ratio = 0.340
 Bending-to-PL+PB+Q Ratio = 0.747
 Plot Reference:
 18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Branch Transition

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4
 17,003 0.000 Life Stress Concentration Factor = 1.000
 Strain Concentration Factor = 1.000
 psi 0.202 Stress Cycles Allowed for this Stress = 1.3578E9
 "B31" Fatigue Stress Allowable = 85500.0
 Allowable Markl Fatigue Stress Allowable = 83402.0
 83,994 WRC 474 Mean Cycles to Failure = 4,436,346.
 psi WRC 474 99% Probability Cycles = 1,030,623.
 WRC 474 95% Probability Cycles = 1,430,911.
 20% BS5500 Allowed Cycles(Curve F) = 430,121.
 Membrane-to-Bending Ratio = 1.094
 Bending-to-PL+PB+Q Ratio = 0.478
 Plot Reference:
 18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Pad Outer Edge Weld

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4
 82,089 0.934 Life Stress Concentration Factor = 1.350
 psi 0.977 Stress Strain Concentration Factor = 1.000
 Cycles Allowed for this Stress = 7,493.
 Allowable "B31" Fatigue Stress Allowable = 85500.0
 83,994 Markl Fatigue Stress Allowable = 83402.0
 psi WRC 474 Mean Cycles to Failure = 121,214.
 WRC 474 99% Probability Cycles = 28,160.
 97% WRC 474 95% Probability Cycles = 39,097.
 BS5500 Allowed Cycles(Curve F) = 9,403.
 Membrane-to-Bending Ratio = 0.283
 Bending-to-PL+PB+Q Ratio = 0.779
 Plot Reference:
 18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Header Outside Pad Area

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4
 23,705 0.003 Life Stress Concentration Factor = 1.000
 psi 0.282 Stress Strain Concentration Factor = 1.000
 Cycles Allowed for this Stress = 2,016,155.
 Allowable "B31" Fatigue Stress Allowable = 85500.0
 83,994 Markl Fatigue Stress Allowable = 83402.0
 psi WRC 474 Mean Cycles to Failure = 2,077,143.
 WRC 474 99% Probability Cycles = 482,548.
 28% WRC 474 95% Probability Cycles = 669,967.
 BS5500 Allowed Cycles(Curve F) = 158,705.
 Membrane-to-Bending Ratio = 1.150
 Bending-to-PL+PB+Q Ratio = 0.465
 Plot Reference:
 18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Branch removed from Junction

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
15,933	0.000 Life	Stress Concentration Factor = 1.000
psi	0.190 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 5.4350E9
Allowable		"B31" Fatigue Stress Allowable = 85500.0
83,994		Markl Fatigue Stress Allowable = 83402.0
psi		WRC 474 Mean Cycles to Failure = 5,186,910.
		WRC 474 99% Probability Cycles = 1,204,989.
18%		WRC 474 95% Probability Cycles = 1,673,000.
		BS5500 Allowed Cycles(Curve F) = 522,710.
		Membrane-to-Bending Ratio = 6.835
		Bending-to-PL+PB+Q Ratio = 0.128
		Plot Reference:
		17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Highest Stress Ratios Per Region

FEPIPE Version 15.0	Jobname: NOZZLE	\$P
Released Jan. 2021	2:09pm JAN 16,2023	

Highest Stress Ratios Per Region

\$X

Pad/Header at Junction

Pl	SPL	Primary Membrane Load Case 2
18,011	31,000	Min Prin. Stress = -15927. (69% Neg, 5% NegHi)
psi	psi	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
58%		
Qb	SPS	Primary Bending Load Case 2
26,189	66,000	Min Prin. Stress = -15927. (69% Neg, 5% NegHi)
psi	psi	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2
39%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
33,360	66,000	Min Prin. Stress = -15927. (69% Neg, 5% NegHi)
psi	psi	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
50%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
30,847	66,000	Min Prin. Stress = -15927. (69% Neg, 5% NegHi)
psi	psi	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
46%		
S1+S2+S3	4S	Part 5 (5.3.2) Load Case 2
14,612	68,400	Min Prin. Stress = -15927. (69% Neg, 5% NegHi)
psi	psi	Plot Reference:
		5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
21%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3
10,165	66,000	Min Prin. Stress = -2489. (27% Neg, 0% NegHi)
psi	psi	Plot Reference:
		6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
15%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
7,637	66,000	Min Prin. Stress = -2489. (27% Neg, 0% NegHi)
psi	psi	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
11%		

Page 125 of 148

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Membrane 6,183 psi	User 66,000 psi	Component Evaluation Load Case 3 Min Prin. Stress = -2489. (27% Neg, 0% NegHi) Plot Reference: 8) Membrane < User (OPE,Membrane) Case 3
9%		
Bending 6,611 psi	User 66,000 psi	Component Evaluation Load Case 3 Min Prin. Stress = -2489. (27% Neg, 0% NegHi) Plot Reference: 9) Bending < User (OPE,Bending) Case 3
10%		
Pl+Pb+Q 20,403 psi	SPS 66,000 psi	Primary+Secondary (Inner) Load Case 4 Min Prin. Stress = -9380. (73% Neg, 0% NegHi) Plot Reference: 15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
30%		
Pl+Pb+Q 22,867 psi	SPS 66,000 psi	Primary+Secondary (Outer) Load Case 4 Min Prin. Stress = -9380. (73% Neg, 0% NegHi) Plot Reference: 16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
34%		
Pl+Pb+Q+F 27,545 psi	Damage Ratio 0.017 Life 0.328 Stress	Primary+Secondary+Peak (Inner) Load Case 4 Stress Concentration Factor = 1.350 Strain Concentration Factor = 1.000 Cycles Allowed for this Stress = 416,207. "B31" Fatigue Stress Allowable = 85500.0 Markl Fatigue Stress Allowable = 83402.0 WRC 474 Mean Cycles to Failure = 1,511,339. WRC 474 99% Probability Cycles = 351,105. WRC 474 95% Probability Cycles = 487,471. BS5500 Allowed Cycles(Curve F) = 248,901. Membrane-to-Bending Ratio = 0.401 Bending-to-PL+PB+Q Ratio = 0.714
Allowable 83,994 psi		
32%		
Plot Reference: 17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4		
Pl+Pb+Q+F 30,870 psi	Damage Ratio 0.028 Life 0.368 Stress	Primary+Secondary+Peak (Outer) Load Case 4 Stress Concentration Factor = 1.350 Strain Concentration Factor = 1.000 Cycles Allowed for this Stress = 247,334. "B31" Fatigue Stress Allowable = 85500.0 Markl Fatigue Stress Allowable = 83402.0 WRC 474 Mean Cycles to Failure = 1,122,861. WRC 474 99% Probability Cycles = 260,856. WRC 474 95% Probability Cycles = 362,170. BS5500 Allowed Cycles(Curve F) = 176,818. Membrane-to-Bending Ratio = 0.258 Bending-to-PL+PB+Q Ratio = 0.795 Plot Reference: 18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
Allowable 83,994 psi		
36%		

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Branch at Junction

P1 21,267 psi	SPL 31,000 psi	Primary Membrane Load Case 2 Min Prin. Stress = -47599. (90% Neg, 32% NegHi) Plot Reference: 1) P1 < SPL (SUS,Membrane) Case 2
68%		
Qb 49,336 psi	SPS 66,000 psi	Primary Bending Load Case 2 Min Prin. Stress = -47599. (90% Neg, 32% NegHi) Plot Reference: 2) Qb < SPS (SUS,Bending) Case 2
74%		
P1+Pb+Q 44,331 psi	SPS 66,000 psi	Primary+Secondary (Inner) Load Case 2 Min Prin. Stress = -47599. (90% Neg, 32% NegHi) Plot Reference: 3) P1+Pb+Q < SPS (SUS,Inside) Case 2
67%		
P1+Pb+Q 61,705 psi	SPS 66,000 psi	Primary+Secondary (Outer) Load Case 2 Min Prin. Stress = -47599. (90% Neg, 32% NegHi) Plot Reference: 4) P1+Pb+Q < SPS (SUS,Outside) Case 2
93%		
S1+S2+S3 -29,183 psi	4S 68,400 psi	Part 5 (5.3.2) Load Case 2 Min Prin. Stress = -47599. (90% Neg, 32% NegHi) Plot Reference: 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
42%		
P1+Pb+Q 8,712 psi	SPS 66,000 psi	Primary+Secondary (Inner) Load Case 3 Min Prin. Stress = -8319. (48% Neg, 6% NegHi) Plot Reference: 6) P1+Pb+Q < SPS (OPE,Inside) Case 3
13%		
P1+Pb+Q 13,318 psi	SPS 66,000 psi	Primary+Secondary (Outer) Load Case 3 Min Prin. Stress = -8319. (48% Neg, 6% NegHi) Plot Reference: 7) P1+Pb+Q < SPS (OPE,Outside) Case 3
20%		
Membrane 5,204 psi	User 66,000 psi	Component Evaluation Load Case 3 Min Prin. Stress = -8319. (48% Neg, 6% NegHi) Plot Reference: 8) Membrane < User (OPE,Membrane) Case 3
7%		
Bending 10,993 psi	User 66,000 psi	Component Evaluation Load Case 3 Min Prin. Stress = -8319. (48% Neg, 6% NegHi) Plot Reference: 9) Bending < User (OPE,Bending) Case 3
16%		
P1+Pb+Q 32,028 psi	SPS 66,000 psi	Primary+Secondary (Inner) Load Case 4 Min Prin. Stress = -31075. (89% Neg, 36% NegHi) Plot Reference: 15) P1+Pb+Q < SPS (EXP,Inside) Case 4
48%		

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4
44,272 66,000 Min Prin. Stress = -31075. (89% Neg, 36% NegHi)
psi psi Plot Reference:
16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
67%

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4
43,238 0.114 Life Stress Concentration Factor = 1.350
psi 0.515 Stress Strain Concentration Factor = 1.000
Cycles Allowed for this Stress = 61,490.
Allowable "B31" Fatigue Stress Allowable = 85500.0
83,994 Markl Fatigue Stress Allowable = 83402.0
psi WRC 474 Mean Cycles to Failure = 871,913.
WRC 474 99% Probability Cycles = 202,557.
51% WRC 474 95% Probability Cycles = 281,229.
BS5500 Allowed Cycles(Curve F) = 64,346.
Membrane-to-Bending Ratio = 0.340
Bending-to-PL+PB+Q Ratio = 0.747
Plot Reference:
17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4
59,768 0.333 Life Stress Concentration Factor = 1.350
psi 0.712 Stress Strain Concentration Factor = 1.000
Cycles Allowed for this Stress = 21,037.
Allowable "B31" Fatigue Stress Allowable = 85500.0
83,994 Markl Fatigue Stress Allowable = 83402.0
psi WRC 474 Mean Cycles to Failure = 247,918.
WRC 474 99% Probability Cycles = 57,595.
71% WRC 474 95% Probability Cycles = 79,964.
BS5500 Allowed Cycles(Curve F) = 24,363.
Membrane-to-Bending Ratio = 0.340
Bending-to-PL+PB+Q Ratio = 0.747
Plot Reference:
18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Branch Transition

Pl SPL Primary Membrane Load Case 2
17,470 31,000 Min Prin. Stress = -15064. (86% Neg, 16% NegHi)
psi psi Plot Reference:
1) Pl < SPL (SUS,Membrane) Case 2
56%

Qb SPS Primary Bending Load Case 2
10,391 66,000 Min Prin. Stress = -15064. (86% Neg, 16% NegHi)
psi psi Plot Reference:
2) Qb < SPS (SUS,Bending) Case 2
15%

Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2
17,927 66,000 Min Prin. Stress = -15064. (86% Neg, 16% NegHi)
psi psi Plot Reference:
3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
27%

Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2
20,208 66,000 Min Prin. Stress = -15064. (86% Neg, 16% NegHi)
psi psi Plot Reference:
4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
30%

S1+S2+S3 4S Part 5 (5.3.2) Load Case 2
15,911 68,400 Min Prin. Stress = -15064. (86% Neg, 16% NegHi)
psi psi Plot Reference:
5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
23%

Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3
5,217 66,000 Min Prin. Stress = -1518. (37% Neg, 2% NegHi)
psi psi Plot Reference:
6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
7%

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Pl+Pb+Q 4,321 psi	SPS 66,000 psi	Primary+Secondary (Outer) Load Case 3 Min Prin. Stress = -1518. (37% Neg, 2% NegHi) Plot Reference: 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
6%		
Membrane 4,203 psi	User 66,000 psi	Component Evaluation Load Case 3 Min Prin. Stress = -1518. (37% Neg, 2% NegHi) Plot Reference: 8) Membrane < User (OPE,Membrane) Case 3
6%		
Bending 4,315 psi	User 66,000 psi	Component Evaluation Load Case 3 Min Prin. Stress = -1518. (37% Neg, 2% NegHi) Plot Reference: 9) Bending < User (OPE,Bending) Case 3
6%		
Pl+Pb+Q 14,741 psi	SPS 66,000 psi	Primary+Secondary (Inner) Load Case 4 Min Prin. Stress = -13341. (99% Neg, 17% NegHi) Plot Reference: 15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
22%		
Pl+Pb+Q 17,003 psi	SPS 66,000 psi	Primary+Secondary (Outer) Load Case 4 Min Prin. Stress = -13341. (99% Neg, 17% NegHi) Plot Reference: 16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
25%		
Pl+Pb+Q+F 14,741 psi	Damage Ratio 0.000 Life 0.176 Stress	Primary+Secondary+Peak (Inner) Load Case 4 Stress Concentration Factor = 1.000 Strain Concentration Factor = 1.000 Cycles Allowed for this Stress = 2.5500E10 "B31" Fatigue Stress Allowable = 85500.0 Markl Fatigue Stress Allowable = 83402.0 WRC 474 Mean Cycles to Failure = 6,584,434. WRC 474 99% Probability Cycles = 1,529,653. WRC 474 95% Probability Cycles = 2,123,760. BS5500 Allowed Cycles(Curve F) = 660,009. Membrane-to-Bending Ratio = 20.668 Bending-to-PL+PB+Q Ratio = 0.046 Plot Reference: 17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
Allowable 83,994 psi		
17%		
Pl+Pb+Q+F 17,003 psi	Damage Ratio 0.000 Life 0.202 Stress	Primary+Secondary+Peak (Outer) Load Case 4 Stress Concentration Factor = 1.000 Strain Concentration Factor = 1.000 Cycles Allowed for this Stress = 1.3578E9 "B31" Fatigue Stress Allowable = 85500.0 Markl Fatigue Stress Allowable = 83402.0 WRC 474 Mean Cycles to Failure = 4,436,346. WRC 474 99% Probability Cycles = 1,030,623. WRC 474 95% Probability Cycles = 1,430,911. BS5500 Allowed Cycles(Curve F) = 430,121. Membrane-to-Bending Ratio = 1.094 Bending-to-PL+PB+Q Ratio = 0.478 Plot Reference: 18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
Allowable 83,994 psi		
20%		
Pad Outer Edge Weld		
Pl 18,565 psi	SPL 31,000 psi	Primary Membrane Load Case 2 Min Prin. Stress = -8469. (40% Neg, 0% NegHi) Plot Reference: 1) Pl < SPL (SUS,Membrane) Case 2
59%		
Qb 45,891 psi	SPS 66,000 psi	Primary Bending Load Case 2 Min Prin. Stress = -8469. (40% Neg, 0% NegHi) Plot Reference: 2) Qb < SPS (SUS,Bending) Case 2
69%		

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Pl+Pb+Q 36,135 psi	SPS 66,000 psi	Primary+Secondary (Inner) Load Case 2 Min Prin. Stress = -8469. (40% Neg, 0% NegHi) Plot Reference: 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
54%		
Pl+Pb+Q 60,242 psi	SPS 66,000 psi	Primary+Secondary (Outer) Load Case 2 Min Prin. Stress = -8469. (40% Neg, 0% NegHi) Plot Reference: 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
91%		
S1+S2+S3 28,403 psi	4S 68,400 psi	Part 5 (5.3.2) Load Case 2 Min Prin. Stress = -8469. (40% Neg, 0% NegHi) Plot Reference: 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
41%		
Pl+Pb+Q 11,532 psi	SPS 66,000 psi	Primary+Secondary (Inner) Load Case 3 Min Prin. Stress = -1539. (23% Neg, 0% NegHi) Plot Reference: 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
17%		
Pl+Pb+Q 22,637 psi	SPS 66,000 psi	Primary+Secondary (Outer) Load Case 3 Min Prin. Stress = -1539. (23% Neg, 0% NegHi) Plot Reference: 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
34%		
Membrane 10,196 psi	User 66,000 psi	Component Evaluation Load Case 3 Min Prin. Stress = -1539. (23% Neg, 0% NegHi) Plot Reference: 8) Membrane < User (OPE,Membrane) Case 3
15%		
Bending 12,707 psi	User 66,000 psi	Component Evaluation Load Case 3 Min Prin. Stress = -1539. (23% Neg, 0% NegHi) Plot Reference: 9) Bending < User (OPE,Bending) Case 3
19%		
Pl+Pb+Q 38,254 psi	SPS 66,000 psi	Primary+Secondary (Inner) Load Case 4 Min Prin. Stress = -5978. (51% Neg, 0% NegHi) Plot Reference: 15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
57%		
Pl+Pb+Q 60,806 psi	SPS 66,000 psi	Primary+Secondary (Outer) Load Case 4 Min Prin. Stress = -5978. (51% Neg, 0% NegHi) Plot Reference: 16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
92%		
Pl+Pb+Q+F 51,643 psi	Damage Ratio 0.212 Life 0.615 Stress	Primary+Secondary+Peak (Inner) Load Case 4 Stress Concentration Factor = 1.350 Strain Concentration Factor = 1.000 Cycles Allowed for this Stress = 32,943. "B31" Fatigue Stress Allowable = 85500.0 MarkI Fatigue Stress Allowable = 83402.0 WRC 474 Mean Cycles to Failure = 801,932. WRC 474 99% Probability Cycles = 186,300. WRC 474 95% Probability Cycles = 258,657. BS5500 Allowed Cycles(Curve F) = 37,765. Membrane-to-Bending Ratio = 0.283 Bending-to-PL+PB+Q Ratio = 0.779 Plot Reference: 17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
Allowable 83,994 psi		
61%		

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4
82,089 0.934 Life Stress Concentration Factor = 1.350
psi 0.977 Stress Strain Concentration Factor = 1.000
Cycles Allowed for this Stress = 7,493.
Allowable "B31" Fatigue Stress Allowable = 85500.0
83,994 Markl Fatigue Stress Allowable = 83402.0
psi WRC 474 Mean Cycles to Failure = 121,214.
WRC 474 99% Probability Cycles = 28,160.
WRC 474 95% Probability Cycles = 39,097.
BS5500 Allowed Cycles (Curve F) = 9,403.
Membrane-to-Bending Ratio = 0.283
Bending-to-PL+PB+Q Ratio = 0.779
Plot Reference:
18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Header Outside Pad Area

Pl	SPL	Primary Membrane Load Case 2
15,644	31,000	Min Prin. Stress = -3881. (61% Neg, 0% NegHi)
psi	psi	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
50%		
Qb	SPS	Primary Bending Load Case 2
13,737	66,000	Min Prin. Stress = -3881. (61% Neg, 0% NegHi)
psi	psi	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2
20%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
24,414	66,000	Min Prin. Stress = -3881. (61% Neg, 0% NegHi)
psi	psi	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
36%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
27,664	66,000	Min Prin. Stress = -3881. (61% Neg, 0% NegHi)
psi	psi	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
41%		
S1+S2+S3	4S	Part 5 (5.3.2) Load Case 2
28,093	68,400	Min Prin. Stress = -3881. (61% Neg, 0% NegHi)
psi	psi	Plot Reference:
		5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
41%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3
12,465	66,000	Min Prin. Stress = -877. (55% Neg, 0% NegHi)
psi	psi	Plot Reference:
		6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
18%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
14,663	66,000	Min Prin. Stress = -877. (55% Neg, 0% NegHi)
psi	psi	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
22%		
Membrane	User	Component Evaluation Load Case 3
11,325	66,000	Min Prin. Stress = -877. (55% Neg, 0% NegHi)
psi	psi	Plot Reference:
		8) Membrane < User (OPE,Membrane) Case 3
17%		

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Bending
4,529
psi
6%

User
66,000
psi

Component Evaluation Load Case 3
Min Prin. Stress = -877. (55% Neg, 0% NegHi)
Plot Reference:
9) Bending < User (OPE,Bending) Case 3

Pl+Pb+Q
21,554
psi
32%

SPS
66,000
psi

Primary+Secondary (Inner) Load Case 4
Min Prin. Stress = -2380. (68% Neg, 0% NegHi)
Plot Reference:
15) Pl+Pb+Q < SPS (EXP,Inside) Case 4

Pl+Pb+Q
23,705
psi
35%

SPS
66,000
psi

Primary+Secondary (Outer) Load Case 4
Min Prin. Stress = -2380. (68% Neg, 0% NegHi)
Plot Reference:
16) Pl+Pb+Q < SPS (EXP,Outside) Case 4

Pl+Pb+Q+F
21,554
psi
25%

Damage Ratio
0.001 Life
0.257 Stress

Primary+Secondary+Peak (Inner) Load Case 4
Stress Concentration Factor = 1.000
Strain Concentration Factor = 1.000
Cycles Allowed for this Stress = 11,922,788.
"B31" Fatigue Stress Allowable = 85500.0
Mark1 Fatigue Stress Allowable = 83402.0
WRC 474 Mean Cycles to Failure = 2,801,508.
WRC 474 99% Probability Cycles = 650,828.
WRC 474 95% Probability Cycles = 903,606.
BS5500 Allowed Cycles(Curve F) = 211,119.
Membrane-to-Bending Ratio = 1.104
Bending-to-PL+PB+Q Ratio = 0.475
Plot Reference:
17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F
23,705
psi
28%

Damage Ratio
0.003 Life
0.282 Stress

Primary+Secondary+Peak (Outer) Load Case 4
Stress Concentration Factor = 1.000
Strain Concentration Factor = 1.000
Cycles Allowed for this Stress = 2,016,155.
"B31" Fatigue Stress Allowable = 85500.0
Mark1 Fatigue Stress Allowable = 83402.0
WRC 474 Mean Cycles to Failure = 2,077,143.
WRC 474 99% Probability Cycles = 482,548.
WRC 474 95% Probability Cycles = 669,967.
BS5500 Allowed Cycles(Curve F) = 158,705.
Membrane-to-Bending Ratio = 1.150
Bending-to-PL+PB+Q Ratio = 0.465
Plot Reference:
18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Branch removed from Junction

Pl
17,867
psi
57%

SPL
31,000
psi

Primary Membrane Load Case 2
Min Prin. Stress = -15400. (93% Neg, 42% NegHi)
Plot Reference:
1) Pl < SPL (SUS,Membrane) Case 2

Qb
3,172
psi
4%

SPS
66,000
psi

Primary Bending Load Case 2
Min Prin. Stress = -15400. (93% Neg, 42% NegHi)
Plot Reference:
2) Qb < SPS (SUS,Bending) Case 2

Pl+Pb+Q
19,097
psi
28%

SPS
66,000
psi

Primary+Secondary (Inner) Load Case 2
Min Prin. Stress = -15400. (93% Neg, 42% NegHi)
Plot Reference:
3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

Page 132 of 148

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Pl+Pb+Q 17,095 psi	SPS 66,000 psi	Primary+Secondary (Outer) Load Case 2 Min Prin. Stress = -15400. (93% Neg, 42% NegHi) Plot Reference: 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
25%		
S1+S2+S3 16,798 psi	4S 68,400 psi	Part 5 (5.3.2) Load Case 2 Min Prin. Stress = -15400. (93% Neg, 42% NegHi) Plot Reference: 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
24%		
Pl+Pb+Q 4,605 psi	SPS 66,000 psi	Primary+Secondary (Inner) Load Case 3 Min Prin. Stress = -1656. (52% Neg, 20% NegHi) Plot Reference: 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
6%		
Pl+Pb+Q 4,430 psi	SPS 66,000 psi	Primary+Secondary (Outer) Load Case 3 Min Prin. Stress = -1656. (52% Neg, 20% NegHi) Plot Reference: 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
6%		
Membrane 4,339 psi	User 66,000 psi	Component Evaluation Load Case 3 Min Prin. Stress = -1656. (52% Neg, 20% NegHi) Plot Reference: 8) Membrane < User (OPE,Membrane) Case 3
6%		
Bending 645 psi	User 66,000 psi	Component Evaluation Load Case 3 Min Prin. Stress = -1656. (52% Neg, 20% NegHi) Plot Reference: 9) Bending < User (OPE,Bending) Case 3
0%		
Pl+Pb+Q 15,933 psi	SPS 66,000 psi	Primary+Secondary (Inner) Load Case 4 Min Prin. Stress = -9148. (98% Neg, 55% NegHi) Plot Reference: 15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
24%		
Pl+Pb+Q 13,503 psi	SPS 66,000 psi	Primary+Secondary (Outer) Load Case 4 Min Prin. Stress = -9148. (98% Neg, 55% NegHi) Plot Reference: 16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
20%		
Pl+Pb+Q+F 15,933 psi	Damage Ratio 0.000 Life 0.190 Stress	Primary+Secondary+Peak (Inner) Load Case 4 Stress Concentration Factor = 1.000 Strain Concentration Factor = 1.000
Allowable 83,994 psi		Cycles Allowed for this Stress = 5.4350E9 "B31" Fatigue Stress Allowable = 85500.0 Markl Fatigue Stress Allowable = 83402.0 WRC 474 Mean Cycles to Failure = 5,186,910. WRC 474 99% Probability Cycles = 1,204,989. WRC 474 95% Probability Cycles = 1,673,000. BS5500 Allowed Cycles(Curve F) = 522,710. Membrane-to-Bending Ratio = 6.835 Bending-to-PL+PB+Q Ratio = 0.128 Plot Reference: 17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
18%		

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4
 13,503 0.000 Life Stress Concentration Factor = 1.000
 psi 0.161 Stress Strain Concentration Factor = 1.000
 Cycles Allowed for this Stress = 1.0000E11
 Allowable "B31" Fatigue Stress Allowable = 85500.0
 83,994 Markl Fatigue Stress Allowable = 83402.0
 psi WRC 474 Mean Cycles to Failure = 8,688,525.
 WRC 474 99% Probability Cycles = 2,018,462.
 16% WRC 474 95% Probability Cycles = 2,802,420.
 BS5500 Allowed Cycles(Curve F) = 858,654.
 Membrane-to-Bending Ratio = 9.496
 Bending-to-PL+PB+Q Ratio = 0.095
 Plot Reference:
 18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Stress Intensification Factors
 FEPipe Version 15.0 Jobname: NOZZLE \$P
 Released Jan. 2021 2:09pm JAN 16,2023

Stress Intensification Factors \$X

Branch/Nozzle Sif Summary

	Peak	Primary	Secondary	SSI
Axial :	10.643	7.884	15.768	2.604
Inplane :	1.985	1.471	2.941	1.899
Outplane:	4.963	3.677	7.353	2.185
Torsion :	0.764	0.981	1.132	1.322
Pressure:	1.361	1.009	2.017	1.623

The above stress intensification factors are to be used in a beam-type analysis of the piping system. Inplane, Outplane and Torsional sif's should be used with the matching branch pipe whose diameter and thickness is given below. The axial sif should be used to intensify the axial stress in the branch pipe calculated by F/A. The pressure sif should be used to intensify the nominal pressure stress in the PARENT or HEADER, calculated from $PD_o/2t$. B31 calculations use mean diameters and Section VIII calculations use outside diameters. SSIs are based on peak stress factors and correlated test results.

Pipe OD : 6.625 in.
 Pipe Thk: 0.307 in.
 Z approx: 9.625 cu.in.
 Z exact : 9.200 cu.in.

(SSI = SIF^x)	Axial	Inpl	Outpl	Tors	Pres
SIF/SSI Exponents:	0.873	0.562	0.813	0.070	0.028

SIF/SSI exponent based on relationship between primary and peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor = 10.421
 Header Pressure i-factor = 2.757

The B31.3 pressure i-factors should be used with with F/A, where F is the axial force due to pressure, and A is the area of the pipe wall. This is equivalent to finding the pressure stress from (ip) (PD/4t).

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

B31.3 (Branch)
Peak Stress Sif 0.000 Axial
4.987 Inplane
6.146 Outplane
1.000 Torsional

B31.1 (Branch)
Peak Stress Sif 0.000 Axial
6.146 Inplane
6.146 Outplane
6.146 Torsional

WRC 330 (Branch)
Peak Stress Sif 0.000 Axial
4.066 Inplane
6.146 Outplane
4.066 Torsional

Allowable Loads
FEPipe Version 15.0 Jobname: NOZZLE \$P
Released Jan. 2021 2:09pm JAN 16, 2023

Allowable Loads \$X

SECONDARY Load Type (Range):	Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force (lb.)	24044.	5442.	8163.
Inplane Moment (in. lb.)	194626.	32953.	69904.
Outplane Moment (in. lb.)	77847.	9564.	20289.
Torsional Moment (in. lb.)	505484.	116510.	174765.
Pressure (psi)	783.31	375.00	375.00

PRIMARY Load Type:	Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force (lb.)	23960.	5406.	8108.
Inplane Moment (in. lb.)	193945.	32793.	69564.
Outplane Moment (in. lb.)	77575.	9500.	20153.
Torsional Moment (in. lb.)	290612.	69491.	104236.
Pressure (psi)	780.16	375.00	375.00

NOTES:

- 1) Maximum Individual Occuring Loads are the maximum allowed values of the respective loads if all other load components are zero, i.e. the listed axial force may be applied if the inplane, outplane and torsional moments, and the pressure are zero.
- 2) The Conservative Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A conservative stress combination equation is used that typically produces stresses within 50-70% of the allowable stress.
- 3) The Realistic Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A more realistic stress combination equation is used based on experience at Paulin Research. Stresses are typically produced within 80-105% of the allowable.
- 4) Secondary allowable loads are limits for expansion and operating piping loads.
- 5) Primary allowable loads are limits for weight, primary and sustained type piping loads.
- 6) High D/T low pressure systems may be subject to instability and should be checked when compressive stresses are present.

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Compressive Stress Summary (psi)

\$X

Nomenclature:

 Min Stress - Compressive Membrane and Bending Stress
 Pts in Region - No. of nodes in the model region
 >5% Compression - 5% or more of Compressive Stress Limit
 >50% Compression - 50% or more of Compressive Stress Limit

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section
 slenderness ratio (elastic buckling) not considered.

#	Load Type	Case	Min Stress	Pts in Region	>5% Compression and Bending	>50% Compression and Bending	Region
1	SUSTAINED	2	-15927.	1032	69%	5%	Pad/Header at Junction
2	OPERATING	3	-2489.	1032	27%	0%	Pad/Header at Junction
3	EXPANSION	4	-9380.	1032	73%	0%	Pad/Header at Junction
4	SUSTAINED	2	-8469.	624	40%	0%	Pad Outer Edge Weld
5	OPERATING	3	-1539.	624	23%	0%	Pad Outer Edge Weld
6	EXPANSION	4	-5978.	624	51%	0%	Pad Outer Edge Weld
7	SUSTAINED	2	-3881.	648	61%	0%	Header Outside Pad Area
8	OPERATING	3	-877.	648	55%	0%	Header Outside Pad Area
9	EXPANSION	4	-2380.	648	68%	0%	Header Outside Pad Area
10	SUSTAINED	2	-47599.	840	90%	32%	Branch at Junction
11	OPERATING	3	-8319.	840	48%	6%	Branch at Junction
12	EXPANSION	4	-31075.	840	89%	36%	Branch at Junction
13	SUSTAINED	2	-15400.	192	93%	42%	Branch removed from Junction
14	OPERATING	3	-1656.	192	52%	20%	Branch removed from Junction
15	EXPANSION	4	-9148.	192	98%	55%	Branch removed from Junction
16	SUSTAINED	2	-15064.	1080	86%	16%	Branch Transition
17	OPERATING	3	-1518.	1080	37%	2%	Branch Transition
18	EXPANSION	4	-13341.	1080	99%	17%	Branch Transition

[Table of Contents](#)

Flexibilities

\$X

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

Outside Diameter = 6.625 in.
 Wall Thickness = 0.307 in.

Axial Translational Stiffness = 518771. lb./in.
 Inplane Rotational Stiffness = 702618. in.lb./deg
 Outplane Rotational Stiffness = 141184. in.lb./deg
 Torsional Rotational Stiffness = 4465528. in.lb./deg

Estimated Radial Shell Displacement due to Allowable Loads

SECONDARY:

Axial (in.) = 0.046 In-Plane (in.) = 0.015 Out-Plane (in.) = 0.030

Revisions to this Page

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

PRIMARY

Axial (in.) = 0.046 In-Plane (in.) = 0.015 Out-Plane (in.) = 0.030

Secondary Conservative Displacement = 0.017 in.

Secondary Realistic Displacement = 0.029 in.

Primary Conservative Displacement = 0.017 in.

Primary Realistic Displacement = 0.029 in.

Intersection Flexibility Factors for Branch/Nozzle

Find axial stiffness: $K = 3EI/(kd)^3$ lb./in.

Find bending and torsional stiffnesses: $K = EI/(kd)$ in.lb.per radian.

The EI product is 0.89600E+09 lb.in.^2

The value of (d) to use is: 6.318 in..

The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor (k) = 2.739

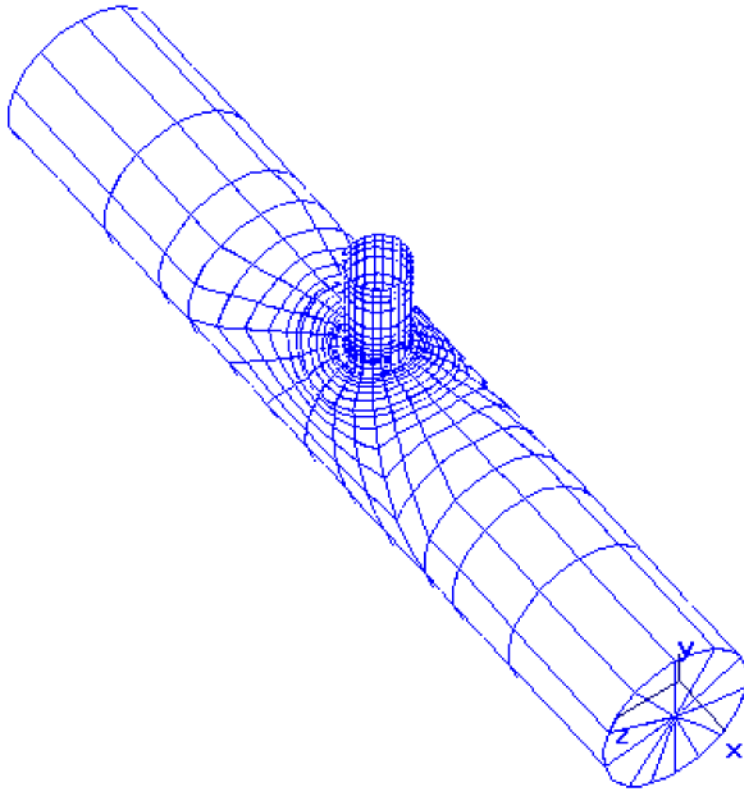
Inplane Flexibility Factor (k) = 3.523

Outplane Flexibility Factor (k) = 17.532

Torsional Flexibility Factor (k) = 0.554

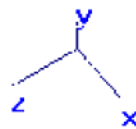
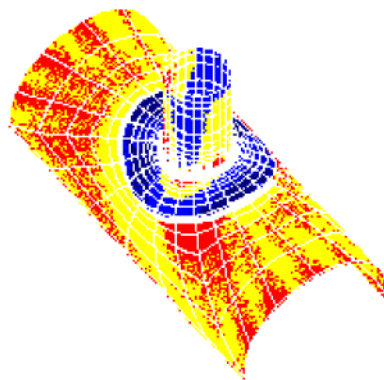
Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Finite Element Model



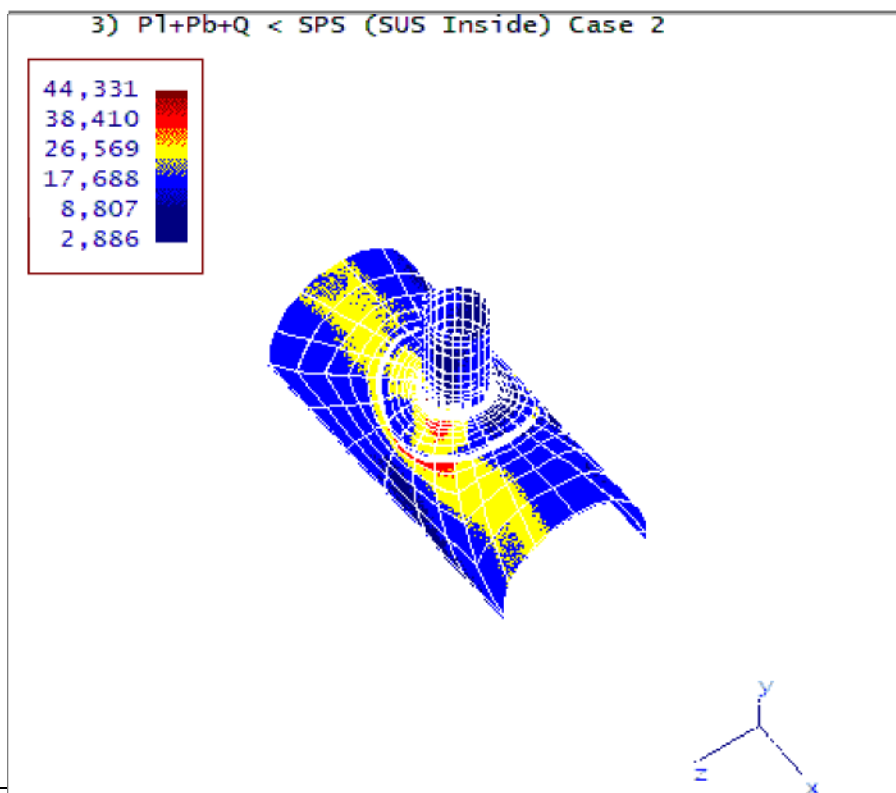
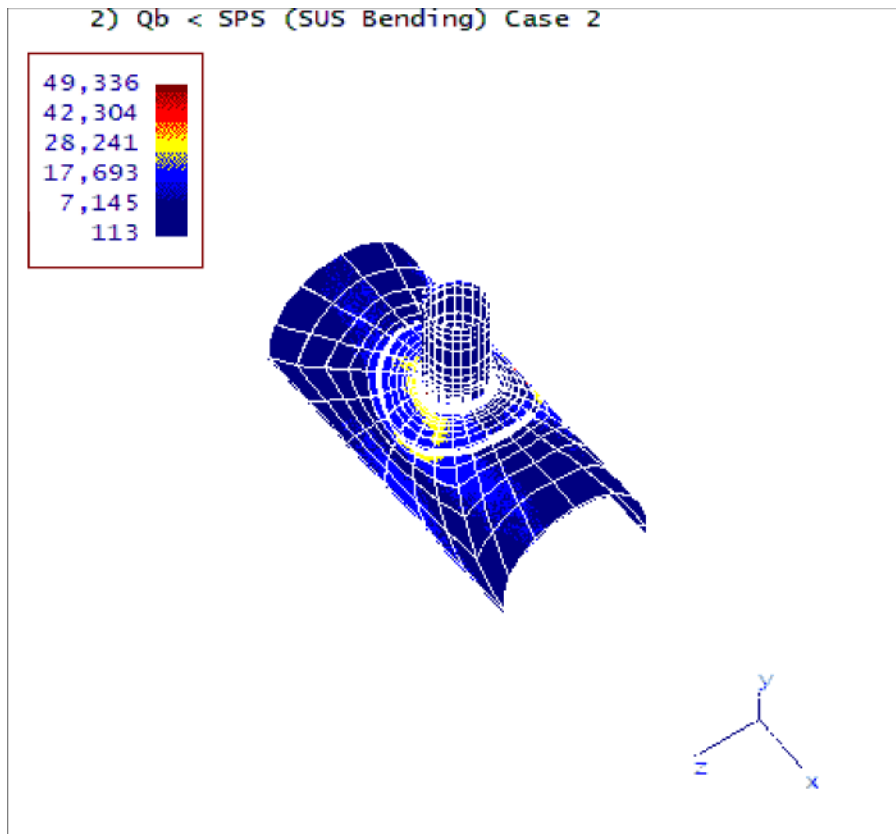
1) P1 < SPL (SUS Membrane) Case 2

21,267
18,627
13,349
9,390
5,431
2,792

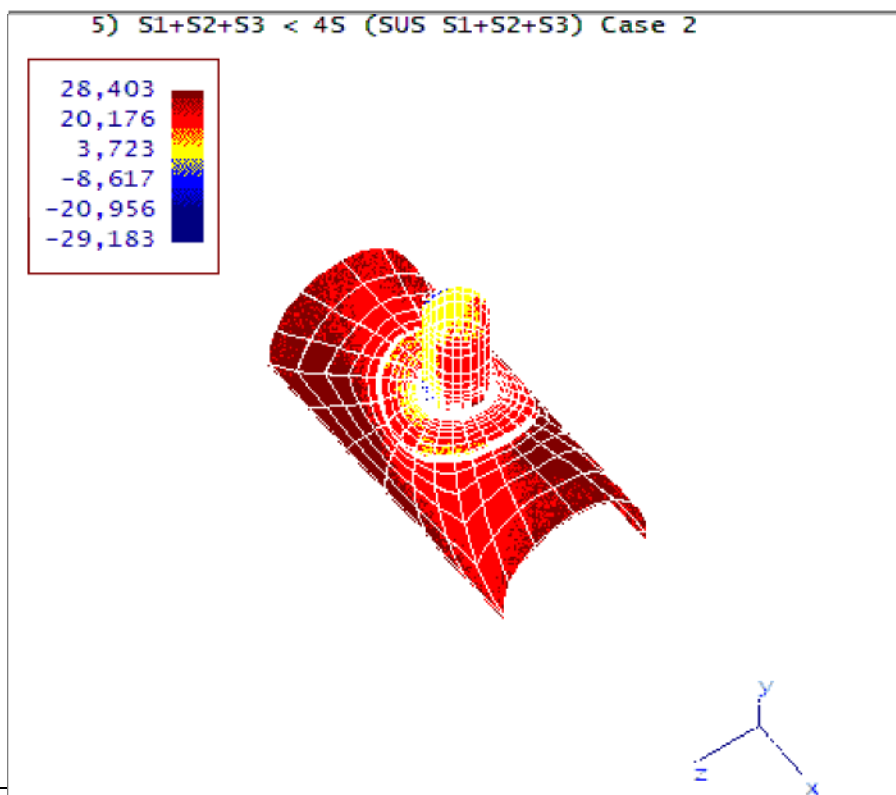
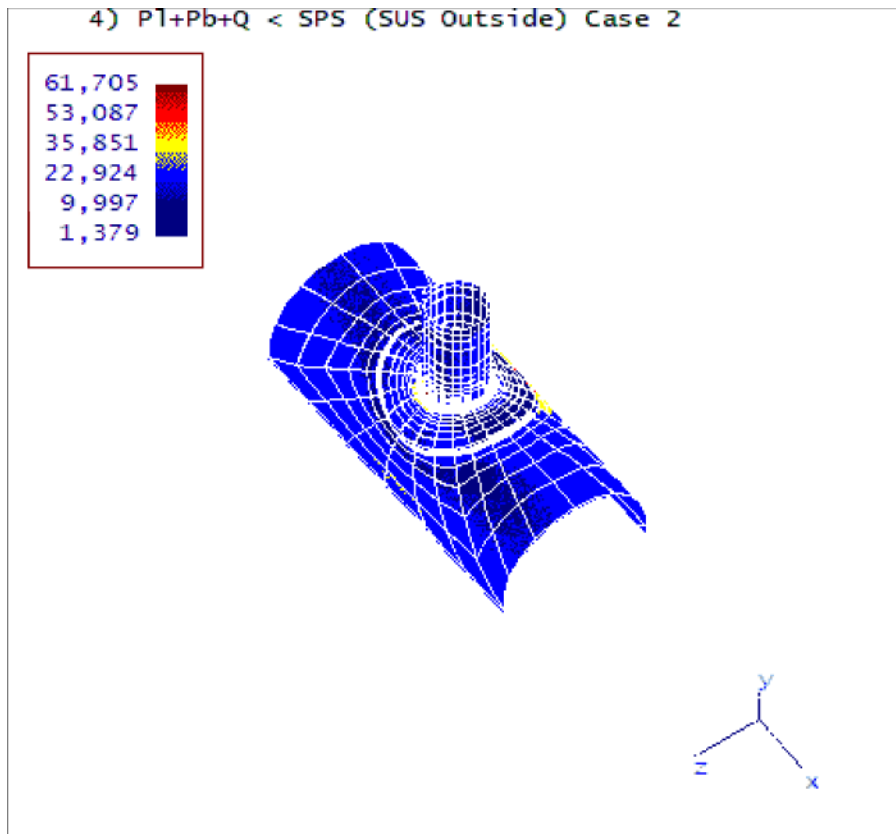


Page 138 of 148

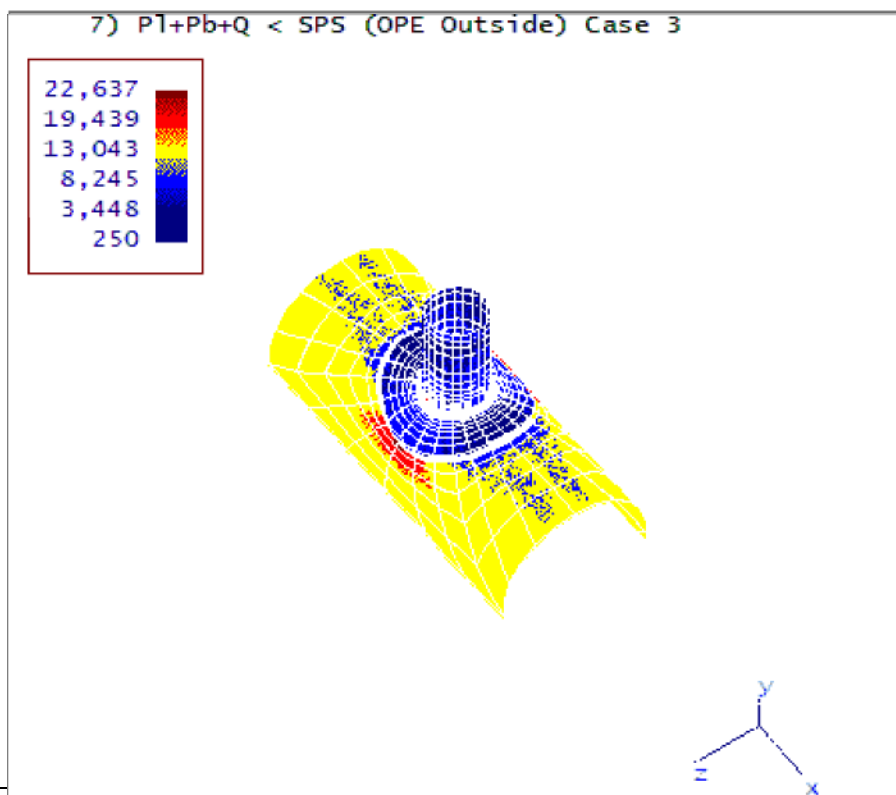
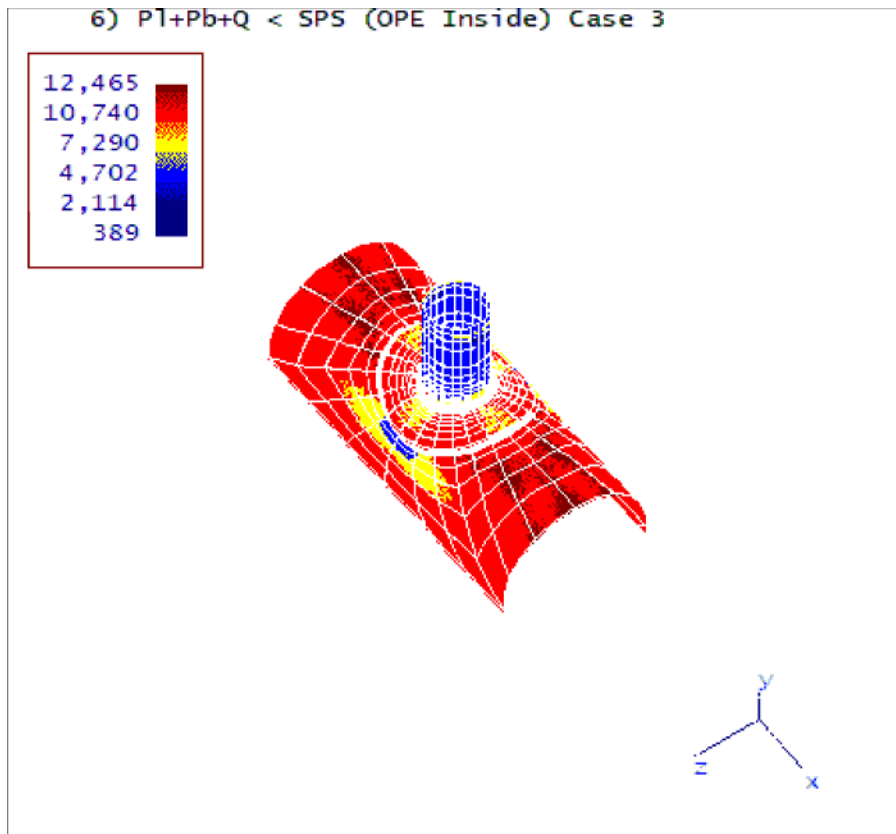
Rev.	Detail	Rev.	Date
1	Rev./Cust. Comments	EG	5/13/22
2	Rev./Cust. Comments	EG	7/15/22
3	Rev./Cust. Comments	EG	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23



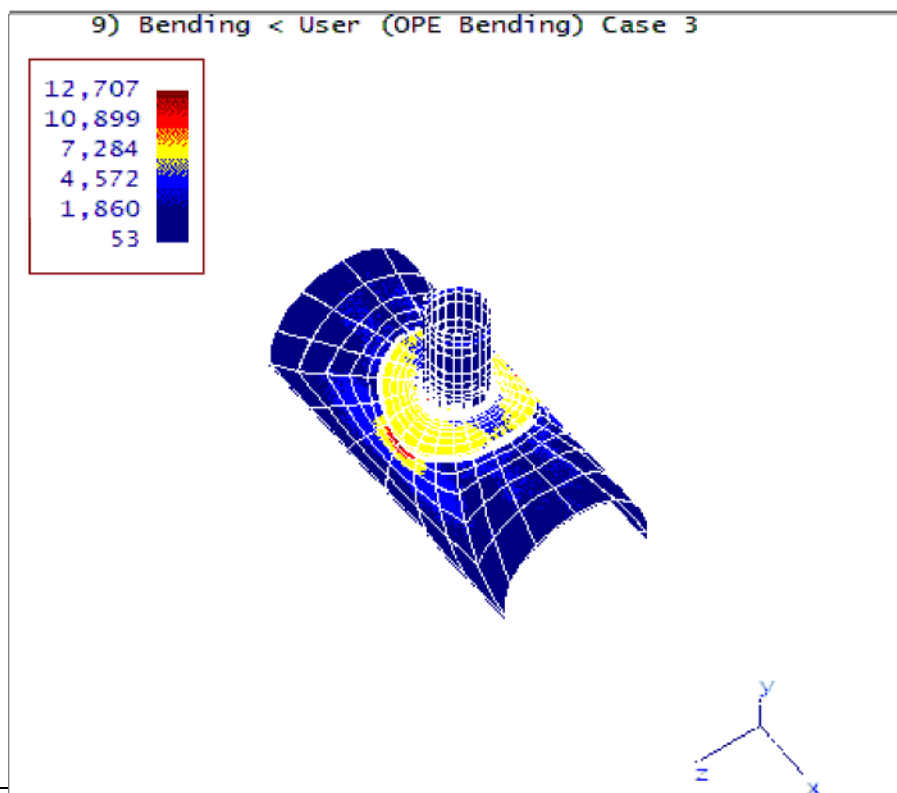
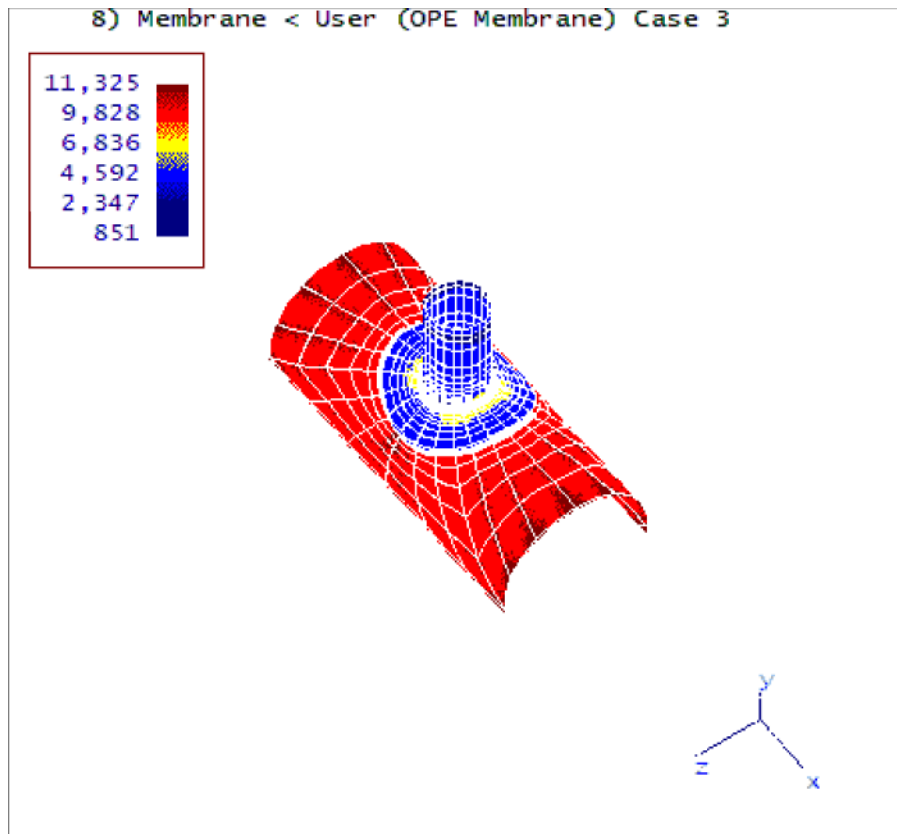
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23



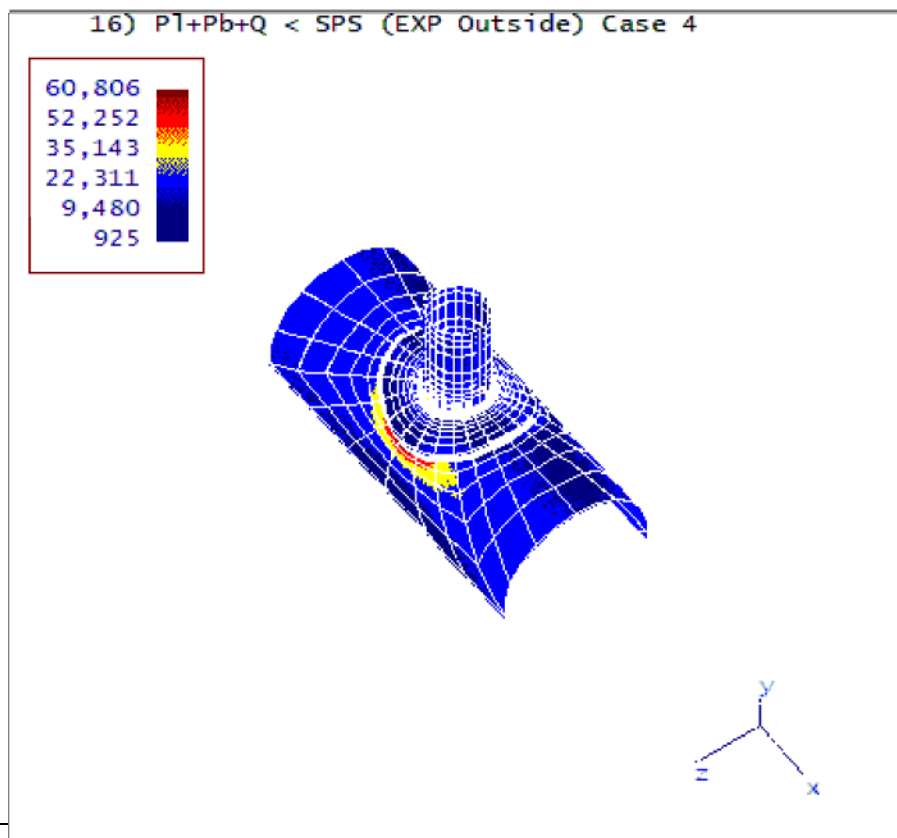
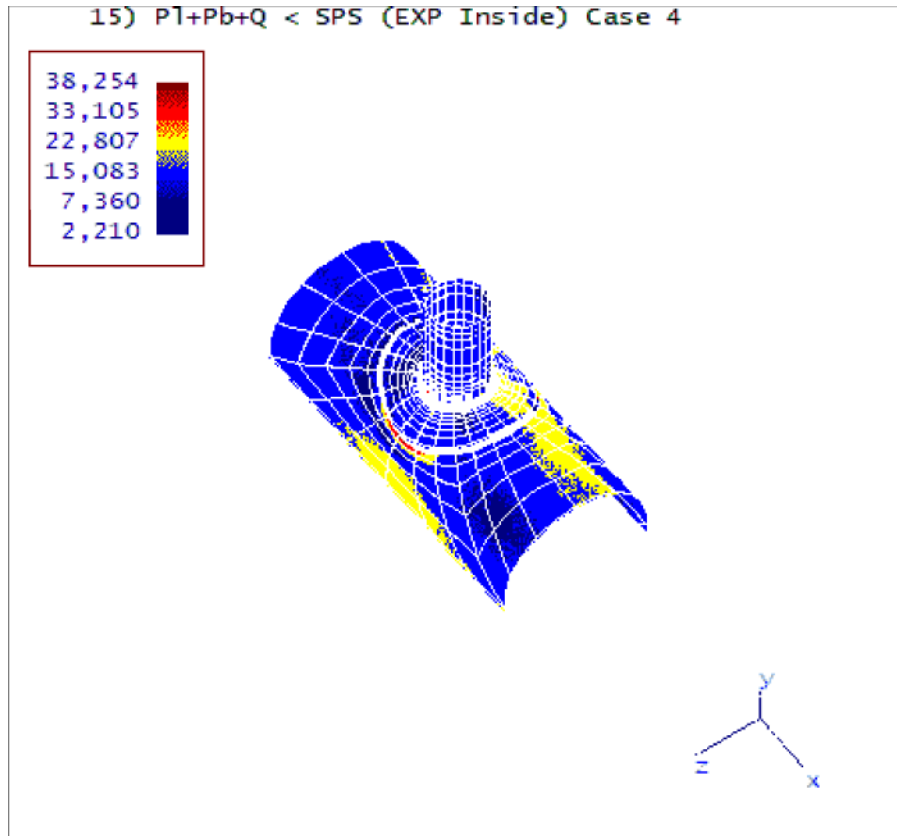
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23



Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23



Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23



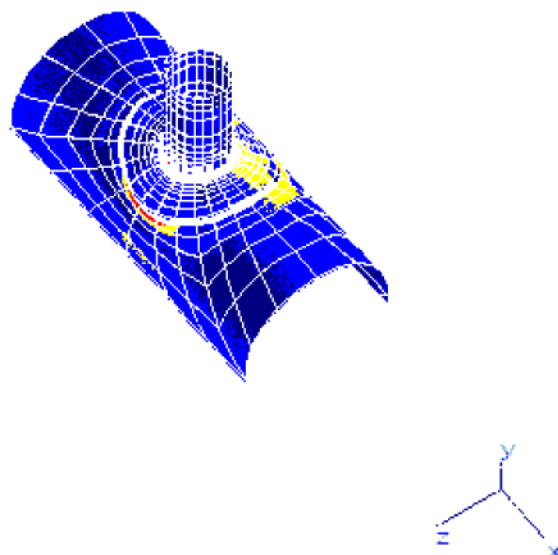
Page 143 of 148

REVISIONS TO THIS PAGE

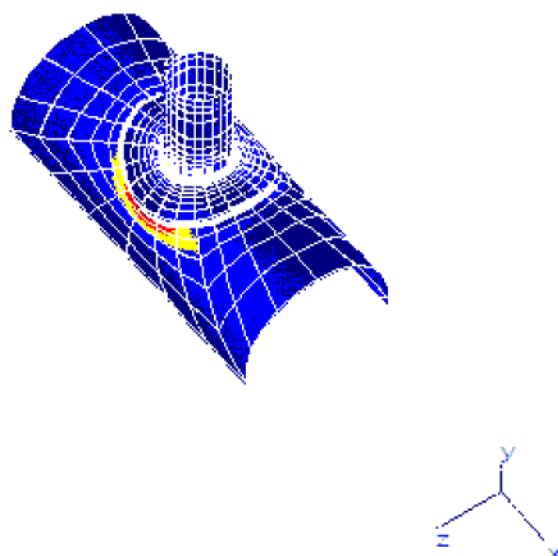
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

17) $P1+Pb+Q+F < 2Sa$ (EXP Inside) Case 4

51,643
44,689
30,781
20,350
9,919
2,965


18) $P1+Pb+Q+F < 2Sa$ (EXP Outside) Case 4

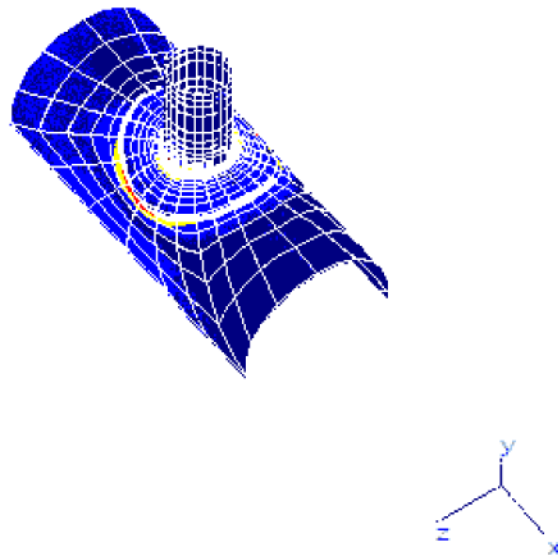
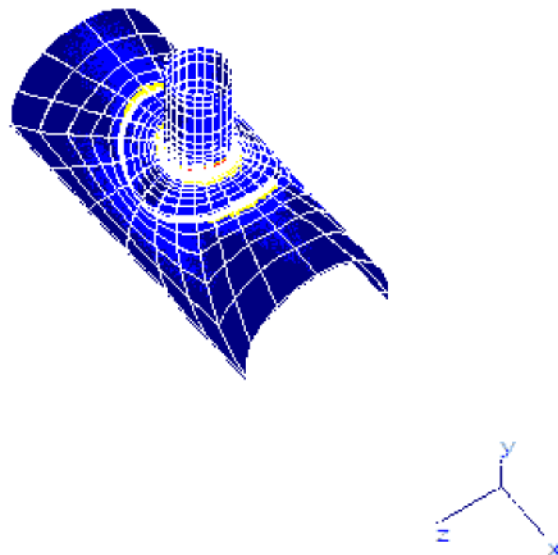
82,089
70,540
47,443
30,120
12,797
1,249

Page 144 of 148

REVISIONS TO THIS PAGE

Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

10) $P1+Pb+Q+F < 2Sa$ (SIF Outside) Case 511) $P1+Pb+Q+F < 2Sa$ (SIF Outside) Case 6

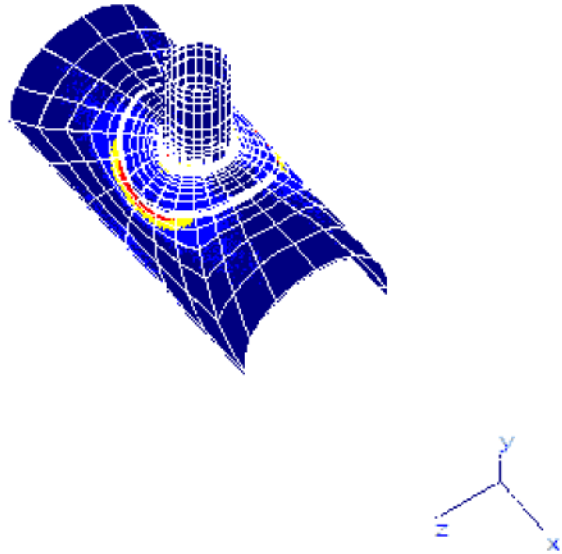
Page 145 of 148

REVISIONS TO THIS PAGE

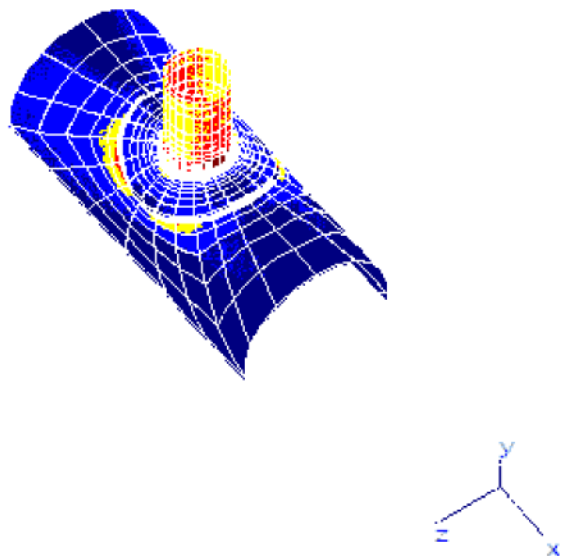
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

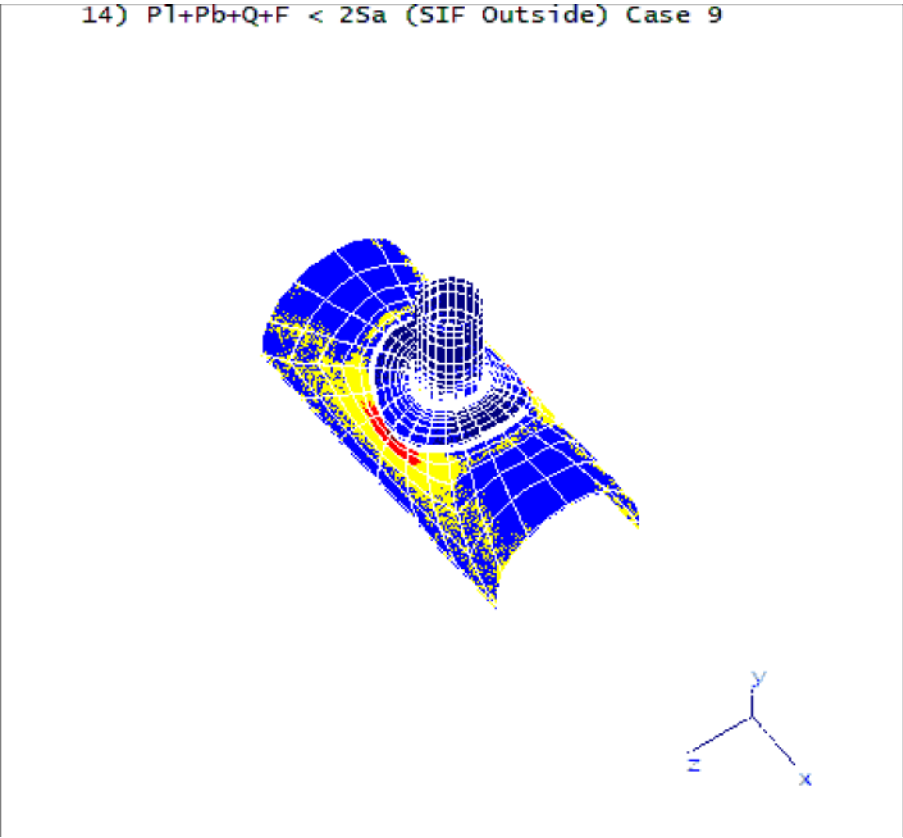
12) $P_1 + P_b + Q + F < 2S_a$ (SIF Outside) Case 7



13) $P_1 + P_b + Q + F < 2S_a$ (SIF Outside) Case 8



Rev.				Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23



Revisions to this Page					
Rev.	Detailed Description of the Revision	By	Date	Apvd.	Date
1	Rev./Cust. Comments	EG	5/13/22	GS	5/13/22
2	Rev./Cust. Comments	EG	7/15/22	GS	7/15/22
3	Rev./Cust. Comments	EG	10/13/22	GS	10/13/22
4	Add Pad Edge Calc/Nozzle Pro/R Factor	EG	12/17/22	GS	11/17/22
5	Replace Pad Edge/FEA 6"-600# Nozz. Analysis/Cust	EG	2/1/23	GS	2/1/23

E



P.O. BOX 988
2410 INDUSTRIAL ROAD
SAPULPA, OK 74066
(918)224-7550 FAX(918)224-3564

FABSCO JOB #: S21-13258-10
PO #: 4505600057
18-X-372B

SHELL & TUBE
QUALITY CONTROL INSPECTION PLAN/CHECKLIST

(*) DENOTES A.I. HOLD POINTS

JS

8/24/22

INSPECTIONS PERFORMED	FABSCO Q.C.	AUTHORIZED INSPECTOR	DATE	REMARKS
REVIEW DWG/CALC, WPS/PQR AND WELDER QUALIFICATION RECORDS	W <i>09.13.22 JS</i>	<i>JS 8/24/22</i>		
EXAM. PLATE EDGES/SURF.	W <i>JS</i>			
CHECK NOZZ. PIPE THKNS.	W <i>JS</i>			
CHECK HEAD/SHELL THKNS.	W <i>JS</i>			
VERIFY NOZZ. FLG. RATING	W <i>JS</i>			
CHECK MATERIAL IDENTIF.	W <i>JS</i>			
REVIEW MILL TEST REPORTS	W <i>JS</i>	<i>JS 10/25/23</i>		
CHK FITUP CHAN. LONG SEAM	W <i>N/A</i>			
CHK FITUP CHAN. GIRTH SEAMS	W <i>09.13.22 JS</i>			
CHK FITUP CHAN NOZZ.	W <i>JS</i>			
CHK. FITUP SHELL LONGSEAM	W <i>N/A</i>			
CHK FITUP SHELL GIRTH SEAM	W <i>09.13.22 JS</i>			
CHK FITUP SHELL NOZZLES	W <i>09.29.22 JS</i>			
PERFORM PMI (IF REQUIRED)	W			
PERFORM/WITNESS NDE PT	W <i>JS</i>			
PERFORM/WITNESS NDE MT	W <i>JS</i>			
PERFORM/WITNESS NDE UT	W <i>JS</i>			
CHECK OUT OF ROUNDNESS	W <i>10.12.22 JS</i>			
AIR TEST NOZZLE REPAD	W <i>10.12.22 JS</i>			
BUNDLE SKEL. CHECK	W <i>JS 9/23/22</i>			
BUNDLE SKEL. INSERTION	W <i>JS</i>			
CHK ALL WELDS FOR APPEARANCE, SIZE & WELDERS STAMP	W <i>09.28.23 JS</i>	<i>JS 9/28/23</i>		
REVIEW RADIOGRAPHS	W <i>09.28.23 JS</i>	<i>JS 10/25/23</i>		
INTERNAL INSP. CHANNEL	W <i>JS 10/10/22</i>	<i>JS 10/10/22</i>		
~~SHELL I.D. BEFORE HEAD F/U~~	W <i>10.05.22 JS</i>	<i>JS 10/5/22</i>		
INTERNAL INSP. SHELL	W <i>JS 10/12/22</i>	<i>JS 10/12/22</i>		
REVIEW HEAT CHARTS	W <i>N/A</i>			
WITNESS HYDROSTATIC TEST SS	W <i>09.26.23 JS</i>	<i>JS 9/26/23</i>		STACKED
WITNESS HYDROSTATIC TEST TS	W <i>09.28.23 JS</i>	<i>JS 9/28/23</i>		"
CHECK FLANGE FINISH AFTER HYDRO	W			
CHK NAMEPLATE/STAMPING	W <i>08.24.23 JS</i>	<i>JS 8/24/23</i>		
DATA REPORT CHECKED/SIGNED	W	<i>JS 10/25/23</i>		
CHK FINAL DIMENSIONAL	W <i>09.26.23 JS</i>			STACKED
CHK FINAL APPEARANCE/PAINT	W			

NOTES: W= WITNESS BLANK LINES ARE FOR CUSTOMER REQUIREMENTS

FABSCO SHELL - TUBE

DOCUMENT #: S21-13258-10-ITP REV 1 PO#: 4505600057 DATE: 08/03/22								
ITP \ QUALITY PLAN								
TAG No.:		EQUIPMENT TITLE						
18-X-372B		STRIPPER FEED/DEB BOT EXCHANGER						
LEGEND: V=VERIFY I=INSPECT R=REVIEW W=WITNESS H=HOLD M=MONITOR D=DIMENSIONAL								
TASK #	ACTIVITY	ACCEPTANCE CRITERIA	PROCEDURE / INSTRUCTION	VERIFYING DOCUMENT	FABSCO	AIR PRODUCTS	FLUOR	Comments
	PRE INSPECTION MEETING	Purchase Order	*****	*****		H W		
	* Review of PO and specifications QC requirements documents							
	* Review and establish Quality Surveillance requirements	Purchase Order /						
	APPLICABLE DESIGN CODES:							
	API 660 9TH EDITION ADD 1				R	R		
	ASME SECTION VIII DIV. 1							
	ASME SECTION II, PART D							
	TEMA CLASS R, 10TH ED							
	ASME B16.5							
	FABSCO PROCEDURES				R	R		
	BRINELL HARDNESS TEST PROCEDURE		NDE #14					
	HYDROSTATIC TEST PROCEDURE		NDE #13					
	MAGNETIC PARTICLE EXAMINATION PROCEDURE		NDE #2					
	LIQUID PENETRANT EXAMINATION PROCEDURE		NDE #4					
	RADIOGRAPHY PROCEDURE		GXS 1-B-RT-ASME					
	PWHT PROCEDURE		PROCEDURE #24					
	ULTRASONIC TEST PROCEDURE		GXS II-F					
	PMI PROCEDURE		GXS PROC VII-A PMI IDENT					
	CUSTOMER SPECIFICATIONS/STANDARDS				R	R		
	STRIPPER FEED/DEBUTANIZER BOTTOMS EXCH(18-X-372B)	A8KM-18-070-540357-A REV D						
	FLUOR DIMENSIONAL OUTLINE(18-X-372B)	A8KM-18-070-510086-A REV D						
	ENGINEERING BILL OF MATERIALS	A8KM-4-402-PO-2-BOM REV D						
	EXCH	A8KM-E-402-PO-2-SDDC REV D						
	SUPPLIER DOCUMENT & DATA SUBMITTAL SPECIFICATION							
	SUPPLIER/CONTRACTOR INBOUND TRANSMITTAL(IBTS)	A8KM-4-402-PO-2-IBTS-0001						
	QUALITY & CERTIFICATION REQUIREMENTS-S&T EXCH	A8KM-4-402-PO-2 Q&CR REV D						
	WEP SPARE PART INVENTORY FORM							
	VENTOR INPUT TO PCMS	A8KM-PCMS-001 REV 0						
	WELDING OF HYCO PLANT EQUIPMENT	4WEQ-1051 REV 0						
	SHIPMENT AND PACKING SPECIFICATION	4WGN-10001 REV 6						
	BOLT-UP PROCEDURE FOR FLANGED CONNECTIONS	4WPI-670210 REV 5						
	STRUCTURAL DATA FOR MECHANICAL EQUIPMENT	A8KM-PP-000-40002-A REV 0						

FABSCO SHELL - TUBE

DOCUMENT #: S21-13258-10-ITP REV 1 PO#: 4505600057 DATE: 08/03/22								
ITP \ QUALITY PLAN								
TAG No.:		EQUIPMENT TITLE						
18-X-372B		STRIPPER FEED/DEB BOT EXCHANGER						
LEGEND: V=VERIFY I=INSPECT R=REVIEW W=WITNESS H=HOLD M=MONITOR D=DIMENSIONAL								
TASK #	ACTIVITY	ACCEPTANCE CRITERIA	PROCEDURE / INSTRUCTION	VERIFYING DOCUMENT	FABSCO	AIR PRODUCTS	FLUOR	Comments
	SHELL & TUBE HEAT EXCHANGERS	A8KM-PP-000-50720-A REV 0						
	PLANT SITE DATA SHEET	A8KM-PP-000-200001-A REV 0B						
	HOT INSULATION	A8KM-PP-000-500510-A REV 0C						
	FLANGED JOINT ASSEMBLY RECORD & TIGHTENING SEQUENCE	FORM 8232						
	PAINTING	A8KM-PP-000-500520-A REV 0D						
	MAT & FAB REQ FOR DUPLEX SS	A8KM-PP-000-500550-A REV 0B						
	WELDING-NDE REQUIREMENTS FOR EQUIPMENT	SPEC-ENG-DOC001 REV 0						
	SUPPLIER-DESIGNED, SHOP-FABRICATED PRESSURE EQUIPMENT	A8KM-PP-000-500005-A REV 0						
	DESIGN OF LIFTING COMPONENT FOR MECH EQUIP	SPEC-ENG-DOC002 REV 0						
	SHELL & TUBE HEAT EXCHANGERS	SPEC-ENG-MQ042 REV 0						
	MATERIAL CERTIFICATION AND RETESTING REQUIREMENTS	SPEC-ENG-MQ057 REV 1						
	MECHANICAL EQUIPMENT GASKETS	A8KM-PP-000-530400-D REV B						
	EXPANDED METAL PERSONNEL PROTECTION DETAILS FOR SHELL & TUBE EXCHANGERS	SPEC-MED-DOC001 REV 0						
	DESIGN BASIS FOR MECHANICAL EQUIPMENT	SPEC-MED-DOC001 REV 0						
FABRICATION								
1	REVIEW DWG/CALC, WPS/PQR AND WELDER QUALIFICATION RECORDS	ASME SEC. VIII/IX, API660, TEMA	Project Specification	Apprvd Submittal	<i>MD</i>	R		
2	WELD ROD CONSUMABLE CONTROL	ASME SEC IX	PROCEDURE NDE #28	NDE #28	I	V		
3	IN-PROCESS WELDING FOR COMPLIANCE TO WPS	ASME SEC IX	WELD MAP	WELD MAP	I	I/R		
4	EXAM. PLATE EDGES/SURFACE	ASME VIII, DIV I	FABSCO QC MANUAL	CERT.	I	I/R		
5	CHECK NOZZLE PIPE THICKNESS	DRAWING	FABSCO QC MANUAL	DWG	I	I/R		
6	CHECK HEAD/SHELL THICKNESS	DRAWING	FABSCO QC MANUAL	DWG/MTR	I	I/R		
7	VERIFY NOZZLE FLG. RATING	DRAWING	FABSCO QC MANUAL	DWG/MTR	I	R		
8	CHECK MATERIAL IDENTIFICATION	ASME SEC. VIII, DIV I	FABSCO QC MANUAL	DWG/MTR	<i>MD</i>	I/R		
9	REVIEW MATERIAL TEST REPORTS	ASME SEC II	ASME SEC II	CMTR	<i>MD</i>	I/R		
10	CHECK FITUP CHANNEL LONG SEAM	DRAWING/ASME SEC VIII	DRAWING	TRAVELER	<i>MD</i>	I/R		
11	CHECK FITUP CHANNEL GIRTH SEAMS	DRAWING/ASME SEC VIII	DRAWING	TRAVELER	<i>MD</i>	I/R		
12	CHECK FITUP SHELL NOZZLES	DRAWING	DRAWING	TRAVELER	<i>MD</i>	I/R		
13	PERFORM/WITNESS NDE PT	ASME SEC VIII, DIV I	PROCEDURE NDE #4	CERT/DWG	<i>MD</i>	R		W-1ST ARTICLE
14	PERFORM/WITNESS NDE MT	ASME SEC VII, DIV I	PROCEDURE #2	CERT	<i>MD</i>	R		W-1ST ARTICLE
15	CHECK OUT ROUNDNESS	ASME SEC VIII, DIV I	FABSCO QC MANUAL	-----	<i>MD</i>	I		
16	CHK ALL WELDS FOR APPERANCE SIZE & WELDERS STAMP	ASME SEC VIII, DIV I		CERT	<i>MD</i>	I/R		
17	REVIEW RADIOGRAPHS	ASME SEC VIII, DIV I	PROCEDURE I.B.	CERT	<i>MD</i>	R		
18	INTERNAL INSP. CHANNEL	ASME SEC VIII, DIV I	NDE #7	TRAVELER	<i>MD</i>	I/R		

FABSCO SHELL - TUBE

DOCUMENT #: S21-13258-10-ITP REV 1 PO#: 4505600057 DATE: 08/03/22								
ITP \ QUALITY PLAN								
TAG No.: EQUIPMENT TITLE								
18-X-372B STRIPPER FEED/DEB BOT EXCHANGER								
LEGEND: V=VERIFY I=INSPECT R=REVIEW W=WITNESS H=HOLD M=MONITOR D=DIMENSIONAL								
TASK #	ACTIVITY	ACCEPTANCE CRITERIA	PROCEDURE / INSTRUCTION	VERIFYING DOCUMENT	FABSCO	AIR PRODUCTS	FLUOR	Comments
19	INTERNAL INSP. SHELL	ASME SEC VIII, DIV I	NDE #7	TRAVELER	<i>W</i>	I/R		
20	FLANGE TYPE / SIZE / FINISH	DRAWING	TEMA/DRAWING	TRAVELER	<i>W</i>	R		
21	CHECK BUNDLE SKELETON PRIOR TO TUBE INSERTION				<i>W</i>	I/R		
22	TUBE BUNDLE INSPECTION / INSERTION	TEMA/DRAWING	*****	*****	<i>W</i>	H		
23	CHECK FINAL DIMENSIONAL	DRAWING	DRAWING	CERT/DWG	<i>W</i>	I		
24	AIR TEST REPADS (IF APPLICABLE)	ASME SEC VIII	NDE #15	CERT	<i>W</i>	I/R		W-1ST ARTICLE
25	MAJOR REPAIRS(NCR) IF NECESSARY	ASME SEC VIII	NCR	NCR	H	H		
26	PMI (IF APPLICABLE)	ASME SEC VIII	GXS VII-A PMI IDENT	CERT	H	I/R		W-1ST ARTICLE
27	TUBE WELDING (STRENGHT WELD) (IF APPLICABLE)	ASME SEC VIII	NDE #18	DWG	<i>W</i>	M/R		
28	TUBE EXPANSION / ROLLING PROCESS	ASME SEC VIII	NDE #8	CERT	<i>W</i>	I/R		
29	EQUIPMENT DRY OUT	ASME SEC VIII	NDE #13	CERT	<i>W</i>	I/R		
30	SAND BLAST / SURFACE PROFILE	DRAWING	PESCO	CERT	<i>W</i>	I/R		
31	WITNESS HYDROSTATIC TEST SS	ASME SEC VII, DIV I	NDE #13	CERT/DWG	<i>W</i>	H <i>M</i>		CHART
32	WITNESS HYDROSTATIC TEST TS	ASME SEC VII, DIV I	NDE #13	CERT/DWG	<i>W</i>	H <i>M</i>		CHART
33	PAINTING / COATING APPLICATION	DRAWING	PESCO	CERT	<i>W</i>	I/R		
34	DRY FILM THICKNESS	DRAWING	PESCO	CERT	<i>W</i>	I/R/H		
35	FINAL CLEANLINESS INSPECTION	FINAL CLEANLINESS	*****	*****	<i>W</i>	I/R/H		
36	FINAL DOCUMENTATION PACKAGE	ASME SEC. VIII / P.O.	P.O.	DATABOOK	<i>W</i>	R <i>W</i>		
37	CHECK NAMEPLATES/STAMPING FOR , U STAMP, NB STAMP	ASME SEC. VIII, DIV I / DRAWING	DRAWING / P.O.	RUBBING	<i>W</i>	V/H		
38	DATA REPORT CHECKED/SIGNED	ASME SEC. VII, DIV I	FABSCO QC MANUAL	DATABOOK	<i>W</i>	R		
39	CHECK FINAL APPEARANCE/PAINT	P.O. / DRAWING	PESCO	REPORT	<i>W</i>	I/R		
40	Q.C. DOCUMENTATION	ASME SEC. VIII / P.O.	ASME SEC VIII	DATABOOK	<i>W</i>	R <i>M</i>		
41	INSPECTION RELEASE	*****	P.O.	*****		R <i>M</i>		
42	SHIPPING RELEASE	*****	P.O.	*****		R		
43	PREP FOR SHIPPING, PKG, MARKING, PRESERVATION & PRESERVATION INSTRUCTIONS	P.O. / DRAWING	P.O.	*****	<i>W</i>			

**FABSCO**

SHELL & TUBE, LLC

2410 Industrial Road

P.O. Box 988

Sapulpa, OK 74066

918/224-7550 Fax 918/224-3564

CERTIFICATE OF HYDROSTATIC TESTING

FABSCO SHELL & TUBE, L.L.C. JOB NUMBER:	S21-13258-10
CUSTOMER NAME:	AIR PRODUCTS MANUFACTURING LLC
CUSTOMER PURCHASE ORDER NUMBER:	4505600057 / ABKM-4-402-P0-2
CUSTOMER ITEM NUMBER:	18-X-372B

THIS IS TO CERTIFY THE ABOVE UNIT WAS HYDROSTATICALLY TESTED PER
ASME CODE SECTION VIII DIVISION 1.

TESTED IN STACKED POSITION W/18-X372A

SHELLSIDE TEST PRESSURE PSI	TUBESIDE TEST PRESSURE PSI	DATE TESTING PERFORMED
631		09.26.23
	631	09.28.23

S.S.		T.S.	
GAUGE#:	27	CAL. DATE:	04.05.23
GAUGE#:	ST.3	CAL. DATE:	07.27.23

GAUGE#:	96	CAL. DATE:	06.22.23
GAUGE#:	ST.4	CAL. DATE:	07.27.23

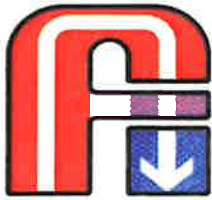
WITNESSED BY: BUREAU VERITAS INSPECTION AND INSURANCE COMPANY
AUTHORIZED INSPECTOR


FABSCO SHELL & TUBE, LLC.
QUALITY CONTROL DEPARTMENT

09.28.23
DATE

FABSCO SHELL TUBE, L.L.C., 2410 INDUSTRIAL ROAD, SAPULPA, OK 74066
TELEPHONE (918) 224-7550 FAX (918) 224-3564

mre
9/28/23



FABSCO SHELL & TUBE, LLC

2410 Industrial Road
P.O. Box 988
Sapulpa, OK 74066
918/224-7550 Fax 918/224-3564

FABSCO HARDNESS TEST REPORT

FABSCO JOB #: S21-13258-10	CUSTOMER PO #: 4505600057
CUSTOMER NAME: AIR PRODUCTS	CUSTOMER ITEM #: 18-X-372B

FRONT CHANNEL

RS-1		RS-2	
W	172	W	168
HAZ	204	HAZ	178
B		B	
LS	N/A	LS	N/A
W		W	
HAZ		HAZ	
B		B	

CHANNEL NOZZLES

NOZ 81 ATT		NOZ 85 ATT	
W	190	W	208
HAZ	155	HAZ	190
B		B	
NOZ 83	ATT	NOZ 82	ATT
W	196	W	205
HAZ	198	HAZ	160
B		B	

SHELL

RS-1		RS-2	
W	177	W	175
HAZ	175	HAZ	175
B		B	
LS	N/A	LS	N/A
W		W	
HAZ		HAZ	
B		B	

SHELL NOZZLES

NOZ 71 RS		NOZ 72 RS	
W	200	W	187
HAZ	166	HAZ	158
B		B	
NOZ 74	ATT.	NOZ 73	ATT.
W	177	W	187
HAZ	170	HAZ	156
B		B	

CHANNEL NOZZLES

NOZ 84 ATT		NOZ 86 ATT	
W	208	W	175
HAZ	185	HAZ	205
B		B	

SHELL NOZZLES

NOZ 71 ATT.		NOZ 72 ATT.	
W	187	W	182
HAZ	174	HAZ	165
B		B	

W	
HAZ	
B	

10/13/2022

DATE:

Alonso Griffin

FABSCO SHELL & TUBE, LLC
QUALITY CONTROL DEPARTMENT
NDE EXAMINER

FABSCO SHELL TUBE, L.L.C., 2410 INDUSTRIAL ROAD, SAPULPA, OK 74066
TELEPHONE (918) 224-7550 FAX (918) 224-3564

10/13/22

**FABSCO****SHELL & TUBE, LLC**

2410 Industrial Road

P.O. Box 988

Sapulpa, OK 74066

(918)224-7550 Fax(918)224-3564

MAGNETIC PARTICLE EXAMINATION**FABSCO SHELL & TUBE, L.L.C. JOB NUMBER:** S21-13258-10**CUSTOMER NAME:** AIRPRODUCTS MANUFACTURING LLC**CUSTOMER P. O. NUMBER:** 4505600657 / ABKM-4-402-BD-2**CUSTOMER ITEM NUMBER:** 18-X-372B**PARTS EXAMINED / WELD JOINT EXAMINED:** ALL FORGINGS PARTS # 1,2,3,7 & 19

ENTIRE SURFACE OF FORGINGS INCLUDING WELD BEVELS PRIOR TO WELDING

Magnetic particles: Dry Powder**Magnetic particles:****Technique:** 90° PERP, yoke**Lifting Power:**

10 lbs at 6" spacing

Equipment Type: ac yoke**Current Type:**

ac

Lighting Equipment: STREAMLIGHT LED**Illumination Level:****Demag Performed:**

no

RESULTS: NO RELEVANT INDICATIONS**REMARKS:**

No defects found.

09-12-22

Date:

*John Burris L II***FABSCO SHELL & TUBE, L.L.C.
QUALITY CONTROL DEPARTMENT
NDE EXAMINER***11/16/22*



FABSCO
SHELL & TUBE, LLC
2410 Industrial Road
P.O. Box 988
Sapulpa, OK 74066
918/224-7550 Fax 918/224-3564

Liquid Penetrant Examination Record

Customer: AIR PRODUCTS Date: _____

Job/P.O. No.: S21-13258-10 Reference Code/Specification: ASME V, VIII

Acceptance Criteria: ASME VIII

PT Procedure No. 4 Rev. No. 4

Liquid Penetrant Type: ☒ Visible ☐ Fluorescent

☒ VP30

Other: _____

Cleaner/Remover: E-59A Other: H₂O

Developer: ☒ D70 Other: _____

Part/Item Material Type: SA-516-70N, SA-350LF2CL1, SA-106B Material Thickness _____

Lighting Equipment: ☐ Fluorescent Light Model # _____ Serial # _____

☐ Verified Supplemental White Light Source: STREAMLIGHT LED

Max. Distance from object: _____

Other: _____

Light Intensity Meter When Used: Model# _____ Ser.# _____ Calibration Due Date: _____

Light Intensity On Surface To Be Examined When Measured: _____ min/max foot candles _____ Min. $\mu\text{W}/\text{cm}^2$

Comments: _____

Examination Results				
Item #	Part Identification	Accept	Reject	Indication Description
	ROOT PASS-ALL DOUBLE WELDED GROOVE			
	JOINTS, COMPLETED WELDS PRIOR TO			
	ANY REINFORCEMENT PADS AND			
	COMPLETED WELDS.	☒		
	ALL TEMPORARY ATTACHMENTS AND			
	ARC MARKS AFTER REMOVAL	☒		

Examiner: John Burgo LII Date: 10-12-22

m
11/12

**FABSCO**

SHELL & TUBE, LLC

2410 Industrial Road

P.O. Box 980

Sapulpa, OK 74066

918/224-7550 Fax 918/224-3564

Liquid Penetrant Examination Record

Customer: AIR PRODUCTS Date: _____Job/P.O. No.: S21-13258-10 Reference Code/Specification: ASME V, VIIIAcceptance Criteria: ASME VIIIPT Procedure No. 4 Rev. No. 4Liquid Penetrant Type: ☒ Visible ☐ Fluorescent☒ VP30

Other: _____

Cleaner/Remover: _____ E-59A Other: H₂ODeveloper: ☒ D70 Other: _____Part/Item Material Type: SA-516-70N, SA-179 Material Thickness _____Lighting Equipment: ☐ Fluorescent Light Model # _____ Serial # _____☐ Verified Supplemental White Light Source: STREAMLIGHT LED

Max. Distance from object: _____

☐ Other: _____

Light Intensity Meter When Used: Model# _____ Ser.# _____ Calibration Due Date: _____

Light Intensity On Surface To Be Examined When Measured: _____ min/max foot candles _____ Min. $\mu\text{W}/\text{cm}^2$

Comments: _____

Examination Results				
Item #	Part Identification	Accept	Reject	Indication Description
	<u>TUBE TO TUBESHEET WELDS</u>	☒	☐	

Examiner: John Burgis LIIDate: 10.01.22m
11m



FABSCO SHELL & TUBE, LLC JOB NUMBER: S21-13258-10

CUSTOMER NAME: AIR PRODUCTS

CUSTOMER PO NUMBER: 4505600057 / A8KM-4-402-PO-2

CUSTOMER ITEM NUMBER: 18-X-372B

PARTS EXAMINED BY DIRECT PRESSURE: FRONT CHANNEL, SHELL

ALL NOZZLE REINFORCEMENT PADS

MATERIAL IDENTIFICATION: SA 516.70N

MATERIAL THICKNESS:

GAUGE MFG: ASHCROFT

MODEL:

RANGE: 0-30

PSI:

PRESSURE GAUGE #: 53

CALIBRATION DATE: 02.22.23

TEST PRESSURE: 17 PSI

TEST CONDITIONS:

PSI:

TRACER GAS:

GAS CONCENTRATION:

PPM:

RESULTS: No LEAKS

REMARKS: AFTER ADDITION OF PAD EXTENSIONS

08.24.23

DATE:

John Burzio

FABSCO SHELL & TUBE, LLC

QUALITY CONTROL DEPARTMENT

NDE EXAMINER

21

INSPECTION FORM

ETS job # H-22-318 F50

Description of repairs needed Run out 18" Bundle 13258
Front side ~~12358~~ ±10

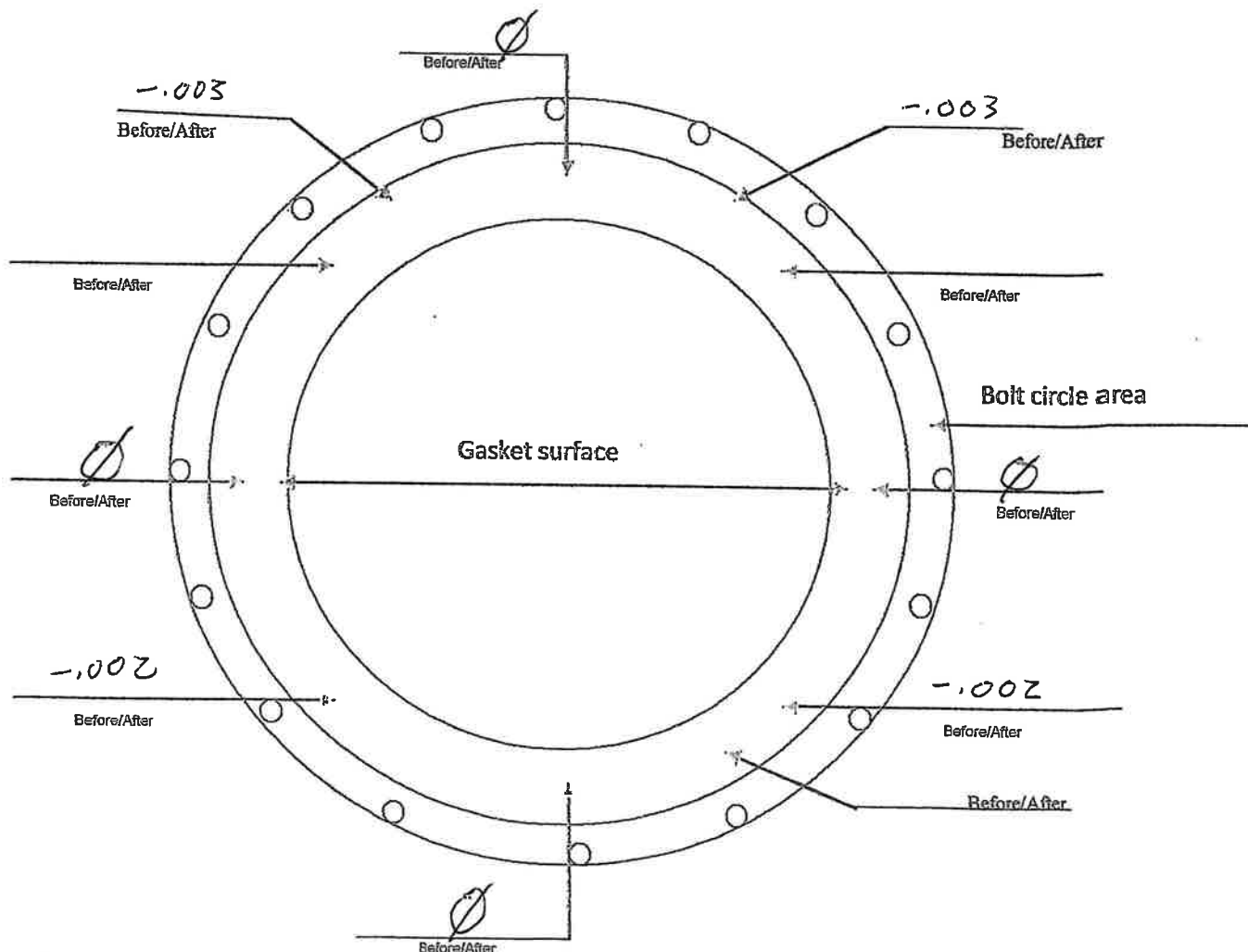
Machinist
1) Mike Wheeler [Signature] 10-12-22
PRINT NAME SIGNATURE DATE

Flange OD 17 5/8" Flange ID N/A Raise face height N/A

Flange thickness before machining 1.660 after machining N/A

Total run-out of gasket surface .003 Raise face height after machining N/A

*Insert Indicator reading on appropriate lines.



ACCEPTANCE:
For Client: [Signature] Date: 10-12-22
For ETS: [Signature] Date: 10-12-22

m/leh

INSPECTION FORM

ETS job # H-22-318 FSO

Description of repairs needed Runout 18" Bundle

13258

~~12358~~-10

Backside

Machinist

1) Mike Wheeler

PRINT NAME

[Signature]

SIGNATURE

10-12-22

DATE

Flange OD 17 5/16"

Flange ID N/A

Raise face height N/A

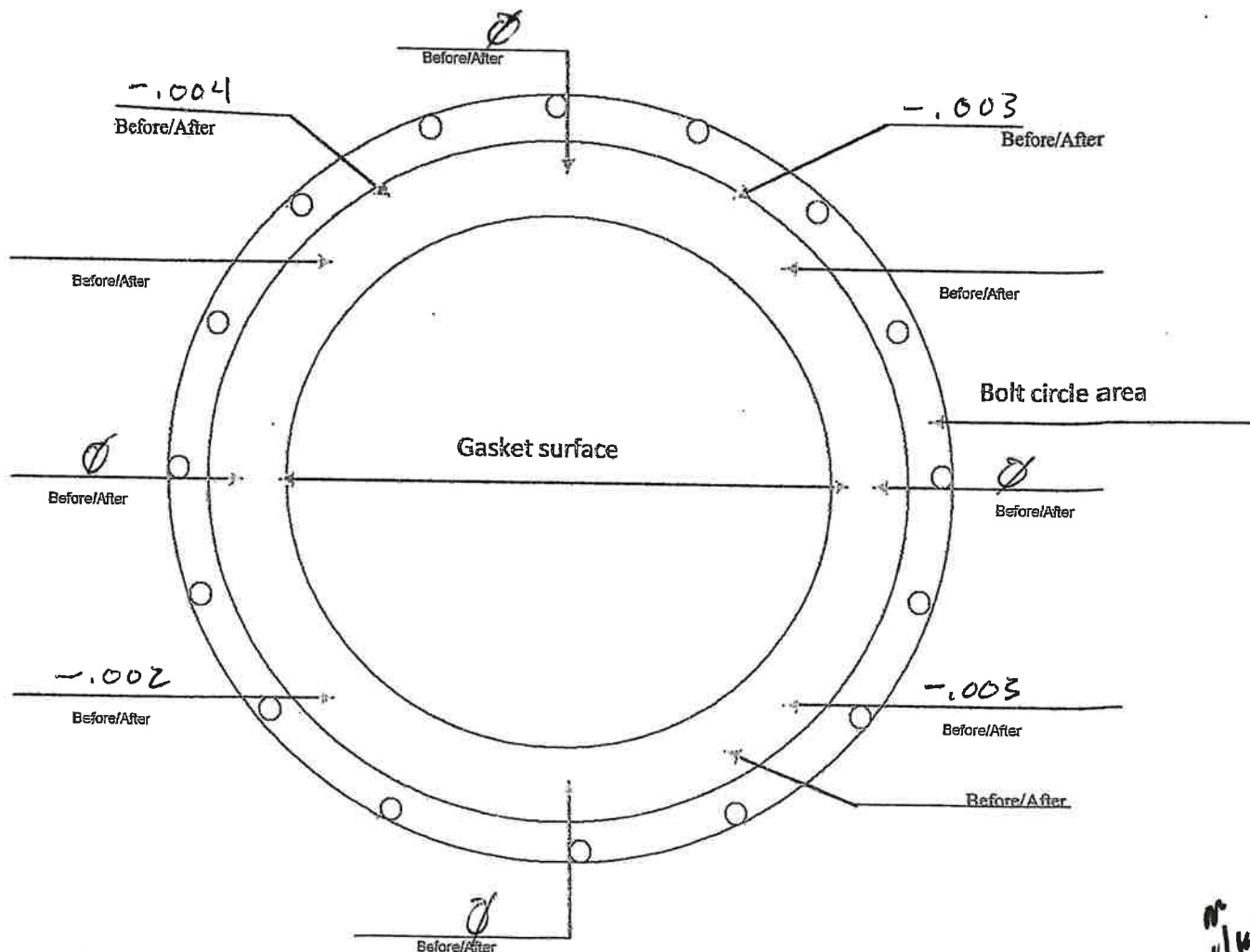
Flange thickness before machining 1.660

after machining N/A

Total run-out of gasket surface

Raise face height after machining N/A

**Insert Indicator reading on appropriate lines.*



ACCEPTANCE:

For Client:

[Signature]

Date: 10-12-22

For ETS:

[Signature]

Date: 10-12-22

*m
1/16*



NON DESTRUCTIVE TESTING
AND INSPECTION

17110 East Pine St, Tulsa, OK 74116

Tele: (918) 234-6300 Fax: (918) 234-6301

ULTRASONIC INSPECTION AND CALIBRATION REPORT

CUSTOMER DATA

NAME FABSCO SHELL AND TUBE
ADDRESS TULSA, OK.
PURCHASE ORDER # _____
ATTENTION _____
DAY WEDNESDAY DATE 10/5/2022

JOB NUMBER: 13258-10

APPLICABLE CODE: ASME SEC VIII DIV 1

PROCEDURE # 2.5

REVISION # 1

REV. DATE: 2/18/2022

EQUIPMENT DATA

EQUIPMENT MANUFACTURER: OLYMPUS MODEL# EPOCH 650 S/N 180725210
SEARCH UNIT CABLES: #1 TYPE SINGLE LENGTH 6FT S/N _____
SEARCH UNIT CABLES: #2 TYPE _____ LENGTH _____ S/N _____
LONGITUDINAL SEARCH UNIT MFG. #1 OLYMPUS ANGLE 0 FREQ. 7.5 MHz SIZE 0.375 S/N S4940
LONGITUDINAL SEARCH UNIT MFG. #2 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
SHEAR WAVE SEARCH UNIT MFG #1 OLYMPUS ANGLE 60 FREQ. 5 MHz SIZE 0.5 S/N _____
SHEAR WAVE SEARCH UNIT MFG #2 OLYMPUS ANGLE 70 FREQ. 5 MHz SIZE 0.5 S/N _____
SHEAR WAVE SEARCH UNIT MFG #3 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
COUPLANT BRAND NAME: SONATECH TYPE: ULTRA GEL II
SPECIAL EQUIPMENT: (IF USED) N/A
CALIBRATION BLOCK TYPE: SN#65857 BCB
SIMULATION BLOCK TYPE: SN#65857 BCB

CALIBRATION DATA

LONGITUDINAL - #1 REFERENCE LEVEL 42 (db) SCANNING LEVEL 48 (db)
LONGITUDINAL - #2 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
SHEAR WAVE - ANGLE #1 REFERENCE LEVEL 44 (db) SCANNING LEVEL 50 (db)
SHEAR WAVE - ANGLE #2 REFERENCE LEVEL 48 (db) SCANNING LEVEL 54 (db)
SHEAR WAVE - ANGLE #3 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
Initial Cal. Time _____ Cal. Check _____ Ending Cal. Time _____

TEST CONDITIONS

PART CONDITION: CLEAN AND SMOOTH
SIMULATION BLOCK TEMP: AMBIENT F PART TEMP. AMBIENT F
SCANNING TYPE: CONTACT X IMMERSION _____ MANUAL _____ AUTOMATIC _____
SCANNING SPEED: LESS THAN 6" PER SECOND
SCANNING SURFACE: INSIDE _____ OUTSIDE X VERTICLE X HORIZONTAL X
SCANNING DIRECTIONS: PARALLEL X PERPENDICULAR X OPPOSING _____

PART IDENTIFICATION: UT ON NOZZLE ATTACHMENT WELDS LISTED

N-71 ACCEPTABLE
N-72 ACCEPTABLE

RESULTS: No relevant indications found of rejectable size. UT is performed

TECHNICIAN HRS. _____ ASST. HRS. _____ TRAVEL HRS. _____ MILEAGE _____ PERDIEM _____

TECHNICIAN: CHANCE BOWLING LEVEL II Cert. Type SNT-TC-1A

ASSISTANT: _____ LEVEL _____ Page _____ OF _____

CUSTOMER REPRESENTATIVE: _____ TOTAL TIME _____ Hrs.



NON DESTRUCTIVE TESTING
AND INSPECTION

17110 East Pine St, Tulsa, OK 74116

Tele: (918) 234-6300 Fax: (918) 234-6301

ULTRASONIC INSPECTION AND CALIBRATION REPORT

CUSTOMER DATA

NAME FABSCO SHELL AND TUBE
ADDRESS _____
PURCHASE ORDER # 13258
ATTENTION _____
DAY WEDNESDAY DATE 9/7/2022

JOB NUMBER: 13258

APPLICABLE CODE: ASME SEC 5 ART 4

PROCEDURE # UT2

REVISION # 15

REV. DATE: 6/8/2020

EQUIPMENT DATA

EQUIPMENT MANUFACTURER: OLYMPUS MODEL# EPOCH 650 S/N 150133512
SEARCH UNIT CABLES: #1 TYPE SINGLE LENGTH 6FT S/N _____
SEARCH UNIT CABLES: #2 TYPE _____ LENGTH _____ S/N _____
LONGITUDINAL SEARCH UNIT MFG. #1 OLYMPUS ANGLE 0 FREQ. 2.25 MHz SIZE 1" S/N 1203849
LONGITUDINAL SEARCH UNIT MFG. #2 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
SHEAR WAVE SEARCH UNIT MFG #1 OLYMPUS ANGLE 60 FREQ. 5 MHz SIZE .25" S/N 1071047
SHEAR WAVE SEARCH UNIT MFG #2 OLYMPUS ANGLE 70 FREQ. 5 MHz SIZE .25" S/N 1071047
SHEAR WAVE SEARCH UNIT MFG #3 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
COUPLANT BRAND NAME: SONATECH TYPE: ULTRA GEL II
SPECIAL EQUIPMENT: (IF USED) N/A
CALIBRATION BLOCK TYPE: IIW TYPE 2
SIMULATION BLOCK TYPE: ASME 5

CALIBRATION DATA

LONGITUDINAL - #1 REFERENCE LEVEL 42 (db) SCANNING LEVEL 48 (db)
LONGITUDINAL - #2 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
SHEAR WAVE - ANGLE #1 REFERENCE LEVEL 42 (db) SCANNING LEVEL 48 (db)
SHEAR WAVE - ANGLE #2 REFERENCE LEVEL 46 (db) SCANNING LEVEL 52 (db)
SHEAR WAVE - ANGLE #3 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
Initial Cal. Time 2:00 PM Cal. Check _____ Ending Cal. Time _____

TEST CONDITIONS

PART CONDITION: CLEAN
SIMULATION BLOCK TEMP: AMBIENT F PART TEMP. AMBIENT F
SCANNING TYPE: CONTACT X IMMERSION _____ MANUAL X AUTOMATIC _____
SCANNING SPEED: LESS THAN 6" PER SECOND
SCANNING SURFACE: INSIDE OUTSIDE X VERTICLE X HORIZONTAL X
SCANNING DIRECTIONS: PARALLEL X PERPENDICULAR X OPPOSING _____

PART IDENTIFICATION: UT ON INCERTION WELDS THROUGH 16" X .375"t SHELL :

13258-10

NOZ 81 3"

NOZ 82 3"

NOZ 83 2"

NOZ 84 2"

RESULTS: No relevant indications found of rejectable size. UT is performed

ASME SEC 8 DIV 1 APP 12

TECHNICIAN HRS. _____ ASST. HRS. _____ TRAVEL HRS. _____ MILEAGE _____ PERDIEM _____

TECHNICIAN: ISAAC DUCLOS LEVEL II Cert. Type SNT-TC-1A

ASSISTANT: _____ LEVEL _____ Page 1 OF 1

CUSTOMER REPRESENTATIVE: _____ TOTAL TIME _____ Hrs.

American Piping Inspection

TECHNIQUE/INSPECTION REPORT

DATE 9/14/2022 DAY WEDNESDAY

CUSTOMER DATA

NAME: FABSCO SHELL & TUBE
 ADDRESS: SAPULPA
 PHONE: ATTN:
 W.O: 13258-10 AFE:
 JOB LOCATION: TULSA
 DESCRIPTION: F/C MATERIAL TYPE: CS

DEFECT CODE

AB-ARC BURN
 AI-ALIGNED INDICATION
 BT-BURN THOUGH
 CON-CONCAVITY
 CRACK-CRACK
 HB- HOLLOW BEAD
 IF- INADEQUATE FUSION
 IP- INCOMPLETE PENETRATION
 MA -MISALIGNMENT
 POR- POROSITY

SLI- SLAG INCLUSION
 SLL- SLAG LINE
 SURF- SURFACE INDICATION
 UCE- UNDERCUT EXTERNAL
 UCI- UNDERCUT INTERNAL

ABBREVIATED TERMS

SOD - SOURCE TO OBJECT DISTANCE
 OFD - SOURCE SIDE OF OBJECT TO FILM DISTANCE
 OD - OUTER DIAMETER
 WT - WELD THICKNESS
 WR - WELD REINFORCEMENT
 REP-REPAIR
 RES-RESHOOT
 RET-RETAKE
 BM - BASE MATERIAL

WELD/FILM NUMBER	WELDER ID	OD	BM	WR	WT	WITHIN STD'S YES NO	# FILM	FILM SIZE/MFG/TYPE	SOD	OFD	IQI S-F	#EXP	DEFECT LOCATION
1	F/C RS-1												
2	1-2	P	16	.375	.1875	.5625	✓	1	4.5X17 F80	8	.5625	B	1
3	F/C RS-2												
4	1-2	P	16	.375	.1875	.5625	✓	1	4.5X17 F80	8	.5625	B	1
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													

METHOD	RT	SOURCE SIZE DIAG.	0.124	ISOTOPE	IR-192	NO. CURIES	81	DEV. TIME	AUTO	DEV. TEMP	AUTO	DENSITY	2.0-4.0
NO. OF WELDS	2	FT. LONG SEAMS		STANDARDS	ASME VIII DIV 5	PER DIEM		NO. OF FILM	2	EXPOSURE:	DBL WALL	S. WALL X	R Factor
										VIEWING:	DBL WALL	S. WALL X	SCREEN
TRUCK NO.	210	REPORT NUMBER	2	PAGE NUMBER	1	TECH HOURS		ASST. HOURS		TRAVEL HOURS		TOTAL HOURS	MILEAGE
													38
FILM INTERPRETER	Bryon LI 09.25.22				ASSISTANT NAME				RAVEN LAXTON				ASNT LEVEL
													I
COMPANY REPRESENTATIVE					NDT TECHNICIAN				ROB FOSTER				ASNT LEVEL
													II

SIGNATURE CERTIFIES TIME AND MATERIALS CORRECT - AMERICAN PIPING INSPECTION, INC ASSUMES NO RESPONSIBILITY FOR LOSSES OF ANY KIND DUE TO INTERPRETATION

Handwritten signature

American Piping Inspection

TECHNIQUE/INSPECTION REPORT

DATE 9/16/2022 DAY FRIDAY

CUSTOMER DATA

NAME: FABSCO SHELL & TUBE
 ADDRESS: SAPULPA
 PHONE: ATTN:
 W.O: 13258-10 AFE:
 JOB LOCATION: TULSA
 DESCRIPTION: SHELL MATERIAL TYPE: CS

DEFECT CODE

AB-ARC BURN
 AI- ALIGNED INDICATION
 BT-BURN THOUGH
 CON- CONCAVITY
 CRACK-CRACK
 HB- HOLLOW BEAD
 IF- INADEQUATE FUSION
 IP- INCOMPLETE PENETRATION
 MA -MISALIGNMENT
 POR- POROSITY

SLI- SLAG INCLUSION
 SLL- SLAG LINE
 SURF- SURFACE INDICATION
 UCE- UNDERCUT EXTERNAL
 UCI- UNDERCUT INTERNAL

ABBREVIATED TERMS

SOD - SOURCE TO OBJECT DISTANCE
 OFD - SOURCE SIDE OF OBJECT TO FILM DISTANCE
 OD - OUTER DIAMETER
 WT - WELD THICKNESS
 WR - WELD REINFORCEMENT
 REP-REPAIR
 RES-RESHOOT
 RET-RETAKE
 BM - BASE MATERIAL

WELD/FILM NUMBER	WELDER ID	OD	BM	WR	WT	WITHIN STD'S YES NO	# FILM	FILM SIZE/MFG/TYPE	SOD	OFD	IQI S-F	#EXP	DEFECT LOCATION
1 SHELL RS-1													
2 1-2	66	16	.375	.1875	.5625	✓	1	4.5X17 F80	8	.5625	B	1	
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													

METHOD	RT	SOURCE SIZE DIAG.	0.124	ISOTOPE	IR-192	NO. CURIES	78	DEV. TIME	AUTO	DEV. TEMP	AUTO	DENSITY	2.0-4.0		
NO. OF WELDS	1	FT. LONG SEAMS	STANDARDS ASME VIII 4251 API	PER DIEM	NO. OF FILM	1	EXPOSURE: DBL WALL		S. WALL X		R Factor	SCREEN			
							VIEWING: DBL WALL		S. WALL X			PB			
TRUCK NO. 210	REPORT NUMBER	2	PAGE NUMBER	1	TECH HOURS	ASST. HOURS	TRAVEL HOURS	TOTAL HOURS	MILEAGE	38					
FILM INTERPRETER					Benjie LII 09.19.22					ASSISTANT NAME		AVERY PSALIDAS		ASNT LEVEL	I
COMPANY REPRESENTATIVE						NDT TECHNICIAN					ROB FOSTER		ASNT LEVEL	II	

SIGNATURE CERTIFIES TIME AND MATERIALS CORRECT - AMERICAN PIPING INSPECTION, INC ASSUMES NO RESPONSIBILITY FOR LOSSES OF ANY KIND DUE TO INTERPRETATION

Handwritten signature

American Piping Inspection

TECHNIQUE/INSPECTION REPORT

DATE 10/7/2022 DAY FRIDAY

CUSTOMER DATA

NAME: FABSCO SHELL & TUBE	
ADDRESS: SAPULPA	
PHONE:	ATTN:
W.O: 13258-10	PO#
JOB LOCATION: SAPULPA	
DESCRIPTION: SHELL	MATERIAL TYPE: CS

METHOD

ABREVIATED TERMS

AB-ARC BURN	HB- HOLLOW BEAD	SLI- SLAG INCLUSION	SOD - SOURCE TO OBJECT DISTANCE
AI- ALIGNED INDICATION	IF- INADEQUATE FUSION	SL- SLAG LINE	OFD - SOURCE SIDE OF OBJECT TO FILM DISTANCE
BT- BURN THROUGH	IP- INCOMPLETE PENETRATION	SURF- SURFACE INDICATION	OD - OUTER DIAMETER
CON- CONCAVITY	MA - MISALIGNMENT	UCE- UNDERCUT EXTERNAL	REP-REPAIR
CRACK-CRACK	POR- POROSITY	UCI- UNDERCUT INTERNAL	RES-RESHOOT
			RET-RETAKE
			BM - BASE MATERIAL

WELD/FILM NUMBER	WELDER ID	OD	BM	WR	WT	WITHIN STD'S YES NO	# FILM	FILM SIZE/MFG/TYPE	SOD	OFD	IQI S-F	#EXP	DEFECT LOCATION
1	SHELL												
2	RS-2	66	13	.375	.094	.469	✓	1	4.5X17 F80	13	.469	BF	1
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													

METHOD	RT	SOURCE SIZE DIAG.	0.131	ISOTOPE	IR 192	NO. CURIES	98	DEV. TIME	AUTO	DEV. TEMP	AUTO	DENSITY	2.0-4.0
NO. OF WELDS	2	FT. LONG SEAMS		STANDARDS ASME SEC. VIII DIV I	PER DIEM	NO. OF FILM	1	EXPOSURE:	DBL WALL	S. WALL X	R Factor	SCREEN	
								VIEWING:	DBL WALL	S. WALL X	2.8	PB	
TRUCK NO.	210	REPORT NUMBER	3	PAGE NUMBER	1	TECH HOURS		ASST. HOURS		TRAVEL HOURS		TOTAL HOURS	
FILM INTERPRETER	10/10/22						ASSISTANT NAME	NATE SPARKS			ASNT LEVEL	I	
COMPANY REPRESENTATIVE							NDT TECHNICIAN	ROB FOSTER			ASNT LEVEL	II	

SIGNATURE CERTIFIES TIME AND MATERIALS CORRECT - AMERICAN PIPING INSPECTION, INC ASSUMES NO RESPONSIBILITY FOR LOSSES OF ANY KIND DUE TO INTERPRETATION

Handwritten signature/initials

**FABSCO****SHELL & TUBE, LLC**

2410 Industrial Road

P.O. Box 988

Sapulpa, OK 74066

918/224-7550 Fax 918/224-3564

CERTIFICATE OF HYDROSTATIC TESTING**FABSCO SHELL & TUBE, L.L.C. JOB NUMBER:****521-13258-10****CUSTOMER NAME:****AIR PRODUCTS MANUFACTURING LLC****CUSTOMER PURCHASE ORDER NUMBER:****4505600057 / A8KM-4-402-P0-2****CUSTOMER ITEM NUMBER:****18-X-372B**THIS IS TO CERTIFY THE ABOVE UNIT WAS HYDROSTATICALLY TESTED PER
ASME CODE SECTION VIII DIVISION 1.**TESTED IN STACKED POSITION W/18-X372A**

SHELLSIDE TEST PRESSURE PSI	TUBESIDE TEST PRESSURE PSI	DATE TESTING PERFORMED
631		09.26.23
	631	09.28.23

S.S.		T.S.	
GAUGE#:	27	CAL. DATE:	04.05.23
GAUGE#:	ST.3	CAL. DATE:	07.27.23

GAUGE#:	96	CAL. DATE:	06.22.23
GAUGE#:	ST.4	CAL. DATE:	07.27.23

WITNESSED BY: BUREAU VERITAS INSPECTION AND INSURANCE COMPANY
AUTHORIZED INSPECTOR
FABSCO SHELL & TUBE, LLC.
QUALITY CONTROL DEPARTMENT**09.28.23**
DATEFABSCO SHELL TUBE, L.L.C., 2410 INDUSTRIAL ROAD, SAPULPA, OK 74066
TELEPHONE (918) 224-7550 FAX (918) 224-3564**mm**
9/28/23



FABSCO SHELL & TUBE, LLC

2410 Industrial Road
P.O. Box 988
Sapulpa, OK 74066
918/224-7550 Fax 918/224-3564

FABSCO HARDNESS TEST REPORT

FABSCO JOB #: S21-13258-10	CUSTOMER PO #: 4505600057
CUSTOMER NAME: AIR PRODUCTS	CUSTOMER ITEM #: 18-X-372B

FRONT CHANNEL

RS-1		RS-2	
W	172	W	168
HAZ	204	HAZ	178
B		B	
LS	N/A	LS	N/A
W		W	
HAZ		HAZ	
B		B	

CHANNEL NOZZLES

NOZ 81 ATT		NOZ 85 ATT	
W	190	W	208
HAZ	155	HAZ	190
B		B	
NOZ 83	ATT	NOZ 82	ATT
W	196	W	205
HAZ	198	HAZ	160
B		B	

SHELL

RS-1		RS-2	
W	177	W	175
HAZ	175	HAZ	175
B		B	
LS	N/A	LS	N/A
W		W	
HAZ		HAZ	
B		B	

SHELL NOZZLES

NOZ 71 RS		NOZ 72 RS	
W	200	W	187
HAZ	166	HAZ	158
B		B	
NOZ 74	ATT	NOZ 73	ATT
W	177	W	187
HAZ	170	HAZ	156
B		B	

CHANNEL NOZZLES

NOZ 84 ATT		NOZ 86 ATT	
W	208	W	175
HAZ	185	HAZ	205
B		B	

SHELL NOZZLES

NOZ 71 ATT		NOZ 72 ATT	
W	187	W	182
HAZ	174	HAZ	165
B		B	

W	
HAZ	
B	

10/13/2022

DATE:

Alonso Griffin

FABSCO SHELL & TUBE, LLC
QUALITY CONTROL DEPARTMENT
NDE EXAMINER

FABSCO SHELL TUBE, L.L.C., 2410 INDUSTRIAL ROAD, SAPULPA, OK 74066
TELEPHONE (918) 224-7550 FAX (918) 224-3564

10/13/22

**FABSCO****SHELL & TUBE, LLC**

2410 Industrial Road

P.O. Box 988

Sapulpa, OK 74066

(918)224-7550 Fax (918)224-3564

MAGNETIC PARTICLE EXAMINATION**FABSCO SHELL & TUBE, L.L.C. JOB NUMBER:** S21-13258-10**CUSTOMER NAME:** AIRPRODUCTS MANUFACTURING LLC**CUSTOMER P. O. NUMBER:** 4505600657 / A8KM-4-402-BD.2**CUSTOMER ITEM NUMBER:** 18-X-372B**PARTS EXAMINED / WELD JOINT EXAMINED:** ALL FORGINGS PARTS # 1,2,3,7 & 19

ENTIRE SURFACE OF FORGINGS INCLUDING WELD BEVELS PRIOR TO WELDING

Magnetic particles: DRY POWDER**Magnetic particles:****Technique:** 90° PERP, yoke**Lifting Power:**

10 lbs at 6" spacing

Equipment Type: ac yoke**Current Type:**

ac

Lighting Equipment: STREAMLIGHT LED**Illumination Level:****Demag Performed:**

no

RESULTS: NO RELEVANT INDICATIONS**REMARKS:**

No defects found.

09.12.22

Date:

*JL Burris L II***FABSCO SHELL & TUBE, L.L.C.
QUALITY CONTROL DEPARTMENT
NDE EXAMINER***M
11/16/22*

**FABSCO**

SHELL & TUBE, LLC

2410 Industrial Road

P.O. Box 988

Sapulpa, OK 74068

918/224-7550 Fax 918/224-3564

Liquid Penetrant Examination Record

Customer: AIR PRODUCTS Date: _____Job/P.O. No.: S21-13258-10 Reference Code/Specification: ASME V, VIIIAcceptance Criteria: ASME VIIIPT Procedure No. 4 Rev. No. 4Liquid Penetrant Type: ☒ Visible ☐ Fluorescent☒ VP30

Other: _____

Cleaner/Remover: E-59A Other: H₂ODeveloper: ☒ D70 Other: _____Part/Item Material Type: SA-516-70N, SA-350LF2CL1, SA-106B Material Thickness _____Lighting Equipment: ☐ Fluorescent Light Model # _____ Serial # _____☐ Verified Supplemental White Light Source: STREAMLIGHT LED

Max. Distance from object: _____

Other: _____

Light Intensity Meter When Used: Model# _____ Ser.# _____ Calibration Due Date: _____

Light Intensity On Surface To Be Examined When Measured: _____ min/max foot candles _____ Min. μ W/cm²

Comments: _____

Examination Results				
Item #	Part Identification	Accept	Reject	Indication Description
	ROOT PASS-ALL DOUBLE WELDED GROOVE			
	JOINTS, COMPLETED WELDS PRIOR TO			
	ANY REINFORCEMENT PADS AND			
	COMPLETED WELDS.	☒		
	ALL TEMPORARY ATTACHMENTS AND			
	ARC MARKS AFTER REMOVAL	☒		

Examiner: John Bungio LII Date: 10.12.22*m*
11/12



FABSCO
SHELL & TUBE, LLC
2410 Industrial Road
P.O. Box 988
Sapulpa, OK 74066
918/224-7550 Fax 918/224-3564

Liquid Penetrant Examination Record

Customer: AIR PRODUCTS Date: _____

Job/P.O. No.: S21-13258-10 Reference Code/Specification: ASME V, VIII

Acceptance Criteria: ASME VIII

PT Procedure No. 4 Rev. No. 4

Liquid Penetrant Type: ☒ Visible ☐ Fluorescent

☒ VP30

Other: _____

Cleaner/Remover: E-59A Other: H₂O

Developer: ☒ D70 Other: _____

Part/Item Material Type: SA-516-70N, SA-179 Material Thickness _____

Lighting Equipment: ☐ Fluorescent Light Model # _____ Serial # _____

☐ Verified Supplemental White Light Source: STREAMLIGHT LED

Max. Distance from object: _____

Other: _____

Light Intensity Meter When Used: Model# _____ Ser.# _____ Calibration Due Date: _____

Light Intensity On Surface To Be Examined When Measured: _____ min/max foot candles _____ Min. $\mu\text{W}/\text{cm}^2$

Comments: _____

Examination Results				
Item #	Part Identification	Accept	Reject	Indication Description
	<u>TUBE TO TUBESHEET WELDS</u>	☒		

Examiner: John Burgo LII Date: 10.01.22

m
ilw



FABSCO
SHELL & TUBE, LLC



Member HTRI

AIR & SOAP EXAMINATION

FABSCO SHELL & TUBE, LLC JOB NUMBER: S21-13258-10
CUSTOMER NAME: AIR PRODUCTS
CUSTOMER PO NUMBER: 4505600057 / A8KM-4-402-PO-2
CUSTOMER ITEM NUMBER: 18-X-372B

PARTS EXAMINED BY DIRECT PRESSURE: FRONT CHANNEL, SHELL
ALL NOZZLE REINFORCEMENT PADS

MATERIAL IDENTIFICATION: SA-516-70N	MATERIAL THICKNESS:

GAUGE MFG: ASHCROFT	MODEL:	RANGE: 0-30	PSI:
PRESSURE GAUGE #: 53	CALIBRATION DATE: 02-22-23		
TEST PRESSURE: 17 PSI	TEST CONDITIONS:		PSI:
TRACER GAS:	GAS CONCENTRATION:		PPM:
RESULTS: NO LEAKS			

REMARKS: AFTER ADDITION OF PAD EXTENSIONS

08.24.23
DATE:

John Bunjo
FABSCO SHELL & TUBE, LLC
QUALITY CONTROL DEPARTMENT
NDE EXAMINER

m
ulm

INSPECTION FORM

ETS job # H-22-318 F50

Description of repairs needed Run out 18" Bundle 13258
Front side ~~12358~~ ±10

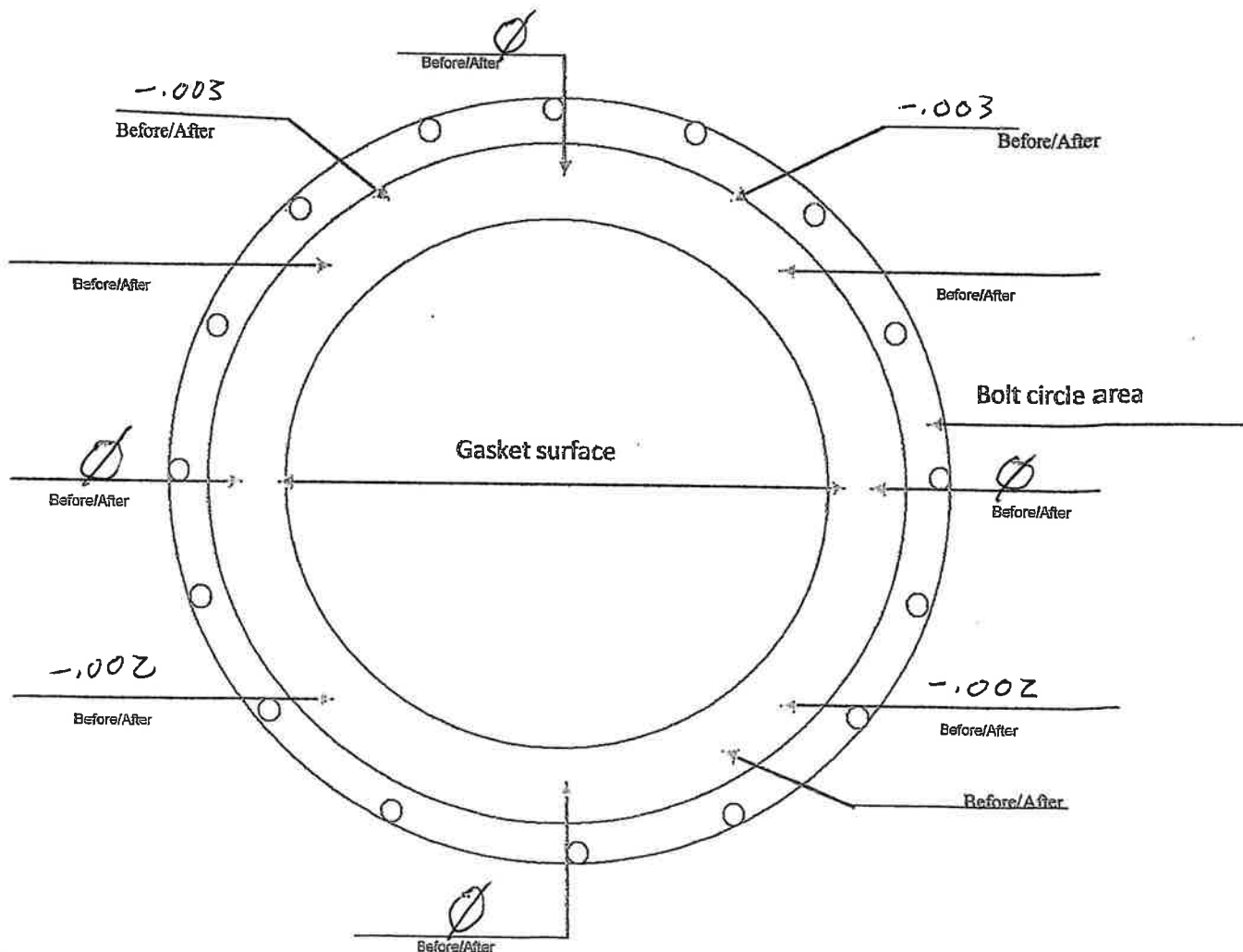
Machinist
1) Mike Wheeler [Signature] 10-12-22
PRINT NAME SIGNATURE DATE

Flange OD 17 5/16 Flange ID N/A Raise face height N/A

Flange thickness before machining 1.660 after machining N/A

Total run-out of gasket surface .003 Raise face height after machining N/A

*Insert Indicator reading on appropriate lines.



ACCEPTANCE:
For Client: [Signature] Date: 10-12-22
For ETS: [Signature] Date: 10-12-22

m/leh

INSPECTION FORM

ETS job # H-22-318 FSO

Description of repairs needed Runout 18" Bundle

13258

~~13358~~-10

Backside

Machinist

1) M. Ke Wheeler

PRINT NAME

[Signature]

SIGNATURE

10-12-22

DATE

Flange OD 17 15/16"

Flange ID N/A

Raise face height N/A

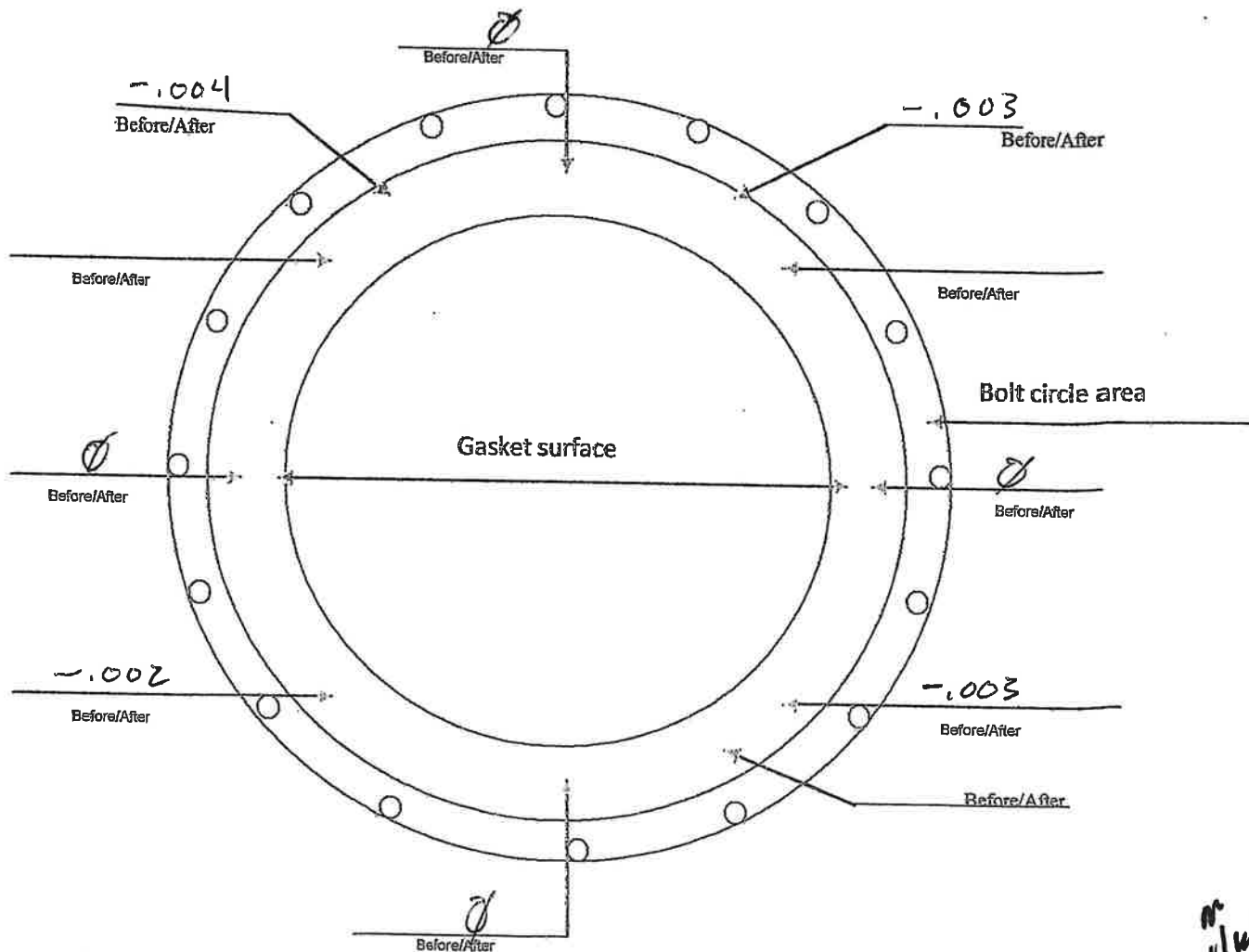
Flange thickness before machining 1.660

after machining N/A

Total run-out of gasket surface

Raise face height after machining N/A

**Insert Indicator reading on appropriate lines.*



ACCEPTANCE:

For Client:

[Signature]

Date: 10-12-22

For ETS:

[Signature]

Date: 10-12-22

Mr. [Signature]



NON DESTRUCTIVE TESTING AND INSPECTION

17110 East Pine St, Tulsa, OK 74116

Tele: (918) 234-6300 Fax: (918) 234-6301

ULTRASONIC INSPECTION AND CALIBRATION REPORT

CUSTOMER DATA

NAME FABSCO SHELL AND TUBE
ADDRESS TULSA, OK.
PURCHASE ORDER # _____
ATTENTION _____
DAY WEDNESDAY DATE 10/5/2022

JOB NUMBER: 13258-10

APPLICABLE CODE: ASME SEC VIII DIV 1

PROCEDURE # 2.5

REVISION # 1

REV. DATE: 2/18/2022

EQUIPMENT DATA

EQUIPMENT MANUFACTURER: OLYMPUS MODEL# EPOCH 650 S/N 180725210
SEARCH UNIT CABLES: #1 TYPE SINGLE LENGTH 6FT S/N _____
SEARCH UNIT CABLES: #2 TYPE _____ LENGTH _____ S/N _____
LONGITUDINAL SEARCH UNIT MFG. #1 OLYMPUS ANGLE 0 FREQ. 7.5 MHz SIZE 0.375 S/N S4940
LONGITUDINAL SEARCH UNIT MFG. #2 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
SHEAR WAVE SEARCH UNIT MFG #1 OLYMPUS ANGLE 60 FREQ. 5 MHz SIZE 0.5 S/N _____
SHEAR WAVE SEARCH UNIT MFG #2 OLYMPUS ANGLE 70 FREQ. 5 MHz SIZE 0.5 S/N _____
SHEAR WAVE SEARCH UNIT MFG #3 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
COUPLANT BRAND NAME: SONATECH TYPE: ULTRA GEL II
SPECIAL EQUIPMENT: (IF USED) N/A
CALIBRATION BLOCK TYPE: SN#65857 BCB
SIMULATION BLOCK TYPE: SN#65857 BCB

CALIBRATION DATA

LONGITUDINAL - #1 REFERENCE LEVEL 42 (db) SCANNING LEVEL 48 (db)
LONGITUDINAL - #2 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
SHEAR WAVE - ANGLE #1 REFERENCE LEVEL 44 (db) SCANNING LEVEL 50 (db)
SHEAR WAVE - ANGLE #2 REFERENCE LEVEL 48 (db) SCANNING LEVEL 54 (db)
SHEAR WAVE - ANGLE #3 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
Initial Cal. Time _____ Cal. Check _____ Ending Cal. Time _____

TEST CONDITIONS

PART CONDITION: CLEAN AND SMOOTH
SIMULATION BLOCK TEMP: AMBIENT F PART TEMP. AMBIENT F
SCANNING TYPE: CONTACT X IMMERSION _____ MANUAL _____ AUTOMATIC _____
SCANNING SPEED: LESS THAN 6" PER SECOND
SCANNING SURFACE: INSIDE _____ OUTSIDE X VERTICLE X HORIZONTAL X
SCANNING DIRECTIONS: PARALLEL X PERPENDICULAR X OPPOSING _____
PART IDENTIFICATION: UT ON NOZZLE ATTACHMENT WELDS LISTED

N-71 ACCEPTABLE
N-72 ACCEPTABLE

RESULTS: No relevant indications found of rejectable size. UT is performed

TECHNICIAN HRS. _____ ASST. HRS. _____ TRAVEL HRS. _____ MILEAGE _____ PERDIEM _____

TECHNICIAN: CHANCE BOWLING LEVEL II Cert. Type SNT-TC-1A

ASSISTANT: _____ LEVEL _____ Page _____ OF _____

CUSTOMER REPRESENTATIVE: _____ TOTAL TIME _____ Hrs.



NON DESTRUCTIVE TESTING
AND INSPECTION

17110 East Pine St, Tulsa, OK 74116

Tele: (918) 234-6300 Fax: (918) 234-6301

ULTRASONIC INSPECTION AND CALIBRATION REPORT

CUSTOMER DATA

NAME FABSCO SHELL AND TUBE
ADDRESS _____
PURCHASE ORDER # 13258
ATTENTION _____
DAY WEDNESDAY DATE 9/7/2022

JOB NUMBER: 13258

APPLICABLE CODE: ASME SEC 5 ART 4

PROCEDURE # UT2

REVISION # 15

REV. DATE: 6/8/2020

EQUIPMENT DATA

EQUIPMENT MANUFACTURER: OLYMPUS MODEL# EPOCH 650 S/N 150133512
SEARCH UNIT CABLES: #1 TYPE SINGLE LENGTH 6FT S/N _____
SEARCH UNIT CABLES: #2 TYPE _____ LENGTH _____ S/N _____
LONGITUDINAL SEARCH UNIT MFG. #1 OLYMPUS ANGLE 0 FREQ. 2.25 MHz SIZE 1" S/N 1203849
LONGITUDINAL SEARCH UNIT MFG. #2 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
SHEAR WAVE SEARCH UNIT MFG #1 OLYMPUS ANGLE 60 FREQ. 5 MHz SIZE .25" S/N 1071047
SHEAR WAVE SEARCH UNIT MFG #2 OLYMPUS ANGLE 70 FREQ. 5 MHz SIZE .25" S/N 1071047
SHEAR WAVE SEARCH UNIT MFG #3 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
COUPLANT BRAND NAME: SONATECH TYPE: ULTRA GEL II
SPECIAL EQUIPMENT: (IF USED) N/A
CALIBRATION BLOCK TYPE: IIW TYPE 2
SIMULATION BLOCK TYPE: ASME 5

CALIBRATION DATA

LONGITUDINAL - #1 REFERENCE LEVEL 42 (db) SCANNING LEVEL 48 (db)
LONGITUDINAL - #2 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
SHEAR WAVE - ANGLE #1 REFERENCE LEVEL 42 (db) SCANNING LEVEL 48 (db)
SHEAR WAVE - ANGLE #2 REFERENCE LEVEL 46 (db) SCANNING LEVEL 52 (db)
SHEAR WAVE - ANGLE #3 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
Initial Cal. Time 2:00 PM Cal. Check _____ Ending Cal. Time _____

TEST CONDITIONS

PART CONDITION: CLEAN
SIMULATION BLOCK TEMP: AMBIENT F PART TEMP. AMBIENT F
SCANNING TYPE: CONTACT X IMMERSION _____ MANUAL X AUTOMATIC _____
SCANNING SPEED: LESS THAN 6" PER SECOND
SCANNING SURFACE: INSIDE OUTSIDE X VERTICLE X HORIZONTAL X
SCANNING DIRECTIONS: PARALLEL X PERPENDICULAR X OPPOSING _____

PART IDENTIFICATION: UT ON INCERTION WELDS THROUGH 16" X .375"t SHELL :

13258-10

NOZ 81 3"

NOZ 82 3"

NOZ 83 2"

NOZ 84 2"

RESULTS: No relevant indications found of rejectable size. UT is performed

ASME SEC 8 DIV 1 APP 12

TECHNICIAN HRS. _____ ASST. HRS. _____ TRAVEL HRS. _____ MILEAGE _____ PERDIEM _____

TECHNICIAN: ISAAC DUCLOS LEVEL II Cert. Type SNT-TC-1A

ASSISTANT: _____ LEVEL _____ Page 1 OF 1

CUSOMER REPRESENTATIVE: _____ TOTAL TIME _____ Hrs.

American Piping Inspection

TECHNIQUE/INSPECTION REPORT

DATE 9/14/2022 DAY WEDNESDAY

CUSTOMER DATA

NAME: FABSCO SHELL & TUBE
 ADDRESS: SAPULPA
 PHONE: ATTN:
 W.O: 13258-10 AFE:
 JOB LOCATION: TULSA
 DESCRIPTION: F/C MATERIAL TYPE: CS

DEFECT CODE

AB-ARC BURN
 AI- ALIGNED INDICATION
 BT-BURN THOUGH
 CON- CONCAVITY
 CRACK-CRACK
 HB- HOLLOW BEAD
 IF- INADEQUATE FUSION
 IP- INCOMPLETE PENETRATION
 MA -MISALIGNMENT
 POR- POROSITY

SLI- SLAG INCLUSION
 SLL- SLAG LINE
 SURF- SURFACE INDICATION
 UCE- UNDERCUT EXTERNAL
 UCI- UNDERCUT INTERNAL

ABBREVIATED TERMS

SOD - SOURCE TO OBJECT DISTANCE
 OFD - SOURCE SIDE OF OBJECT TO FILM DISTANCE
 OD - OUTER DIAMETER
 WT - WELD THICKNESS
 WR - WELD REINFORCEMENT
 REP-REPAIR
 RES-RESHOOT
 RET-RETAKE
 BM - BASE MATERIAL

WELD/FILM NUMBER	WELDER ID	OD	BM	WR	WT	WITHIN STD'S YES NO	# FILM	FILM SIZE/MFG/TYPE	SOD	OFD	IQI S-F	#EXP	DEFECT LOCATION
1 F/C RS-1													
2 1-2	P	16	.375	.1875	.5625	✓	1	4.5X17 F80	8	.5625	B	1	
3 F/C RS-2													
4 1-2	P	16	.375	.1875	.5625	✓	1	4.5X17 F80	8	.5625	B	1	
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													

METHOD RT	SOURCE SIZE DIAG. 0.124	ISOTOPE IR-192	NO. CURIES 81	DEV. TIME AUTO	DEV. TEMP AUTO	DENSITY 2.0-4.0

NO. OF WELDS 2	FT. LONG SEAMS	STANDARDS ASME VIII DIV 5	PER DIEM	NO. OF FILM 2	EXPOSURE: DBL WALL	S. WALL X	R Factor	SCREEN
					VIEWING: DBL WALL	S. WALL X		PB

TRUCK NO. 210	REPORT NUMBER 2	PAGE NUMBER 1	TECH HOURS	ASST. HOURS	TRAVEL HOURS	TOTAL HOURS	MILEAGE	38

FILM INTERPRETER <i>Burgin LII</i> 09.25.22	ASSISTANT NAME RAVEN LAXTON	ASNT LEVEL I
COMPANY REPRESENTATIVE	NDT TECHNICIAN ROB FOSTER	ASNT LEVEL II

SIGNATURE CERTIFIES TIME AND MATERIALS CORRECT - AMERICAN PIPING INSPECTION, INC ASSUMES NO RESPONSIBILITY FOR LOSSES OF ANY KIND DUE TO INTERPRETATION

Handwritten signature/initials

American Piping Inspection

TECHNIQUE/INSPECTION REPORT

DATE 9/16/2022 DAY FRIDAY

CUSTOMER DATA

NAME: FABSCO SHELL & TUBE	
ADDRESS: SAPULPA	
PHONE:	ATTN:
W.O: 13258-10	AFE:
JOB LOCATION: TULSA	
DESCRIPTION: SHELL	MATERIAL TYPE: CS

DEFECT CODE

AB-ARC BURN
AI- ALIGNED INDICATION
BT-BURN THOUGH
CON- CONCAVITY
CRACK-CRACK

HB- HOLLOW BEAD
IF- INADEQUATE FUSION
IP- INCOMPLETE PENETRATION
MA -MISALIGNMENT
POR- POROSITY

SLI- SLAG INCLUSION
SLL- SLAG LINE
SURF- SURFACE INDICATION
UCE- UNDERCUT EXTERNAL
UCI- UNDERCUT INTERNAL

ABBREVIATED TERMS

SOD - SOURCE TO OBJECT DISTANCE
OFD - SOURCE SIDE OF OBJECT TO FILM DISTANCE
OD - OUTER DIAMETER
WT - WELD THICKNESS
WR - WELD REINFORCEMENT

REP-REPAIR
RES-RESHOOT
RET-RETAKE
BM - BASE MATERIAL

WELD/FILM NUMBER	WELDER ID	OD	BM	WR	WT	WITHIN STD'S YES NO	# FILM	FILM SIZE/MFG/TYPE	SOD	OFD	IQI S-F	#EXP	DEFECT LOCATION
1 SHELL RS-1													
2 1-2	66	16	.375	.1875	.5625	✓	1	4.5X17 F80	8	.5625	B	1	
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													

METHOD RT	SOURCE SIZE DIAG. 0.124	ISOTOPE IR-192	NO. CURIES 78	DEV. TIME AUTO	DEV. TEMP AUTO	DENSITY 2.0-4.0
NO. OF WELDS 1	FT. LONG SEAMS	STANDARDS ASME VIII 4251 API	PER DIEM	NO. OF FILM 1	EXPOSURE: DBL WALL VIEWING: DBL WALL	S. WALL X S. WALL X
TRUCK NO. 210	REPORT NUMBER 2	PAGE NUMBER 1	TECH HOURS	ASST. HOURS	TRAVEL HOURS	TOTAL HOURS
FILM INTERPRETER	B. J. L. II 09.19.22			ASSISTANT NAME		ASNT LEVEL
COMPANY REPRESENTATIVE			ROB FOSTER			ASNT LEVEL II

SIGNATURE CERTIFIES TIME AND MATERIALS CORRECT - AMERICAN PIPING INSPECTION, INC ASSUMES NO RESPONSIBILITY FOR LOSSES OF ANY KIND DUE TO INTERPRETATION

Handwritten signature/initials



TECHNIQUE/INSPECTION REPORT

DATE 10/7/2022 DAY FRIDAY

CUSTOMER DATA														
NAME: FABSCO SHELL & TUBE														
ADDRESS: SAPULPA														
PHONE:										ATTN:				
W.O: 13258-10										PO#				
JOB LOCATION: SAPULPA														
DESCRIPTION: SHELL MATERIAL TYPE: CS														
METHOD										ABREVIATED TERMS				
AB-ARC BURN		HB- HOLLOW BEAD		SLI- SLAG INCLUSION		SOD - SOURCE TO OBJECT DISTANCE								
AI- ALIGNED INDICATION		IF- INADEQUATE FUSION		SLL- SLAG LINE		OFD - SOURCE SIDE OF OBJECT TO FILM DISTANCE								
BT- BURN THROUGH		IP- INCOMPLETE PENETRATION		SURF- SURFACE INDICATION		OD - OUTER DIAMETER				REP- REPAIR				
CON- CONCAVITY		MA- MISALIGNMENT		UCE- UNDERCUT EXTERNAL		WT - WELD THICKNESS				RES- RESHOOT		RET- RETAKE		
CRACK- CRACK		POR- POROSITY		UCI- UNDERCUT INTERNAL		WR - WELD REINFORCEMENT				BM - BASE MATERIAL				
WELD/FILM NUMBER	WELDER ID	OD	BM	WR	WT	WITHIN STD'S		# FILM	FILM SIZE/MFG/TYPE	SOD	OFD	IQI S-F	#EXP	DEFECT LOCATION
						YES	NO							
1	SHELL													
2	RS-2	66	13	.375	.094	.469	✓	1	4.5X17 F80	13	.469	BF	1	
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														
14														
15														
16														
17														
18														
19														
20														
21														
22														
23														
24														
25														
26														
27														
28														
29														
30														
METHOD RT		SOURCE SIZE DIAG. 0.131		ISOTOPE IR 192		NO. CURIES 98		DEV. TIME AUTO		DEV. TEMP AUTO		DENSITY 2.0-4.0		
NO. OF WELDS 2		FT. LONG SEAMS		STANDARDS ASME SEC. VIII DIV I		PER DIEM		NO. OF FILM 1		EXPOSURE: DBL WALL S. WALL X		R Factor 2.8		SCREEN PB
VIEWING: DBL WALL S. WALL X		TRUCK NO. 210		REPORT NUMBER 3		PAGE NUMBER 1		TECH HOURS		ASST. HOURS		TRAVEL HOURS		TOTAL HOURS
MILEAGE 38		FILM INTERPRETER		10/10/22		ASSISTANT NAME		NATE SPARKS		ASNT LEVEL		I		
COMPANY REPRESENTATIVE				NDT TECHNICIAN		ROB FOSTER		ASNT LEVEL		II				

SIGNATURE CERTIFIES TIME AND MATERIALS CORRECT - AMERICAN PIPING INSPECTION, INC ASSUMES NO RESPONSIBILITY FOR LOSSES OF ANY KIND DUE TO INTERPRETATION

11/10/22



**NON DESTRUCTIVE TESTING
AND INSPECTION**

17110 East Pine St, Tulsa, OK 74116

Tele: (918) 234-6300 Fax: (918) 234-6301

ULTRASONIC INSPECTION AND CALIBRATION REPORT

CUSTOMER DATA

NAME FABSCO SHELL AND TUBE
ADDRESS TULSA, OK.
PURCHASE ORDER # _____
ATTENTION _____
DAY WEDNESDAY DATE 9/28/2022

JOB NUMBER: 13258-10

APPLICABLE CODE: ASME SEC VIII DIV 1

PROCEDURE # 2.5

REVISION # 1

REV. DATE: 2/18/2022

EQUIPMENT DATA

EQUIPMENT MANUFACTURER: OLYMPUS MODEL# EPOCH 650 S/N 180725210
SEARCH UNIT CABLES: #1 TYPE SINGLE LENGTH 6FT S/N _____
SEARCH UNIT CABLES: #2 TYPE _____ LENGTH _____ S/N _____
LONGITUDINAL SEARCH UNIT MFG. #1 OLYMPUS ANGLE 0 FREQ. 7.5 MHz SIZE 0.375 S/N S4940
LONGITUDINAL SEARCH UNIT MFG. #2 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
SHEAR WAVE SEARCH UNIT MFG #1 OLYMPUS ANGLE 60 FREQ. 5 MHz SIZE 0.5 S/N _____
SHEAR WAVE SEARCH UNIT MFG #2 OLYMPUS ANGLE 70 FREQ. 5 MHz SIZE 0.5 S/N _____
SHEAR WAVE SEARCH UNIT MFG #3 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
COUPLANT BRAND NAME: SONATECH TYPE: ULTRA GEL II
SPECIAL EQUIPMENT: (IF USED) N/A
CALIBRATION BLOCK TYPE: SN#65857 BCB
SIMULATION BLOCK TYPE: SN#65857 BCB

CALIBRATION DATA

LONGITUDINAL - #1 REFERENCE LEVEL 42 (db) SCANNING LEVEL 48 (db)
LONGITUDINAL - #2 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
SHEAR WAVE - ANGLE #1 REFERENCE LEVEL 44 (db) SCANNING LEVEL 50 (db)
SHEAR WAVE - ANGLE #2 REFERENCE LEVEL 48 (db) SCANNING LEVEL 54 (db)
SHEAR WAVE - ANGLE #3 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
Initial Cal. Time _____ Cal. Check _____ Ending Cal. Time _____

TEST CONDITIONS

PART CONDITION: CLEAN AND SMOOTH
SIMULATION BLOCK TEMP: AMBIENT F PART TEMP. AMBIENT F
SCANNING TYPE: CONTACT X IMMERSION _____ MANUAL _____ AUTOMATIC _____
SCANNING SPEED: LESS THAN 6" PER SECOND
SCANNING SURFACE: INSIDE _____ OUTSIDE X VERTICLE X HORIZONTAL X
SCANNING DIRECTIONS: PARALLEL X PERPENDICULAR X OPPOSING _____

PART IDENTIFICATION: UT ON NOZZLE ATTACHMENT WELDS LISTED

AUX-74 ACCEPTABLE

AUX-73 ACCEPTABLE

RESULTS: No relevant indications found of rejectable size. UT is performed

TECHNICIAN HRS. _____ ASST. HRS. _____ TRAVEL HRS. _____ MILEAGE _____ PERDIEM _____

TECHNICIAN: CHANCE BOWLING LEVEL II Cert. Type SNT-TC-1A

ASSISTANT: _____ LEVEL _____ Page OF

CUSTOMER REPRESENTATIVE: _____ TOTAL TIME _____ Hrs.



NON DESTRUCTIVE TESTING
AND INSPECTION

17110 East Pine St, Tulsa, OK 74116

Tele: (918) 234-6300 Fax: (918) 234-6301

ULTRASONIC INSPECTION AND CALIBRATION REPORT

CUSTOMER DATA

NAME FABSCO SHELL AND TUBE
ADDRESS TULSA, OK.
PURCHASE ORDER # _____
ATTENTION _____
DAY MONDAY DATE 9/26/2022

JOB NUMBER: 13258-10

APPLICABLE CODE: ASME SEC VIII DIV 1

PROCEDURE # 2.5

REVISION # 1

REV. DATE: 2/18/2022

EQUIPMENT DATA

EQUIPMENT MANUFACTURER: OLYMPUS MODEL# EPOCH 650 S/N 180725210
SEARCH UNIT CABLES: #1 TYPE SINGLE LENGTH 6FT S/N _____
SEARCH UNIT CABLES: #2 TYPE _____ LENGTH _____ S/N _____
LONGITUDINAL SEARCH UNIT MFG. #1 OLYMPUS ANGLE 0 FREQ. 7.5 MHz SIZE 0.375 S/N S4940
LONGITUDINAL SEARCH UNIT MFG. #2 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
SHEAR WAVE SEARCH UNIT MFG #1 OLYMPUS ANGLE 60 FREQ. 5 MHz SIZE 0.5 S/N _____
SHEAR WAVE SEARCH UNIT MFG #2 OLYMPUS ANGLE 70 FREQ. 5 MHz SIZE 0.5 S/N _____
SHEAR WAVE SEARCH UNIT MFG #3 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
COUPLANT BRAND NAME: SONATECH TYPE: ULTRA GEL II
SPECIAL EQUIPMENT: (IF USED) N/A
CALIBRATION BLOCK TYPE: SN#65857 BCB
SIMULATION BLOCK TYPE: SN#65857 BCB

CALIBRATION DATA

LONGITUDINAL - #1 REFERENCE LEVEL 42 (db) SCANNING LEVEL 48 (db)
LONGITUDINAL - #2 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
SHEAR WAVE - ANGLE #1 REFERENCE LEVEL 44 (db) SCANNING LEVEL 50 (db)
SHEAR WAVE - ANGLE #2 REFERENCE LEVEL 48 (db) SCANNING LEVEL 54 (db)
SHEAR WAVE - ANGLE #3 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
Initial Cal. Time _____ Cal. Check _____ Ending Cal. Time _____

TEST CONDITIONS

PART CONDITION: CLEAN AND SMOOTH
SIMULATION BLOCK TEMP: AMBIENT F PART TEMP. AMBIENT F
SCANNING TYPE: CONTACT X IMMERSION _____ MANUAL _____ AUTOMATIC _____
SCANNING SPEED: LESS THAN 6" PER SECOND
SCANNING SURFACE: INSIDE _____ OUTSIDE X VERTICLE X HORIZONTAL X
SCANNING DIRECTIONS: PARALLEL X PERPENDICULAR X OPPOSING _____

PART IDENTIFICATION: UT ON NOZZLE ATTACHMENT WELDS LISTED

AUX-74 REJECT

AUX-73 REJECT

AUX-85 ACCEPTABLE

AUX-86 ACCEPTABLE

48 MILES

RESULTS: All relevant indications found of rejectable size marked for repair. UT is acceptable

TECHNICIAN HRS. _____ ASST. HRS. _____ TRAVEL HRS. _____ MILEAGE _____ PERDIEM _____

TECHNICIAN: CHANCE BOWLING LEVEL II Cert. Type SNT-TC-1A

ASSISTANT: _____ LEVEL _____ Page _____ OF _____

CUSTOMER REPRESENTATIVE: _____ TOTAL TIME _____ Hrs.



NON DESTRUCTIVE TESTING
AND INSPECTION

17110 East Pine St, Tulsa, OK 74116

Tele: (918) 234-6300 Fax: (918) 234-6301

ULTRASONIC INSPECTION AND CALIBRATION REPORT

CUSTOMER DATA

NAME FABSCO SHELL AND TUBE
ADDRESS TULSA, OK.
PURCHASE ORDER #
ATTENTION
DAY FRIDAY DATE 7/7/2023

JOB NUMBER: 13258-10

APPLICABLE CODE: ASME SEC VIII DIV 1

PROCEDURE # 2.5

REVISION # 1

REV. DATE: 2/18/2022

EQUIPMENT DATA

EQUIPMENT MANUFACTURER: OLYMPUS MODEL# EPOCH 650 S/N 180725210
SEARCH UNIT CABLES: #1 TYPE SINGLE LENGTH 6FT S/N
SEARCH UNIT CABLES: #2 TYPE LENGTH S/N
LONGITUDINAL SEARCH UNIT MFG. #1 OLYMPUS ANGLE 0 FREQ. 7.5 MHz SIZE 0.375 S/N S4940
LONGITUDINAL SEARCH UNIT MFG. #2 ANGLE FREQ. MHz SIZE S/N
SHEAR WAVE SEARCH UNIT MFG #1 OLYMPUS ANGLE 60 FREQ. 5 MHz SIZE 0.5 S/N
SHEAR WAVE SEARCH UNIT MFG #2 OLYMPUS ANGLE 70 FREQ. 5 MHz SIZE 0.5 S/N
SHEAR WAVE SEARCH UNIT MFG #3 ANGLE FREQ. MHz SIZE S/N
COUPLANT BRAND NAME: SONATECH TYPE: ULTRA GEL II
SPECIAL EQUIPMENT: (IF USED) N/A
CALIBRATION BLOCK TYPE: SN#65857 BCB
SIMULATION BLOCK TYPE: SN#65857 BCB

CALIBRATION DATA

LONGITUDINAL - #1 REFERENCE LEVEL 42 (db) SCANNING LEVEL 48 (db)
LONGITUDINAL - #2 REFERENCE LEVEL (db) SCANNING LEVEL (db)
SHEAR WAVE - ANGLE #1 REFERENCE LEVEL 44 (db) SCANNING LEVEL 50 (db)
SHEAR WAVE - ANGLE #2 REFERENCE LEVEL 48 (db) SCANNING LEVEL 54 (db)
SHEAR WAVE - ANGLE #3 REFERENCE LEVEL (db) SCANNING LEVEL (db)
Initial Cal. Time Cal. Check Ending Cal. Time

TEST CONDITIONS

PART CONDITION: CLEAN AND SMOOTH
SIMULATION BLOCK TEMP: AMBIENT F PART TEMP. AMBIENT F
SCANNING TYPE: CONTACT X IMMERSION MANUAL AUTOMATIC
SCANNING SPEED: LESS THAN 6" PER SECOND
SCANNING SURFACE: INSIDE OUTSIDE X VERTICLE X HORIZONTAL X
SCANNING DIRECTIONS: PARALLEL X PERPENDICULAR X OPPOSING
PART IDENTIFICATION: UT ON WELDS LISTED

NOZ-72 AUX-75

RESULTS: No relevant indications found of rejectable size. UT is performed

TECHNICIAN HRS. ASST. HRS. TRAVEL HRS. MILEAGE PERDIEM

TECHNICIAN: CHANCE BOWLING LEVEL II Cert. Type SNT-TC-1A

ASSISTANT: LEVEL Page OF

CUSTOMER REPRESENTATIVE: TOTAL TIME Hrs.



NON DESTRUCTIVE TESTING AND INSPECTION

17110 East Pine St, Tulsa, OK 74116

Tele: (918) 234-6300 Fax: (918) 234-6301

ULTRASONIC INSPECTION AND CALIBRATION REPORT

CUSTOMER DATA

NAME FABSCO SHELL AND TUBE
ADDRESS TULSA, OK.
PURCHASE ORDER # _____
ATTENTION _____
DAY WEDNESDAY DATE 9/28/2022

JOB NUMBER: 13258-10

APPLICABLE CODE: ASME SEC VIII DIV 1

PROCEDURE # 2.5

REVISION # 1

REV. DATE: 2/18/2022

EQUIPMENT DATA

EQUIPMENT MANUFACTURER: OLYMPUS MODEL# EPOCH 650 S/N 180725210
SEARCH UNIT CABLES: #1 TYPE SINGLE LENGTH 6FT S/N _____
SEARCH UNIT CABLES: #2 TYPE _____ LENGTH _____ S/N _____
LONGITUDINAL SEARCH UNIT MFG. #1 OLYMPUS ANGLE 0 FREQ. 7.5 MHz SIZE 0.375 S/N S4940
LONGITUDINAL SEARCH UNIT MFG. #2 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
SHEAR WAVE SEARCH UNIT MFG #1 OLYMPUS ANGLE 60 FREQ. 5 MHz SIZE 0.5 S/N _____
SHEAR WAVE SEARCH UNIT MFG #2 OLYMPUS ANGLE 70 FREQ. 5 MHz SIZE 0.5 S/N _____
SHEAR WAVE SEARCH UNIT MFG #3 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
COUPLANT BRAND NAME: SONATECH TYPE: ULTRA GEL II
SPECIAL EQUIPMENT: (IF USED) N/A
CALIBRATION BLOCK TYPE: SN#65857 BCB
SIMULATION BLOCK TYPE: SN#65857 BCB

CALIBRATION DATA

LONGITUDINAL - #1 REFERENCE LEVEL 42 (db) SCANNING LEVEL 48 (db)
LONGITUDINAL - #2 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
SHEAR WAVE - ANGLE #1 REFERENCE LEVEL 44 (db) SCANNING LEVEL 50 (db)
SHEAR WAVE - ANGLE #2 REFERENCE LEVEL 48 (db) SCANNING LEVEL 54 (db)
SHEAR WAVE - ANGLE #3 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
Initial Cal. Time _____ Cal. Check _____ Ending Cal. Time _____

TEST CONDITIONS

PART CONDITION: CLEAN AND SMOOTH
SIMULATION BLOCK TEMP: AMBIENT F PART TEMP. AMBIENT F
SCANNING TYPE: CONTACT X IMMERSION _____ MANUAL _____ AUTOMATIC _____
SCANNING SPEED: LESS THAN 6" PER SECOND
SCANNING SURFACE: INSIDE _____ OUTSIDE X VERTICAL X HORIZONTAL X
SCANNING DIRECTIONS: PARALLEL X PERPENDICULAR X OPPOSING _____
PART IDENTIFICATION: UT ON NOZZLE ATTACHMENT WELDS LISTED

AUX-74 ACCEPTABLE

AUX-73 ACCEPTABLE

RESULTS: No relevant indications found of rejectable size. UT is performed

TECHNICIAN HRS. _____ ASST. HRS. _____ TRAVEL HRS. _____ MILEAGE _____ PERDIEM _____

TECHNICIAN: CHANCE BOWLING LEVEL II Cert. Type SNT-TC-1A

ASSISTANT: _____ LEVEL _____ Page _____ OF _____

CUSOMER REPRESENTATIVE: _____ TOTAL TIME _____ Hrs.



NON DESTRUCTIVE TESTING
AND INSPECTION

17110 East Pine St, Tulsa, OK 74116

Tele: (918) 234-6300 Fax: (918) 234-6301

ULTRASONIC INSPECTION AND CALIBRATION REPORT

CUSTOMER DATA

NAME FABSCO SHELL AND TUBE
ADDRESS TULSA, OK.
PURCHASE ORDER # _____
ATTENTION _____
DAY TUESDAY DATE 9/13/2022

JOB NUMBER: 13258-10

APPLICABLE CODE: ASME SEC VIII DIV 1

PROCEDURE # 2.5

REVISION # 1

REV. DATE: 2/18/2022

EQUIPMENT DATA

EQUIPMENT MANUFACTURER: OLYMPUS MODEL# EPOCH 650 S/N 180725210
SEARCH UNIT CABLES: #1 TYPE SINGLE LENGTH 6FT S/N _____
SEARCH UNIT CABLES: #2 TYPE _____ LENGTH _____ S/N _____
LONGITUDINAL SEARCH UNIT MFG. #1 OLYMPUS ANGLE 0 FREQ. 7.5 MHz SIZE 0.375 S/N S4940
LONGITUDINAL SEARCH UNIT MFG. #2 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
SHEAR WAVE SEARCH UNIT MFG #1 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
SHEAR WAVE SEARCH UNIT MFG #2 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
SHEAR WAVE SEARCH UNIT MFG #3 _____ ANGLE _____ FREQ. _____ MHz SIZE _____ S/N _____
COUPLANT BRAND NAME: SONATECH TYPE: ULTRA GEL II
SPECIAL EQUIPMENT: (IF USED) N/A
CALIBRATION BLOCK TYPE: SN#65857 BCB
SIMULATION BLOCK TYPE: SN#65857 BCB

CALIBRATION DATA

LONGITUDINAL - #1 REFERENCE LEVEL 42 (db) SCANNING LEVEL 48 (db)
LONGITUDINAL - #2 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
SHEAR WAVE - ANGLE #1 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
SHEAR WAVE - ANGLE #2 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
SHEAR WAVE - ANGLE #3 REFERENCE LEVEL _____ (db) SCANNING LEVEL _____ (db)
Initial Cal. Time _____ Cal. Check _____ Ending Cal. Time _____

TEST CONDITIONS

PART CONDITION: CLEAN AND SMOOTH
SIMULATION BLOCK TEMP: AMBIENT F PART TEMP. AMBIENT F
SCANNING TYPE: CONTACT X IMMERSION _____ MANUAL _____ AUTOMATIC _____
SCANNING SPEED: LESS THAN 6" PER SECOND
SCANNING SURFACE: INSIDE _____ OUTSIDE X VERTICLE X HORIZONTAL X
SCANNING DIRECTIONS: PARALLEL X PERPENDICULAR X OPPOSING _____

PART IDENTIFICATION: LAMINATION SCAN ON PARTS LISTED

NOZ-81, NOZ-82

RESULTS: No relevant indications found of rejectable size. UT is performed

TECHNICIAN HRS. _____ ASST. HRS. _____ TRAVEL HRS. _____ MILEAGE _____ PERDIEM _____

TECHNICIAN: CHANCE BOWLING LEVEL II Cert. Type SNT-TC-1A

ASSISTANT: _____ LEVEL _____ Page OF

CUSTOMER REPRESENTATIVE: _____ TOTAL TIME _____ Hrs.

**COATINGS INSPECTION REPORT FORM
SOLUBLE SALTS TEST REPORT**

Contractor: Protective Coating & Sandblasting				Date 1-4-2024	
Passport/Project No.: 21-13258-10				Fabsco Coating System:	
Location:				Company Rep.:	
Description:				Project Eng.:	
Inspector:				Specification Number See notes	

	Chloride	Nitrate	Sulfate	Date	Location
1	Zero	Zero	2 ppm	1 4 24	Channel
2	Zero	Zero	Zero	1 4 24	Shell
3	Zero	Zero	Zero	1 4 24	Shell
4	Zero	Zero	2 ppm	1 4 24	Shell
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Notes Spec

Unit was solvent cleaned / washed with soap and water / washed with Chlor-rid / fresh water rinsed

Maximum Salt Levels

<u>Immersion Service</u>	<u>Non-Immersion Service</u>
Chloride - 3 µg/cm ²	Chloride - 5 µg/cm ²
Nitrate - 5 µg/cm ²	Nitrate - 10 µg/cm ²
Sulfate - 10 µg/cm ²	Sulfate - 15 µg/cm ²

Minimum 3 tests per first 1000 ft² (93 m²), then 1 reading per each additional 3000 ft² (279 m²).

QC Inspector Signature

Date

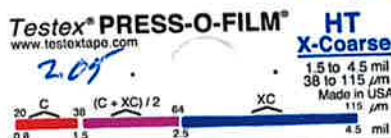
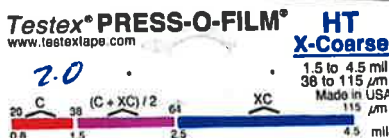
1-4-24

Zachary Veenstra
Nace Level 2
#82477

MT
1/19/24

Protective Coating & Sandblasting Co.
P. O. Box 818
Sand Springs, Ok. 74063

Facility Name/Location: Protective Coating & Sandblasting							
Item Name:		Purchaser/Location:					
Item Tag No.:		Job No: 21-13258-10 Pad 100					
Service: Support		Purchaser Order No.:					
Unit:		Supplier/Location:					
PAID No.:		Supplier Order/Serial Nos.:					
Instructions: This form shall be completed for each work shift to verify compliance with WBU-GIS 06-601-1. Record unsatisfactory work, conditions causing unsatisfactory work, and corrective action. Attach copies of all replica tape readings taken. Attach additional sheets, notes of meetings, or reports as necessary for backup. Submit a copy of all forms and back-up documents to the purchaser's inspector(s).							
Report Date: 1-5-2024							
Condition	Start of Blasting	Start of Painting	Midpoint of Painting	End of Painting			
Time	9 AM	12 PM	2 PM	4 PM			
Ambient Temperature (°F)	40	34	35	35			
Relative Humidity (%)	60	26	26	25			
Dewpoint Temperature (°F)	29	44	44	43			
Substrate Temperature (°F)	30	77	30	32			
Weather Conditions	cloudy	cloudy	cloudy	cloudy			
Surface Preparation:							
Condition of Surface Before Blasting: Mil-Scale / Rust							
Method of Removing Contamination Before Blasting: solvent clean/chlor-rid wash/water rinse							
Method of Blasting: Abrasive		Abrasive Type: Black Diamond Grade: Fine					
Degree of Cleanliness Obtained: SSPC-SP10							
Anchor Profile (mils): 20-205		Method of Measuring Anchor Profile: Press-O-Film					
Application Information:							
Method of Spraying: Conventional							
DFT Gage Type and Model: Postitest 6000			Date Calibrated: 04/01/2023				
Linings	Lining Applied	Batch No.	Lining Color	Thinner No./Type Used	DFT Specified (mils)	DFT Obtained	Actual Overcoat Interval (hrs)
Coat 1	26269	↓	Rid	220	1-2	1.6-2	1 Hr
Coat 2		↓					
Coat 3		↓					
Comments: 4022151049 4022110003 Entering from left later guard 269 Rid							
Supplier's Signature:							
Inspector's Signature:							

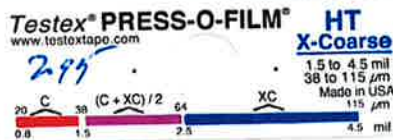
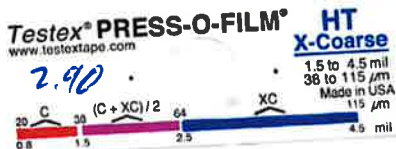


Zachary Veenstra
Nace Level 2
#82477

mi/kah

Protective Coating & Sandblasting Co.
P. O. Box 818
Sand Springs, Ok. 74063

Facility Name/Location: <u>Protective Coating & Sandblasting</u>				
Item Name: _____		Purchaser/Location: _____		
Item Tag No.: _____		Job No: <u>21-13258-10 FAD910</u>		
Service: <u>shell & channel</u>		Purchaser Order No.: _____		
Units: _____		Supplier/Location: _____		
P&ID No.: _____		Supplier Order/Serial No.: _____		
Instructions: This form shall be completed for each work shift to verify compliance with WBU-GIS 06-601-1. Record unsatisfactory work, conditions causing unsatisfactory work, and corrective action. Attach copies of all replica tape readings taken. Attach additional sheets, notes of meetings, or reports as necessary for backup. Submit a copy of all forms and back-up documents to the purchaser's inspector(s).				
Report Date: _____				
Condition	Start of Blasting	Start of Painting	Midpoint of Painting	End of Painting
Time	<u>10 AM</u>	<u>11:30 AM</u>	<u>1 PM</u>	<u>2 PM</u>
Ambient Temperature (°F)	<u>77</u>	<u>84</u>	<u>85</u>	<u>85</u>
Relative Humidity (%)	<u>76</u>	<u>25</u>	<u>24</u>	<u>24</u>
Dewpoint Temperature (°F)	<u>71</u>	<u>45</u>	<u>45</u>	<u>44</u>
Substrate Temperature (°F)	<u>80</u>	<u>84</u>	<u>85</u>	<u>85</u>
Weather Conditions	<u>cloudy</u>	<u>cloudy</u>	<u>cloudy</u>	<u>cloudy</u>
Surface Preparation:				
Condition of Surface Before Blasting: <u>Mil-Scale / Rust</u>				
Method of Removing Contamination Before Blasting: <u>solvent clean/chlor-rid wash/water rinse</u>				
Method of Blasting: <u>Abrasive</u> Abrasive Type: <u>Black Diamond</u> Grade: <u>Fine</u>				
Degree of Cleanliness Obtained: <u>SSPC-SP10</u>				
Anchor Profile (mils): <u>2.90 - 2.95</u> Method of Measuring Anchor Profile: <u>Press-O-Film</u>				
Application Information:				
Method of Spraying: <u>Conventional</u>				
DFT Gage Type and Model: <u>Postitest 6000</u> Date Calibrated: <u>04/01/2023</u>				
Linings	Lining Applied	Batch No.	Lining Color	Thinner No./Type Used
Coat 1	<u>Primer</u>	<u>↓</u>	<u>white</u>	<u>#1</u>
Coat 2				
Coat 3				
DFT Specified (mils) DFT Obtained Actual Overcoat Interval (hrs)				
<u>3-10</u> <u>4 1/2 - 5 1/2</u> <u>30 min</u>				
Comments: <u>XM 2613 BB</u> <u>XM 3343 GX</u> <u>5-W Primer H5 off white</u>				
Supplier's Signature: _____				
Inspector's Signature: <u>[Signature]</u>				



Zachary Veenstra
Nace Level 2
#82477

mf
1/15/12

stored in doc 3 in hatched
Building

Protective Coating & Sandblasting Co.
P. O. Box 818
Sand Springs, Ok. 74063

Facility Name/Location: <u>Protective Coating & Sandblasting</u>							
Item Name: _____		Purchaser/Location: _____					
Item Tag No.: _____		Job No: <u>21-13258-10 F46560</u>					
Service: <u>Shell & Change</u>		Purchaser Order No.: _____					
Unit: _____		Supplier/Location: _____					
PAID No.: _____		Supplier Order/Serial Nos.: _____					
Instructions: This form shall be completed for each work shift to verify compliance with WBU-GIS 06-601-1. Record unsatisfactory work, conditions causing unsatisfactory work, and corrective action. Attach copies of all replica tape readings taken. #3 Attach additional sheets, notes of meetings, or reports as necessary for backup. Submit a copy of all forms and back-up documents to the purchaser's inspector(s).							
Report Date: <u>1-8-2024</u>							
Condition	Start of Blasting	Start of Painting	Midpoint of Painting	End of Painting			
Time		<u>9:30 AM</u>	<u>11:30 AM</u>	<u>2:30 PM</u>			
Ambient Temperature (°F)		<u>30</u>	<u>31</u>	<u>34</u>			
Relative Humidity (%)		<u>31</u>	<u>30</u>	<u>30</u>			
Dewpoint Temperature (°F)		<u>47</u>	<u>47</u>	<u>47</u>			
Substrate Temperature (°F)		<u>30</u>	<u>31</u>	<u>34</u>			
Weather Conditions		<u>cloudy</u>	<u>cloudy</u>	<u>cloudy</u>			
Surface Preparation:							
Condition of Surface Before Blasting: <u>Mil-Scale / Rust</u>							
Method of Removing Contamination Before Blasting: <u>solvent clean/chlor-rid wash/water rinse</u>							
Method of Blasting: <u>Abrasive</u> Abrasive Type: <u>Black Diamond</u> Grade: <u>Fine</u>							
Degree of Cleanliness Obtained: <u>SSPC-SP10</u>							
Anchor Profile (mils): <u>2H #2</u> Method of Measuring Anchor Profile: <u>Press-O-Film</u>							
Application Information:							
Method of Spraying: <u>Conventional</u>							
DFT Gage Type and Model: <u>Postitest 6000</u> Date Calibrated: <u>04/01/2023</u>							
Linings	Lining Applied	Batch No.	Lining Color	Thinner No./Type Used	DFT Specified (mils)	DFT Obtained	Actual Overcoat Interval (hrs)
Coat 1	<u>Phenicon</u>	<u>2H #2</u>	<u>off white</u>	<u>#1</u>	<u>8-10</u>	<u>4 1/2 - 5 1/2</u>	<u>30 min</u>
Coat 2	<u>Phenicon</u>	<u>2H #2</u>	<u>off white</u>	<u>#1</u>		<u>4-5</u>	<u>14 Hr</u>
Coat 3							
Comments:							
<u>S-W Phenicon H2 off white</u>							
Supplier's Signature:							
Inspector's Signature:							

Zachary Veenstra
Nace Level 2
#82477

Protective Coating & Sandblasting Co.
P. O. Box 818
Sand Springs, Ok. 74063

Facility Name/Location: <u>Protective Coating & Sandblasting</u>							
Item Name: _____		Purchaser/Location: _____					
Item Tag No.: _____		Job No: <u>21-13253-10 F45910</u>					
Service: <u>211119 CH90001</u>		Purchaser Order No.: _____					
Unit: _____		Supplier/Location: _____					
P&ID No.: _____		Supplier Order/Serial Nos.: _____					
Instructions: This form shall be completed for each work shift to verify compliance with WBU-GIS 06-601-1. Record unsatisfactory work, conditions causing unsatisfactory work, and corrective action. Attach copies of all replica tape readings taken. Attach additional sheets, notes of meetings, or reports as necessary for backup. Submit a copy of all forms and back-up documents to the purchaser's inspector(s).							
Report Date: <u>1-9-2024</u>							
Condition	Start of Blasting	Start of Painting	Midpoint of Painting	End of Painting			
Time		<u>9 AM</u>	<u>11 AM</u>	<u>1:30 PM</u>			
Ambient Temperature (°F)		<u>80</u>	<u>82</u>	<u>85</u>			
Relative Humidity (%)		<u>22</u>	<u>22</u>	<u>19</u>			
Dewpoint Temperature (°F)		<u>41</u>	<u>40</u>	<u>39</u>			
Substrate Temperature (°F)		<u>80</u>	<u>82</u>	<u>85</u>			
Weather Conditions		<u>cloudy</u>	<u>cloudy</u>	<u>cloudy</u>			
Surface Preparation:							
Condition of Surface Before Blasting: <u>Mil-Scale / Rust</u>							
Method of Removing Contamination Before Blasting: <u>solvent clean/chlor-rid wash/water rinse</u>							
Method of Blasting: <u>Abrasive</u> Abrasive Type: <u>Black Diamond</u> Grade: <u>Fine</u>							
Degree of Cleanliness Obtained: <u>SSPC-SP10</u>							
Anchor Profile (mils): <u>5/16" #2</u> Method of Measuring Anchor Profile: <u>Press-O-Film</u>							
Application Information:							
Method of Spraying: <u>Conventional</u>							
DFT Gage Type and Model: <u>Postit test 6000</u> Date Calibrated: <u>04/01/2023</u>							
Linings	Lining Applied	Batch No.	Lining Color	Thinner No./Type Used	DFT Specified (mils)	DFT Obtained	Actual Overcoat Interval (hrs)
Coat 1	<u>Phenicon</u>	<u>5111#2</u>	<u>off white</u>	<u>#1</u>	<u>8-10</u>	<u>4 1/2 - 5 1/2</u>	<u>30 min</u>
Coat 2	<u>Phenicon</u>	<u>5111#2</u>	<u>off white</u>	<u>#1</u>	<u>8-10</u>	<u>4-5</u>	<u>14 Hrs</u>
Coat 3	<u>Phenicon</u>	<u>5111#2</u>	<u>off white</u>	<u>#1</u>	<u>8-10</u>	<u>5-6</u>	<u>19 1/2</u>
Comments: <u>X.M 2143 2 M</u> <u>X.M 1533 W.A</u> <u>3-W Phenicon H5 LF 6:44</u>							
Supplier's Signature: _____							
Inspector's Signature: _____							

1/1/24

Zachary Veenstra
Nace Level 2
#82477

Protective Coating & Sandblasting Co.
P. O. Box 818
Sand Springs, Ok. 74063

Facility Name/Location: Protective Coating & Sandblasting				
Item Name:		Purchaser/Location:		
Item Tag No.:		Job No: 21-13258-10 #46900		
Service: Shell & Channel		Purchaser Order No.:		
Unit:		Supplier/Location:		
P&ID No.:		Supplier Order/Serial No.:		
Instructions: This form shall be completed for each work shift to verify compliance with WBU-GIS 06-601-1. Record unsatisfactory work, conditions causing unsatisfactory work, and corrective action. Attach copies of all replica tape readings taken. Attach additional sheets, notes of meetings, or reports as necessary for backup. Submit a copy of all forms and back-up documents to the purchaser's inspector(s).				
Report Date: 1-10-2024				
Condition	Start of Blasting	Start of Painting	Midpoint of Painting	End of Painting
Time	X	10 AM	12 PM	2 PM
Ambient Temperature (°F)		31	33	34
Relative Humidity (%)		22	20	18
Dewpoint Temperature (°F)		39	39	37
Substrate Temperature (°F)		31	33	34
Weather Conditions		6/100	6/100	6/100
Surface Preparation:				
Condition of Surface Before Blasting: Mil-Scale / Rust				
Method of Removing Contamination Before Blasting: solvent clean/chlor-rid wash/water rinse				
Method of Blasting: Abrasive Abrasive Type: Black Diamond Grade: Fine				
Degree of Cleanliness Obtained: SSPC-SP10				
Anchor Profile (mils): 261#2 Method of Measuring Anchor Profile: Press-O-Film				
Application Information:				
Method of Spraying: Conventional				
DFT Gage Type and Model: Postitest 6000 Date Calibrated: 04/01/2023				
Linings	Lining Applied	Batch No.	Lining Color	Thinner No./Type Used
Coat 1	Phenicon	261#2	off white	#1
Coat 2	Phenicon	261#2	off white	#1
Coat 3	Phenicon	261#4	off white	#1
	Phenicon	261#4	off white	#1
DFT Specified (mils) DFT Obtained Actual Overcoat Interval (hrs) 8-10 4 1/2 - 5 1/2 30 min 8-10 4-5 19 8-10 5-6 18 1/2 8-10 3 1/2 - 4 1/2 21 1/2				
Comments: 5-W Phenicon H3 LT61AY 17-21				
Supplier's Signature:				
Inspector's Signature:				

mi
1/16/24

Zachary Veenstra
Nace Level 2
#82477

F

**FABSCO****SHELL & TUBE, LLC**2410 Industrial Road
P.O. Box 988
Sapulpa, OK 74066
918/224-7550 Fax 918/224-3564

Member HTRI

HEAT EXCHANGER SPECIFICATION SHEET

Page 1

US Units

Customer	AIR PRODUCTS (WORLD ENERGY PARAMOUNT)	Job No.	S-16030-8-18-X-372REV1XX
Address		Reference No.	A8KM-4-402-RQ
Plant Location	PARAMOUNT, CALIFORNIA	Proposal No.	S-16030
Service of Unit	STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER	Date	07/26/2021 Rev. C1
Size	15 x 156 inch Type AEU Horizontal	Item No.	18-X-372 A/B
Surf/Unit (Gross/Eff)	612.61 / 602.55 ft2 Shell/Unit 2	Connected In	1 Parallel 2 Series
		Surf/Shell (Gross/Eff)	306.31 / 301.27 ft2

PERFORMANCE OF ONE UNIT

Fluid Allocation	Shell Side	Tube Side
Fluid Name	STRIPPER FEED	DEBUANIZED NAPHTHA
Fluid Quantity, Total lb/hr	103250	49482
Vapor (In/Out)		934.03
Liquid	103250	102316
Steam		49482
Water		49482
Noncondensables		
Temperature (In/Out) F	110.70	157.45
Specific Gravity	0.5494	0.5229
Viscosity cP	0.1360	0.0120 V/L 0.1164
Molecular Weight, Vapor		0.1130
Molecular Weight, Noncondensables		0.1770
Specific Heat Btu/lb-F	0.6200	0.5300 V/L 0.6651
Thermal Conductivity Btu/hr-ft-F	0.0520	0.0200 V/L 0.0469
Latent Heat Btu/lb	86.271	138.11
Inlet Pressure psia	294.70	319.70
Velocity ft/sec	4.12	7.26
Pressure Drop, Allow/Calc psi	10.000	8.954
Fouling Resistance (min) ft2-hr-F/Btu	0.00200	20.000
		12.679
Heat Exchanged	3235643 Btu/hr	MTD (Corrected) 54.6 F
Transfer Rate, Service	98.39 Btu/ft2-hr-F	Clean 189.48 Btu/ft2-hr-F
		Actual 100.86 Btu/ft2-hr-F

CONSTRUCTION OF ONE SHELL**Sketch (Bundle/Nozzle Orientation)**

	Shell Side	Tube Side
Design/Test Pressure psig	375/FV / CODE	400/FV / CODE
Design Temperature F	300 / 5	330 / 300 / 32
No Passes per Shell	1	4
Corrosion Allowance inch	0.125	0.125
Connections In inch	1 @ 6"-600# RF	1 @ 3"-600# RF
Size & Rating Out inch	1 @ 6"-600# RF	1 @ 3"-600# RF
Intermediate		

Tube No.	60 U's	OD	0.7500 inch	Thk(Min)	0.083 inch	Length	13.000 ft	Pitch	1.0000 inch
Tube Type	Plain					Material	SA-179		Tube pattern 90
Shell	SA-106-B			OD	16.00 inch	Shell Cover	SA-516-70 (INTEGRAL)		
Channel or Bonnet	SA-106-B					Channel Cover	SA-516-70 (REMOVABLE)		
Tubesheet-Stationary	SA-516-70					Tubesheet-Floating			
Floating Head Cover						Impingement Plate	RODS (2 ROWS x 0.75" OD)		
Baffles-Cross	SA-516-70 (VERT. CUT)	Type	SINGLE SEG.	%Cut (Diam)	27	Spacing(c/c)	8.5042	Inlet	inch
Baffles-Long				Seal Type					
Supports-Tube				U-Bend				Type	FULL SUPPORT
Bypass Seal Arrangement	2 Pair Seal Strips			Tube-Tubesheet Joint		SEAL-WELD, ROLL & EXPAND (2 GROOVES)			
Expansion Joint				Type					
Rho-V2-Inlet Nozzle	lb/ft-sec2			Bundle Entrance		Bundle Exit		lb/ft-sec2	
Gaskets	SPIRAL WOUND								

Code Requirements	ASME SECTION VIII, DIV. 1	NATIONAL BOARD	TEMA Class R	API 660
Weight/Shell	lb	Filled with Water	lb	Bundle
				lb

1. CORN OIL JET MODE - EOR. UNIT IS THERMALLY & MECHANICALLY GUARANTEED.
2. FLOWS & DUTY INCREASED BY 10%.
3. EXCHANGERS ARE TO BE STACKED.
4. PROVIDE (1)2"-300# RFLWN W/ BLIND IN EACH PROCESS NOZZLE.
5. PROVIDE (2)2"-300# RFLWN W/ BLIND IN CHANNEL FOR VENT & DRAIN.

Output Summary

Page 1

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Summary Unit

Horizontal

No Data Check Messages.

No Runtime Messages.

Process Conditions		Cold Shellside		Hot Tubeside	
Fluid name		STRIPPER FEED		DEBUANIZED NAPTHA	
Flow rate	(1000-lb/hr)		103.25 *		49.482 *
Inlet/Outlet Y	(Wt. frac vap.)	0.0000	0.0090	0.0000	0.0000
Inlet/Outlet T	(Deg F)	110.70	157.45	247.40	145.00
Inlet P/Avg	(psia)	294.70		319.70	313.36
dP/Allow.	(psi)	8.954	10.000	12.679	20.000
Fouling	(ft2-hr-F/Btu)		0.00200		0.00200

Exchanger Performance					
Shell h	(Btu/ft2-hr-F)	400.48	Actual U	(Btu/ft2-hr-F)	100.86
Tube h	(Btu/ft2-hr-F)	522.49	Required U	(Btu/ft2-hr-F)	98.39
Hot regime	(--)	Sens. Liquid	Duty	(MM Btu/hr)	3.2356
Cold regime	(--)		Eff. area	(ft2)	602.55
EMTD	(Deg F)	54.6	Overdesign	(%)	2.51

Shell Geometry			Baffle Geometry		
TEMA type	(--)	AEU	Baffle type		
Shell ID	(inch)	15.250	Baffle cut	(Pct Dia.)	27
Series	(--)	2	Baffle orientation	(--)	Parallel
Parallel	(--)	1	Central spacing	(inch)	8.5042
Orientation	(deg)	0.00	Crosspasses	(--)	17

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(inch)	5.7610
Tube OD	(inch)	0.7500	Shell outlet	(inch)	5.7610
Length	(ft)	13.000	Inlet height	(inch)	1.8841
Pitch ratio	(--)	1.3333	Outlet height	(inch)	0.6250
Layout	(deg)	90	Tube inlet	(inch)	2.9000
Tubecount	(--)	120	Tube outlet	(inch)	2.9000
Tube Pass	(--)	4			

Thermal Resistance, %		Velocities, ft/sec			Flow Fractions	
Shell	25.19		Min	Max	A	0.109
Tube	25.45	Tubeside	6.93	7.79	B	0.688
Fouling	46.75	Crossflow	2.45	4.66	C	0.098
Metal	2.61	Longitudinal	2.90	4.16	E	0.104
					F	0.001

Series Summary

Page 2

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Summary Unit

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Unit #	1	2
Performance		
Overdesign (%)	3.14	1.88
Overall U (Btu/ft ² -hr-F)	101.90	99.82
Required U (Btu/ft ² -hr-F)	98.80	97.98
Duty (MM Btu/hr)	2.0126	1.2230
Shellside h (Btu/ft ² -hr-F)	407.43	393.64
Tubeside h (Btu/ft ² -hr-F)	535.60	509.75
Shellside delta P (psi)	4.262	4.692
Tubeside delta P (psi)	6.443	6.236
EMTD (F)	67.6	41.4
Process Conditions		
Inlet T, Shell (F)	129.45	110.70
Outlet T, Shell (F)	157.45	129.45
Inlet T, Tube (F)	247.40	185.61
Outlet T, Tube (F)	185.61	145.00
Inlet Y, Shell (Wt. fraction)	0.0000	0.0000
Outlet Y, Shell (Wt. fraction)	0.0090	0.0000
Inlet Y, Tube (Wt. fraction)	0.0000	0.0000
Outlet Y, Tube (Wt. fraction)	0.0000	0.0000
Geometry		
Shell type (--)	E	E
Parallel (--)	1	1
Effective area (ft ²)	301.27	301.27
Shell orientation (--)	Horizontal	Horizontal
Shell ID (inch)	15.250	15.250
Shellside fluid (--)	Cold	Cold
Baffle type (--)	Single-Seg.	Single-Seg.
Baffle cut (Pct Dia.)	27	27
Baffle orientation (--)	Parallel	Parallel
Central spacing (inch)	8.5042	8.5042
Crosspasses (--)	17	17
Tube type (--)	Plain	Plain
Tube Pass (--)	4	4
Tubecount (--)	120	120
Tube length (ft)	13.000	13.000
Tube OD (inch)	0.7500	0.7500
Tube layout angle (--)	90	90
Pitch ratio (--)	1.3333	1.3333

Data Check Messages

Page 3

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Summary Unit

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Summary Unit

There are no messages for the current message level setting.

Data Check Messages

Page 4

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 1

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Shell 1 - WARNING MESSAGES (CALCULATIONS CONTINUE)

Vapor density (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor viscosity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor thermal conductivity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor heat capacity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid density (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid viscosity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid thermal conductivity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid heat capacity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor density (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor viscosity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor thermal conductivity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor heat capacity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid density (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid viscosity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid thermal conductivity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid heat capacity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Data Check Messages

Page 5

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 2

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Shell 2 - WARNING MESSAGES (CALCULATIONS CONTINUE)

Vapor density (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor viscosity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor thermal conductivity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor heat capacity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid density (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid viscosity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid thermal conductivity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid heat capacity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor density (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor viscosity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor thermal conductivity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor heat capacity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid density (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid viscosity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid thermal conductivity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid heat capacity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Runtime Messages

Page 6

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Summary Unit

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Summary Unit

There are no messages for the current message level setting.

Runtime Messages

Page 7

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 1

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Shell 1 - WARNING MESSAGES (CALCULATIONS CONTINUE)

At least one incremental pressure has exceeded 95% of the boiling fluid critical pressure. This is an upper limit in the selected boiling method. The program assumed a ratio of incremental to critical pressure of 0.95 for the affected increments. HTRI methods require the true-critical pressure as opposed to the pseudo-critical pressure. If the true-critical pressure has been specified, check the specified process conditions and physical properties.

The "Tubecount" has been specified. The program has attempted to design a tube layout that matches the specified tubecount. The user should review the tube layout drawing to assure that clearances and knockout areas are valid. If not valid, the user should specify knockout distances, pass lane dimensions, and clearances or use the "Use tube layout drawing as input" option to more accurately define the bundle.

The physical properties of the cold fluid have been extrapolated beyond the valid temperature range. Check the calculated values. The thermal analysis requires properties at bulk and skin/wall temperatures.

ASME Section VIII Div. 1 Code was used to ESTIMATE all pressure vessel dimensions and weights. The dimensions in this report cannot be used to fabricate the vessel.

Specified inlet channel nozzle thickness does not meet UG-45 requirements - reinforcement calculations aborted.

Specified outlet channel nozzle thickness does not meet UG-45 requirements - reinforcement calculations aborted.

Runtime Messages

Page 8

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 2

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Shell 2 - WARNING MESSAGES (CALCULATIONS CONTINUE)

The "Tubecount" has been specified. The program has attempted to design a tube layout that matches the specified tubecount. The user should review the tube layout drawing to assure that clearances and knockout areas are valid. If not valid, the user should specify knockout distances, pass lane dimensions, and clearances or use the "Use tube layout drawing as input" option to more accurately define the bundle.

The physical properties of the hot fluid have been extrapolated beyond the valid temperature range. Check the calculated values. The thermal analysis requires properties at bulk and skin/wall temperatures.

ASME Section VIII Div. 1 Code was used to ESTIMATE all pressure vessel dimensions and weights. The dimensions in this report cannot be used to fabricate the vessel.

Specified inlet channel nozzle thickness does not meet UG-45 requirements - reinforcement calculations aborted.

Specified outlet channel nozzle thickness does not meet UG-45 requirements - reinforcement calculations aborted.

HEAT EXCHANGER RATING DATA SHEET

Page 9

Released to the following HTRI Member Company:

US Units

ST

Al Nader

Service of Unit STRIPPER FEED / DEBUTANIZER BOTTOMS EXCH Item No. 18-X-372(CORN OIL JET- EOR)

Type AEU Orientation Horizontal Connected In 1 Parallel 2 Series

Surf/Unit (Gross/Eff) 612.61 / 602.55 ft2 Shell/Unit 2 Surf/Shell (Gross/Eff) 306.31 / 301.27 ft2

PERFORMANCE OF ONE UNIT

Fluid Allocation		Shell Side		Tube Side	
Fluid Name		STRIPPER FEED		DEBUANIZED NAPTHA	
Fluid Quantity, Total	1000-lb/hr	103.25		49.482	
Vapor (In/Out)	wt%	0.00	0.90	0.00	0.00
Liquid	wt%	100.00	99.10	100.00	100.00
Temperature (In/Out)	F	110.70	157.45	247.40	145.00
Density	lb/ft3	34.280	1.9000 V/L 32.630	33.270	37.450
Viscosity	cP	0.1360	0.0120 V/L 0.1164	0.1130	0.1770
Specific Heat	Btu/lb-F	0.6200	0.5300 V/L 0.6651	0.6880	0.5890
Thermal Conductivity	Btu/hr-ft-F	0.0520	0.0200 V/L 0.0469	0.0440	0.0550
Critical Pressure	psia				
Inlet Pressure	psia	294.70		319.70	
Velocity	ft/sec	4.12		7.26	
Pressure Drop, Allow/Calc	psi	10.000	8.954	20.000	12.679
Average Film Coefficient	Btu/ft2-hr-F	400.48		522.49	
Fouling Resistance (min)	ft2-hr-F/Btu	0.00200		0.00200	
Heat Exchanged	3.2356 MM Btu/hr	MTD (Corrected)	54.6 F	Overdesign	2.51 %
Transfer Rate, Service	98.39 Btu/ft2-hr-F	Calculated	100.86 Btu/ft2-hr-F	Clean	189.48 Btu/ft2-hr-F

CONSTRUCTION OF ONE SHELL

Sketch (Bundle/Nozzle Orientation)

		Shell Side	Tube Side	
Design Pressure	psig	375.00	400.00	
Design Temperature	F	300.00	330.00	
No Passes per Shell		1	4	
Flow Direction		Upward	Downward	
Connections	In inch	1 @ 5.7610	1 @ 2.9000	
Size & Rating	Out inch	1 @ 5.7610	1 @ 2.9000	
	Liq. Out inch	@	1 @	

Tube No. 120.00	OD 0.7500 inch	Thk(Avg) 0.0905 inch	Length 13.000 ft	Pitch 1.0000 inch	Tube pattern 90
Tube Type Plain		Material Carbon steel		Pairs seal strips	2
Shell ID 15.250 inch		Kettle ID inch		Passlane Seal Rod No.	6
Cross Baffle Type Parallel		%Cut (Diam 27		Impingement Plate	Rods
Spacing(c/c) 8.5042 inch		Inlet inch		No. of Crosspasses	17
Rho-V2-Inlet Nozzle	lb/ft-sec2	Shell Entrance	lb/ft-sec2	Shell Exit	lb/ft-sec2
		Bundle Entrance	lb/ft-sec2	Bundle Exit	lb/ft-sec2
Weight/Shell	lb	Filled with Water	lb	Bundle	lb

Notes:	Thermal Resistance, %	Velocities, ft/sec	Flow Fractions
	Shell 25.19	Shellside 4.12	A 0.109
	Tube 25.45	Tubeside 7.26	B 0.688
	Fouling 46.75	Crossflow 3.72	C 0.098
	Metal 2.61	Window 4.28	E 0.104
Reported duty and flow rates include a user-specified multiplier of 1.10.			F 0.001

HEAT EXCHANGER SPECIFICATION SHEET

Page 10

Released to the following HTRI Member Company:

US Units

ST

Al Nader

Job No. S-16030-8-18-X-372REV1XX

Customer AIR PRODUCTS (WORLD ENERGY PARAMOUNT)

Reference No. A8KM-4-402-RQ

Address

Proposal No. S-16030 REV1

Plant Location PARAMOUNT, CALIFORNIA

Date 7/4/2021 Rev C1

Service of Unit STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER

Item No. 18-X-372(CORN OIL JET- EOR)

Size 15.25 x 156 inch Type AEU Horizontal

Connected In 1 Parallel 2 Series

Surf/Unit (Gross/Eff) 612.61 / 602.55 ft2

Shell/Unit 2

Surf/Shell (Gross/Eff) 306.31 / 301.27 ft2

PERFORMANCE OF ONE UNIT

Fluid Allocation		Shell Side		Tube Side	
Fluid Name		STRIPPER FEED		DEBUANIZED NAPHTHA	
Fluid Quantity, Total lb/hr		103250		49482	
Vapor (In/Out)			934.03		
Liquid		103250	102316	49482	49482
Steam					
Water					
Noncondensables					
Temperature (In/Out) F		110.70	157.45	247.40	145.00
Specific Gravity		0.5494	0.5229	0.5332	0.6002
Viscosity cP		0.1360	0.0120 V/L 0.1164	0.1130	0.1770
Molecular Weight, Vapor					
Molecular Weight, Noncondensables					
Specific Heat Btu/lb-F		0.6200	0.5300 V/L 0.6651	0.6880	0.5890
Thermal Conductivity Btu/hr-ft-F		0.0520	0.0200 V/L 0.0469	0.0440	0.0550
Latent Heat Btu/lb		86.271	138.11		
Inlet Pressure psia			294.70		319.70
Velocity ft/sec			4.12		7.26
Pressure Drop, Allow/Calc psi		10.000	8.954	20.000	12.679
Fouling Resistance (min) ft2-hr-F/Btu			0.00200		0.00200
Heat Exchanged		3235643 Btu/hr		MTD (Corrected) 54.6 F	
Transfer Rate, Service		98.39 Btu/ft2-hr-F		Clean 189.48 Btu/ft2-hr-F Actual 100.86 Btu/ft2-hr-F	

CONSTRUCTION OF ONE SHELL

Sketch (Bundle/Nozzle Orientation)

		Shell Side		Tube Side	
Design/Test Pressure psig		375.00 /		400.00 /	
Design Temperature F		300.00		330.00	
No Passes per Shell		1		4	
Corrosion Allowance inch		0.0000		0.0000	
Connections Size & Rating	In inch	1 @ 5.7610	1 @ 2.9000		
	Out inch	1 @ 5.7610	1 @ 2.9000		
	Intermediate	@	@		

Tube No.	60U	OD	0.7500	inch	Thk(Avg)	0.0905	inch	Length	13.000	ft	Pitch	1.0000	inch		
Tube Type	Plain					Material				Carbon steel				Tube pattern	90
Shell	Chrome-moly steel (1 Cr, 0.5 Mo)					ID	15.250	OD	15.750	inch	Shell Cover	SA-387 11 2 Pl. K11789			(Integ.)
Channel or Bonnet	SA-387 11 2 Pl. K11789									Channel Cover	SA-387 11 2 Pl. K11789				
Tubesheet-Stationary	Carbon steel									Tubesheet-Floating					
Floating Head Cover										Impingement Plate	Rods				
Baffles-Cross	Carbon steel	Type			%Cut (Diam)			27	Spacing(c/c)	8.5042	Inlet	inch			
Baffles-Long						Seal Type									
Supports-Tube						U-Bend				Type				Full support	
Bypass Seal Arrangement	2	pairs seal strips			Tube-Tubesheet Joint			Expanded (2 grooves)							
Expansion Joint						Type									
Rho-V2-Inlet Nozzle	lb/ft-sec2					Bundle Entrance			Bundle Exit			lb/ft-sec2			
Gaskets-Shell Side	Mach. Mtl. (Kammprofile\Flex. Face)					Tube Side	Mach. Mtl. (Kammprofile\Flex. Face)								
- Floating Head	Mach. Mtl. (Kammprofile\Flex. Face)														
Code Requirements										TEMA Class					
Weight/Shell	lb		Filled with Water			lb		Bundle		lb					

Remarks:

Note: Reported duty and flow rates include a user-specified multiplier of 1.10.

Reprinted with Permission

Output Summary

Page 1

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 1

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

See Data Check Messages Report for Warning Messages.

See Runtime Message Report for Warning Messages.

Process Conditions		Cold Shellside		Hot Tubeside	
Fluid name		STRIPPER FEED		DEBUANIZED NAPHTHA	
Flow rate	(1000-lb/hr)		103.25 *		49.482 *
Inlet/Outlet Y	(Wt. frac vap.)	0.0000	0.0090	0.0000	0.0000
Inlet/Outlet T	(Deg F)	129.45	157.45	247.40	185.61
Inlet P/Avg	(psia)	290.01	287.88	319.70	316.48
dP/Allow.	(psi)	4.262	10.000	6.443	20.000
Fouling	(ft2-hr-F/Btu)		0.00200		0.00200

Exchanger Performance					
Shell h	(Btu/ft2-hr-F)	407.43	Actual U	(Btu/ft2-hr-F)	101.90
Tube h	(Btu/ft2-hr-F)	535.60	Required U	(Btu/ft2-hr-F)	98.80
Hot regime	(--)	Sens. Liquid	Duty	(MM Btu/hr)	2.0126
Cold regime	(--)	Flow	Eff. area	(ft2)	301.27
EMTD	(Deg F)	67.6	Overdesign	(%)	3.14

Shell Geometry			Baffle Geometry		
TEMA type	(--)	AEU	Baffle type		Single-Seg.
Shell ID	(inch)	15.250	Baffle cut	(Pct Dia.)	27
Series	(--)	1	Baffle orientation	(--)	Parallel
Parallel	(--)	1	Central spacing	(inch)	8.5042
Orientation	(deg)	0.00	Crosspasses	(--)	17

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(inch)	5.7610
Tube OD	(inch)	0.7500	Shell outlet	(inch)	5.7610
Length	(ft)	13.000	Inlet height	(inch)	1.8841
Pitch ratio	(--)	1.3333	Outlet height	(inch)	0.6250
Layout	(deg)	90	Tube inlet	(inch)	2.9000
Tubecount	(--)	120	Tube outlet	(inch)	2.9000
Tube Pass	(--)	4			

Thermal Resistance, %		Velocities, ft/sec			Flow Fractions	
Shell	25.01		Min	Max	A	0.109
Tube	25.08	Tubeside	7.25	7.79	B	0.688
Fouling	47.24	Crossflow	2.46	4.66	C	0.098
Metal	2.67	Longitudinal	2.91	4.16	E	0.104
					F	0.001

Data Check Messages

Page 2

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 1

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Unit ID 101 - WARNING MESSAGES (CALCULATIONS CONTINUE)

Vapor density (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor viscosity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor thermal conductivity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor heat capacity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid density (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid viscosity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid thermal conductivity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid heat capacity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor density (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor viscosity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor thermal conductivity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor heat capacity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid density (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid viscosity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid thermal conductivity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid heat capacity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Runtime Messages

Page 3

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 1

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Unit ID 101 - WARNING MESSAGES (CALCULATIONS CONTINUE)

At least one incremental pressure has exceeded 95% of the boiling fluid critical pressure. This is an upper limit in the selected boiling method. The program assumed a ratio of incremental to critical pressure of 0.95 for the affected increments. HTRI methods require the true-critical pressure as opposed to the pseudo-critical pressure. If the true-critical pressure has been specified, check the specified process conditions and physical properties.

The "Tubecount" has been specified. The program has attempted to design a tube layout that matches the specified tubecount. The user should review the tube layout drawing to assure that clearances and knockout areas are valid. If not valid, the user should specify knockout distances, pass lane dimensions, and clearances or use the "Use tube layout drawing as input" option to more accurately define the bundle.

The physical properties of the cold fluid have been extrapolated beyond the valid temperature range. Check the calculated values. The thermal analysis requires properties at bulk and skin/wall temperatures.

ASME Section VIII Div. 1 Code was used to ESTIMATE all pressure vessel dimensions and weights. The dimensions in this report cannot be used to fabricate the vessel.

Specified inlet channel nozzle thickness does not meet UG-45 requirements - reinforcement calculations aborted.

Specified outlet channel nozzle thickness does not meet UG-45 requirements - reinforcement calculations aborted.

Final Results

Page 4

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 1

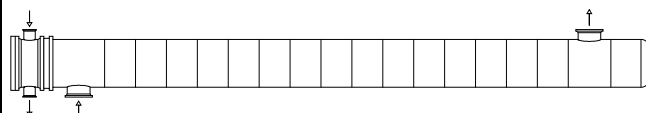
Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Process Data		Cold Shellside		Hot Tubeside	
Fluid name		STRIPPER FEED		DEBUANIZED NAPHTHA	
Fluid condition		Boil. Liquid		Sens. Liquid	
Total flow rate	(1000-lb/hr)		103.25 *		49.482 *
Weight fraction vapor, In/Out	(--)	0.0000	0.0090	0.0000	0.0000
Temperature, In/Out	(Deg F)	129.45	157.45	247.40	185.61
Skin temperature, Min/Max	(Deg F)	144.02	178.49	171.58	219.75
Wall temperature, Min/Max	(Deg F)	155.28	191.90	156.75	193.72
Pressure, In/Average	(psia)	290.01	287.88	319.70	316.48
Pressure drop, Total/Allowed	(psi)	4.262	10.000	6.443	20.000
Velocity, Mid/Max allow	(ft/sec)	4.25		7.47	
Boiling range	(Deg F)		505.0		
Average film coef.	(Btu/ft2-hr-F)		407.43		535.60
Heat transfer safety factor	(--)		1.0000		1.0000
Fouling resistance	(ft2-hr-F/Btu)		0.00200		0.00200

Overall Performance Data

Overall coef., Req'd/Clean/Actual	(Btu/ft2-hr-F)	98.80 /	193.15 /	101.90
Heat duty, Calculated/Specified	(MM Btu/hr)	2.0126 /		
Effective overall temperature difference	(Deg F)	67.6		
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg F)	67.7 *	0.9983 *	1.0000

See Runtime Messages Report for warnings.



Exchanger Fluid Volumes

Approximate shellside (ft3)	13.583
Approximate tubeside (ft3)	4.208

Shell Construction Information

TEMA shell type	AEU	Shell ID	(inch)	15.250
Shells Series	1 Parallel	1	Total area	(ft2) 306.31
Passes Shell	1 Tube	4	Eff. area	(ft2/shell) 301.27
Shell orientation angle (deg)	0.00			
Impingement present	Rods		Impingement rod rows	2
Pairs seal strips	2		Passlane seal rods (inch)	0.7500 No. 6
Shell expansion joint	No		UBend tangent to Support Dist. (inch)	1.0000
Weight estimation Wet/Dry/Bundle		3747.7 /	2637.5 /	1328.4 (lb/shell)

Baffle Information

Type	Parallel	Single-Seg.	Baffle cut (% dia)	27
Crosspasses/shellpass		17	No. (Pct Area)	(inch) to C.L.
Central spacing	(inch)	8.5042	1	22.16 3.5078
Inlet spacing	(inch)	15.125	2	0.00 0.0000
Outlet spacing	(inch)	11.750		
Baffle thickness	(inch)	0.1875		
Use deresonating baffles		No		

Tube Information

Tube type	Plain	Tubecount per shell	120
Length to tangent	(ft)	Pct tubes removed (both)	8.33
Effective length	(ft)	Outside diameter	(inch) 0.7500
Total tubesheet	(inch)	Wall thickness	(inch) 0.0905
Area ratio	(out/in)	Pitch (inch)	1.0000 Ratio 1.3333
Tube metal	Carbon steel	Tube pattern (deg)	90

Final Results Released to the following HTRI Member Company: ST Al Nader						Page 5
Xist 8.1 7/4/2021 2:14 SN: 13528-113450684						US Units
18-X-372 CORN OIL JET MODE - EOR						
STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 1						
Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles						
Shellside Performance						
Nom vel, X-flow/window		3.83 / 4.40				
Flow fractions for vapor phase						
A=0.1089		B=0.6877		C=0.0982 E=0.1042 F=0.0010		
Shellside Heat Transfer Corrections						
Total	Beta	Gamma	End	Fin		
0.982	0.920	1.068	0.979	1.000		
Pressure Drops (Percent of Total)						
Cross	Window	Ends	Nozzle	Shell	Tube	
43.57	39.16	7.54	Inlet	2.81	4.97	
MOMENTUM		0.95	Outlet	5.97	2.94	
Two-Phase Parameters						
Method	Inlet	Center	Outlet	Mix F		
PP/TBR	Subcool	Flow	Flow			
H. T. Parameters			Shell	Tube		
Overall wall correction				0.990		
Midpoint	Prandtl no.			4.30		
Midpoint	Reynolds no.		109287	140512		
Bundle inlet	Reynolds no.		62840	161241		
Bundle outlet	Reynolds no.		89735	126049		
Fouling layer		(inch)				
Thermal Resistance						
Shell	Tube	Fouling	Metal	Over Des		
25.01	25.08	47.24	2.67	3.14		
Total fouling resistance				0.0046		
Differential resistance				3.08e-4		
Shell Nozzles			Inlet	Outlet	Liquid Outlet	
Inlet at channel end-Yes						
Number at each position			1	1	0	
Diameter			(inch)	5.7610	5.7610	
Velocity			(ft/sec)	4.71	5.57	
Pressure drop			(psi)	0.120	0.254	
Height under nozzle			(inch)	1.8841	0.6250	
Nozzle R-V-SQ			(lb/ft-sec2)	746.72	881.91	
Shell ent.			(lb/ft-sec2)	402.73	2531.7	
Tube Nozzle			Inlet	Outlet	Liquid Outlet	
			RADIAL	RADIAL		
Diameter			(inch)	2.9000	2.9000	
Velocity			(ft/sec)	9.01	8.37	
Pressure drop			(psi)	0.320	0.190	
Nozzle R-V-SQ			(lb/ft-sec2)	2698.9	2508.8	
Annular Distributor			Inlet	Outlet		
Length			(inch)			
Height			(inch)			
Slot area			(in2)			
Diametral Clearances (inch)						
Baffle-to-shell		Bundle-to-shell		Tube-to-baffle		
0.1250		0.6549		0.0313		

Supplementary Results

Page 6

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 1

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Externally Enhanced Tube Geometry

Type	Plain
Fin density	(fin/inch)
Fin height	(inch)
Fin thickness	(inch)
Root diameter	(inch)
Area/length	(ft ² /ft)

Internally Enhanced Tube Geometry

Type	None
Thickness	(inch)
Pitch	(L/D)

Mean Metal Temperatures

Mean shell temperature 144.51 (F)

Mean tube metal temperature in each tubepass, (F)

<u>Tube Pass</u>	<u>Inside</u>	<u>Outside</u>	<u>Radial</u>
1	189.02	186.56	187.68
2	180.56	178.58	179.48
3	172.81	171.26	171.97
4	167.05	165.81	166.37

Vibration Analysis

Page 7

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 1

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Shellside condition	Boil. Liquid	(Level 2.3000)	
Axial stress loading (1000-psi)	0.000	Added mass factor	1.394
Beta	2.717		

Position In The Bundle	Inlet	Center	Outlet
Length for natural frequency (ft)	1.969	1.417	1.688
Length/TEMA maximum span (--)	0.394	0.283	0.338
Number of spans (--)	9	9	9
Tube natural frequency (Hz)	199.1 +	229.5	231.6
Shell acoustic frequency (Hz)			

Flow Velocities	Inlet	Center	Outlet
Window parallel velocity (ft/sec)	3.73	3.91	4.41
Bundle crossflow velocity (ft/sec)	2.29	4.36	3.48
Bundle/shell velocity (ft/sec)	2.21	2.32	1.85

Fluidelastic Instability Check	Inlet	Center	Outlet
Log decrement HTRI	0.038	0.027	0.037
Critical velocity (ft/sec)	16.66	27.53	24.04
Baffle tip cross velocity ratio (--)	0.1167	0.1345	0.1230
Average crossflow velocity ratio (--)	0.1376	0.1586	0.1449

Acoustic Vibration Check	Inlet	Center	Outlet
Vortex shedding ratio (--)			
Chen number (--)			
Turbulent buffeting ratio (--)			

Tube Vibration Check	Inlet	Center	Outlet
Vortex shedding ratio (--)	0.065	0.124	0.099
Parallel flow amplitude (inch)	0.0000	0.0000	0.0000
Crossflow amplitude (inch)	0.0002	0.0002	0.0002
Tube gap (inch)	0.2500	0.2500	0.2500
Crossflow RHO-V-SQ (lb/ft-sec2)	176.54	611.55	345.48

Bundle Entrance/Exit (analysis at first tube row)	Entrance	Exit
Fluidelastic instability ratio (--)	0.122	0.245
Vortex shedding ratio (--)	0.058	0.168
Crossflow amplitude (inch)	0.00016	0.00061
Crossflow velocity (ft/sec)	2.04	5.89
Tubesheet to inlet/outlet support (inch)	None	None

Shell Entrance/Exit Parameters	Entrance	Exit
Impingement device	Rods	--
Flow area (ft2)	0.246	0.107
Velocity (ft/sec)	3.46	9.43
RHO-V-SQ (lb/ft-sec2)	402.73	2531.7

Shell type	AEU	Baffle type	Single-Seg.
Tube type	Plain	Baffle layout	Parallel
Pitch ratio	1.3333	Tube diameter, (inch)	0.7500
Layout angle	90	Tube material	Carbon steel
Number U-Bend supports		Elastic modulus, (1000-psi)	28640
Use deresonating baffles	No	Supports/baffle space	

Program Messages

+ Frequency ratios are based upon lowest natural or acoustic frequency

* Items with asterisk exceed a conservative lower limit for vibration-free design. Review your case using the procedure described in Online Help; You may find that a vibration problem is unlikely.

HEAT EXCHANGER RATING DATA SHEET

Page 8

Released to the following HTRI Member Company:

US Units

ST

Al Nader

Service of Unit STRIPPER FEED / DEBUTANIZER BOTTOMS EXCH Item No. 18-X-372(CORN OIL JET- EOR)

Type AEU Orientation Horizontal Connected In 1 Parallel 1 Series

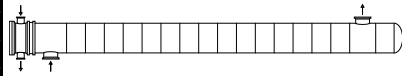
Surf/Unit (Gross/Eff) 306.31 / 301.27 ft2 Shell/Unit 1 Surf/Shell (Gross/Eff) 306.31 / 301.27 ft2

PERFORMANCE OF ONE UNIT

Fluid Allocation		Shell Side		Tube Side	
Fluid Name		STRIPPER FEED		DEBUANIZED NAPHTHA	
Fluid Quantity, Total	1000-lb/hr	103.25		49.482	
Vapor (In/Out)	wt%	0.00	0.90	0.00	0.00
Liquid	wt%	100.00	99.10	100.00	100.00
Temperature (In/Out)	F	129.45	157.45	247.40	185.61
Density	lb/ft3	33.618	1.9000 V/L 32.630	33.270	35.792
Viscosity	cP	0.1281	0.0120 V/L 0.1164	0.1130	0.1456
Specific Heat	Btu/lb-F	0.6381	0.5300 V/L 0.6651	0.6880	0.6283
Thermal Conductivity	Btu/hr-ft-F	0.0500	0.0200 V/L 0.0469	0.0440	0.0506
Critical Pressure	psia				
Inlet Pressure	psia	290.01		319.70	
Velocity	ft/sec	4.25		7.47	
Pressure Drop, Allow/Calc	psi	10.000	4.262	20.000	6.443
Average Film Coefficient	Btu/ft2-hr-F	407.43		535.60	
Fouling Resistance (min)	ft2-hr-F/Btu	0.00200		0.00200	
Heat Exchanged	2.0126 MM Btu/hr	MTD (Corrected)	67.6 F	Overdesign	3.14 %
Transfer Rate, Service	98.80 Btu/ft2-hr-F	Calculated	101.90 Btu/ft2-hr-F	Clean	193.15 Btu/ft2-hr-F

CONSTRUCTION OF ONE SHELL

Sketch (Bundle/Nozzle Orientation)

		Shell Side		Tube Side	
Design Pressure		375.00		400.00	
Design Temperature		300.00		330.00	
No Passes per Shell		1		4	
Flow Direction		Upward		Downward	
Connections	In inch	1 @ 5.7610	1 @ 2.9000		
Size &	Out inch	1 @ 5.7610	1 @ 2.9000		
Rating	Liq. Out inch	@	1 @		

Tube No.	120.00	OD	0.7500	inch	Thk(Avg)	0.0905	inch	Length	13.000	ft	Pitch	1.0000	inch	Tube pattern	90
Tube Type	Plain				Material	Carbon steel				Pairs seal strips		2			
Shell ID	15.250	inch			Kettle ID	inch			Passlane Seal Rod No.		6				
Cross Baffle Type	Parallel		Single-Seg.		%Cut (Diam		27		Impingement Plate		Rods				
Spacing(c/c)	8.5042	inch			Inlet	15.125		inch		No. of Crosspasses		17			
Rho-V2-Inlet Nozzle	746.72	lb/ft-sec2			Shell Entrance	402.73		lb/ft-sec2		Shell Exit	2531.7		lb/ft-sec2		
					Bundle Entrance	140.01		lb/ft-sec2		Bundle Exit	988.77		lb/ft-sec2		
Weight/Shell	2637.5	lb			Filled with Water	3747.7		lb		Bundle	1328.4		lb		

Notes:		Thermal Resistance, %		Velocities, ft/sec		Flow Fractions	
		Shell	25.01	Shellside	4.25	A	0.109
		Tube	25.08	Tubeside	7.47	B	0.688
		Fouling	47.24	Crossflow	3.83	C	0.098
		Metal	2.67	Window	4.40	E	0.104
						F	0.001

HEAT EXCHANGER SPECIFICATION SHEET

Page 9

Released to the following HTRI Member Company:

US Units

ST

Al Nader

Job No. S-16030-8-18-X-372REV1XX

Customer AIR PRODUCTS (WORLD ENERGY PARAMOUNT)

Reference No. A8KM-4-402-RQ

Address

Proposal No. S-16030 REV1

Plant Location PARAMOUNT, CALIFORNIA

Date 7/4/2021 Rev C1

Service of Unit STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER

Item No. 18-X-372(CORN OIL JET- EOR)

Size 15.25 x 156 inch Type AEU Horizontal

Connected In 1 Parallel 1 Series

Surf/Unit (Gross/Eff) 306.31 / 301.27 ft2

Surf/Shell (Gross/Eff) 306.31 / 301.27 ft2

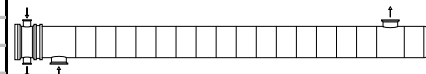
PERFORMANCE OF ONE UNIT

Fluid Allocation		Shell Side		Tube Side	
Fluid Name		STRIPPER FEED		DEBUANIZED NAPHTHA	
Fluid Quantity, Total lb/hr		103250		49482	
Vapor (In/Out)			934.03		
Liquid		103250	102316	49482	49482
Steam					
Water					
Noncondensables					
Temperature (In/Out) F		129.45	157.45	247.40	185.61
Specific Gravity		0.5387	0.5229	0.5332	0.5736
Viscosity cP		0.1281	0.0120 V/L 0.1164	0.1130	0.1456
Molecular Weight, Vapor					
Molecular Weight, Noncondensables					
Specific Heat Btu/lb-F		0.6381	0.5300 V/L 0.6651	0.6880	0.6283
Thermal Conductivity Btu/hr-ft-F		0.0500	0.0200 V/L 0.0469	0.0440	0.0506
Latent Heat Btu/lb		158.85	138.11		
Inlet Pressure psia			290.01		319.70
Velocity ft/sec			4.25		7.47
Pressure Drop, Allow/Calc psi		10.000	4.262	20.000	6.443
Fouling Resistance (min) ft2-hr-F/Btu			0.00200		0.00200
Heat Exchanged		2012632 Btu/hr		MTD (Corrected) 67.6 F	
Transfer Rate, Service		98.80 Btu/ft2-hr-F		Clean 193.15 Btu/ft2-hr-F	
				Actual 101.90 Btu/ft2-hr-F	

CONSTRUCTION OF ONE SHELL

Sketch (Bundle/Nozzle Orientation)

		Shell Side		Tube Side	
Design/Test Pressure psig		375.00 /		400.00 /	
Design Temperature F		300.00		330.00	
No Passes per Shell		1		4	
Corrosion Allowance inch		0.0000		0.0000	
Connections Size & Rating	In inch	1 @ 5.7610		1 @ 2.9000	
	Out inch	1 @ 5.7610		1 @ 2.9000	
	Intermediate	@		@	



Tube No. 60U	OD 0.7500 inch	Thk(Avg) 0.0905 inch	Length 13.000 ft	Pitch 1.0000 inch
Tube Type Plain	Material Carbon steel			Tube pattern 90
Shell Chrome-moly steel (1 Cr, 0.5 Mo)	ID 15.250	OD 15.750 inch	Shell Cover SA-387 11 2 Pl. K11789	(Integ.)
Channel or Bonnet SA-387 11 2 Pl. K11789				Channel Cover SA-387 11 2 Pl. K11789
Tubesheet-Stationary Carbon steel				Tubesheet-Floating
Floating Head Cover				Impingement Plate Rods
Baffles-Cross Carbon steel	Type Single-Seg.	%Cut (Diam) 27	Spacing(c/c) 8.5042	Inlet 15.125 inch
Baffles-Long	Seal Type None			
Supports-Tube	U-Bend			Type Full support
Bypass Seal Arrangement 2	pairs seal strips	Tube-Tubesheet Joint	Expanded (2 grooves)	
Expansion Joint	Type None			
Rho-V2-Inlet Nozzle 746.72	lb/ft-sec2	Bundle Entrance 140.01	Bundle Exit 988.77	lb/ft-sec2
Gaskets-Shell Side Mach. Mtl. (Kammprofile\Flex. Face)	Tube Side Mach. Mtl. (Kammprofile\Flex. Face)			
- Floating Head Mach. Mtl. (Kammprofile\Flex. Face)				
Code Requirements	TEMA Class R			
Weight/Shell 2637.5	lb	Filled with Water 3747.7	lb	Bundle 1328.4 lb

Remarks:

Reprinted with Permission

Output Summary

Page 1

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 2

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

See Data Check Messages Report for Warning Messages.

See Runtime Message Report for Warning Messages.

Process Conditions		Cold Shellside		Hot Tubeside	
Fluid name		STRIPPER FEED		DEBUANIZED NAPHTHA	
Flow rate	(1000-lb/hr)		103.25 *		49.482 *
Inlet/Outlet Y	(Wt. frac vap.)	0.0000	0.0000	0.0000	0.0000
Inlet/Outlet T	(Deg F)	110.70	129.45	185.61	145.00
Inlet P/Avg	(psia)	294.70	292.35	313.26	310.14
dP/Allow.	(psi)	4.692	10.000	6.236	20.000
Fouling	(ft2-hr-F/Btu)		0.00200		0.00200

Exchanger Performance					
Shell h	(Btu/ft2-hr-F)	393.64	Actual U	(Btu/ft2-hr-F)	99.82
Tube h	(Btu/ft2-hr-F)	509.75	Required U	(Btu/ft2-hr-F)	97.98
Hot regime	(--)	Sens. Liquid	Duty	(MM Btu/hr)	1.2230
Cold regime	(--)	Sens. Liquid	Eff. area	(ft2)	301.27
EMTD	(Deg F)	41.4	Overdesign	(%)	1.88

Shell Geometry			Baffle Geometry		
TEMA type	(--)	AEU	Baffle type		Single-Seg.
Shell ID	(inch)	15.250	Baffle cut	(Pct Dia.)	27
Series	(--)	1	Baffle orientation	(--)	Parallel
Parallel	(--)	1	Central spacing	(inch)	8.5042
Orientation	(deg)	0.00	Crosspasses	(--)	17

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(inch)	5.7610
Tube OD	(inch)	0.7500	Shell outlet	(inch)	5.7610
Length	(ft)	13.000	Inlet height	(inch)	1.8841
Pitch ratio	(--)	1.3333	Outlet height	(inch)	0.6250
Layout	(deg)	90	Tube inlet	(inch)	2.9000
Tubecount	(--)	120	Tube outlet	(inch)	2.9000
Tube Pass	(--)	4			

Thermal Resistance, %		Velocities, ft/sec			Flow Fractions	
Shell	25.36		Min	Max	A	0.109
Tube	25.81	Tubeside	6.93	7.24	B	0.688
Fouling	46.28	Crossflow	2.45	4.03	C	0.098
Metal	2.56	Longitudinal	2.90	3.58	E	0.104
					F	0.001

Data Check Messages

Page 2

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 2

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Unit ID 102 - WARNING MESSAGES (CALCULATIONS CONTINUE)

Vapor density (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor viscosity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor thermal conductivity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor heat capacity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid density (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid viscosity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid thermal conductivity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid heat capacity (cold,ibar 1): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor density (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor viscosity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor thermal conductivity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Vapor heat capacity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid density (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid viscosity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid thermal conductivity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Liquid heat capacity (cold,ibar 2): not all profile points were input. Value(s) will be assigned. Please ensure that both dew and bubble point data (at vapor fractions of 1 and 0) of both the liquid and vapor phases are specified.

Runtime Messages

Page 3

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 2

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Unit ID 102 - WARNING MESSAGES (CALCULATIONS CONTINUE)

The "Tubecount" has been specified. The program has attempted to design a tube layout that matches the specified tubecount. The user should review the tube layout drawing to assure that clearances and knockout areas are valid. If not valid, the user should specify knockout distances, pass lane dimensions, and clearances or use the "Use tube layout drawing as input" option to more accurately define the bundle.

The physical properties of the hot fluid have been extrapolated beyond the valid temperature range. Check the calculated values. The thermal analysis requires properties at bulk and skin/wall temperatures.

ASME Section VIII Div. 1 Code was used to ESTIMATE all pressure vessel dimensions and weights. The dimensions in this report cannot be used to fabricate the vessel.

Specified inlet channel nozzle thickness does not meet UG-45 requirements - reinforcement calculations aborted.

Specified outlet channel nozzle thickness does not meet UG-45 requirements - reinforcement calculations aborted.

Final Results

Page 4

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 2

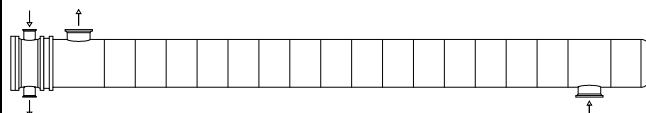
Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Process Data		Cold Shellside		Hot Tubeside	
Fluid name		STRIPPER FEED		DEBUANIZED NAPHTHA	
Fluid condition		Sens. Liquid		Sens. Liquid	
Total flow rate	(1000-lb/hr)		103.25 *		49.482 *
Weight fraction vapor, In/Out	(--)	0.0000	0.0000	0.0000	0.0000
Temperature, In/Out	(Deg F)	110.70	129.45	185.61	145.00
Skin temperature, Min/Max	(Deg F)	120.53	147.49	140.01	172.26
Wall temperature, Min/Max	(Deg F)	128.71	157.62	129.73	158.91
Pressure, In/Average	(psia)	294.70	292.35	313.26	310.14
Pressure drop, Total/Allowed	(psi)	4.692	10.000	6.236	20.000
Velocity, Mid/Max allow	(ft/sec)	4.00		7.05	
Boiling range	(Deg F)		556.5		
Average film coef.	(Btu/ft2-hr-F)		393.64		509.75
Heat transfer safety factor	(--)		1.0000		1.0000
Fouling resistance	(ft2-hr-F/Btu)		0.00200		0.00200

Overall Performance Data

Overall coef., Req'd/Clean/Actual	(Btu/ft2-hr-F)	97.98 /	185.81 /	99.82
Heat duty, Calculated/Specified	(MM Btu/hr)	1.2230 /		
Effective overall temperature difference	(Deg F)	41.4		
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg F)	41.5 *	0.9977 *	1.0000

See Runtime Messages Report for warnings.



Exchanger Fluid Volumes

Approximate shellside (ft3)	13.596
Approximate tubeside (ft3)	4.208

Shell Construction Information

TEMA shell type	AEU	Shell ID	(inch)	15.250
Shells Series	1 Parallel	1	Total area	(ft2) 306.31
Passes Shell	1 Tube	4	Eff. area	(ft2/shell) 301.27
Shell orientation angle (deg)	0.00			
Impingement present	Rods		Impingement rod rows	2
Pairs seal strips	2		Passlane seal rods (inch)	0.7500 No. 6
Shell expansion joint	No		UBend tangent to Support Dist. (inch)	1.0000
Weight estimation Wet/Dry/Bundle		3742.2 /	2631.2 /	1322.0 (lb/shell)

Baffle Information

Type	Parallel	Single-Seg.	Baffle cut (% dia)	27
Crosspasses/shellpass		17	No. (Pct Area)	(inch) to C.L.
Central spacing	(inch)	8.5042	1	22.16 3.5078
Inlet spacing	(inch)	11.750	2	0.00 0.0000
Outlet spacing	(inch)	15.125		
Baffle thickness	(inch)	0.1875		
Use deresonating baffles		No		

Tube Information

Tube type	Plain	Tubecount per shell	120
Length to tangent	(ft)	Pct tubes removed (both)	8.33
Effective length	(ft)	Outside diameter	(inch) 0.7500
Total tubesheet	(inch)	Wall thickness	(inch) 0.0905
Area ratio	(out/in)	Pitch (inch)	1.0000 Ratio 1.3333
Tube metal	Carbon steel	Tube pattern (deg)	90

Final Results Released to the following HTRI Member Company: ST Al Nader						Page 5
Xist 8.1 7/4/2021 2:14 SN: 13528-113450684						US Units
18-X-372 CORN OIL JET MODE - EOR						
STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 2						
Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles						
Shellside Performance						
Nom vel, X-flow/window		3.61 / 4.15				
Flow fractions for heat transfer		0.787				
A=0.1088		B=0.6882	C=0.0979	E=0.1040	F=0.0010	
Shellside Heat Transfer Corrections						
Total	Beta	Gamma	End	Fin		
0.982	0.920	1.068	0.971	1.000		
Pressure Drops (Percent of Total)						
Cross	Window	Ends	Nozzle	Shell	Tube	
48.51	36.80	6.86	Inlet	2.51	4.78	
MOMENTUM		0.00	Outlet	5.33	2.90	
Two-Phase Parameters						
Method	Inlet	Center	Outlet	Mix F		
H. T. Parameters			Shell	Tube		
Overall wall correction				0.996		
Midpoint	Prandtl no.		3.94	4.49		
Midpoint	Reynolds no.		100611	112158		
Bundle inlet	Reynolds no.		76391	125300		
Bundle outlet	Reynolds no.		62746	103526		
Fouling layer			(inch)			
Thermal Resistance						
Shell	Tube	Fouling	Metal	Over Des		
25.36	25.81	46.28	2.56	1.88		
Total fouling resistance				0.0046		
Differential resistance				1.88e-4		
Shell Nozzles					Liquid	
Inlet at channel end-No			Inlet	Outlet	Outlet	
Number at each position			1	1	0	
Diameter			(inch)	5.7610	5.7610	
Velocity			(ft/sec)	4.62	4.71	
Pressure drop			(psi)	0.118	0.250	
Height under nozzle			(inch)	1.8841	0.6250	
Nozzle R-V-SQ			(lb/ft-sec2)	732.29	746.72	
Shell ent.			(lb/ft-sec2)	394.95	2143.6	
Tube Nozzle			Inlet	Outlet	Liquid	
			RADIAL	RADIAL	Outlet	
Diameter			(inch)	2.9000	2.9000	
Velocity			(ft/sec)	8.37	8.00	
Pressure drop			(psi)	0.298	0.181	
Nozzle R-V-SQ			(lb/ft-sec2)	2508.8	2397.7	
Annular Distributor			Inlet	Outlet		
Length			(inch)			
Height			(inch)			
Slot area			(in2)			
Diametral Clearances (inch)						
Baffle-to-shell		Bundle-to-shell		Tube-to-baffle		
0.1250		0.6549		0.0313		

Supplementary Results

Page 6

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 2

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Externally Enhanced Tube Geometry

Type	Plain
Fin density	(fin/inch)
Fin height	(inch)
Fin thickness	(inch)
Root diameter	(inch)
Area/length	(ft ² /ft)

Internally Enhanced Tube Geometry

Type	None
Thickness	(inch)
Pitch	(L/D)

Mean Metal Temperatures

Mean shell temperature 120.62 (F)

Mean tube metal temperature in each tubepass, (F)

<u>Tube Pass</u>	<u>Inside</u>	<u>Outside</u>	<u>Radial</u>
1	148.66	147.17	147.84
2	142.35	141.20	141.72
3	137.83	136.92	137.33
4	133.62	132.92	133.24

Vibration Analysis

Page 7

Released to the following HTRI Member Company:

ST

Al Nader

Xist 8.1 7/4/2021 2:14 SN: 13528-113450684

US Units

18-X-372 CORN OIL JET MODE - EOR

STRIPPER FEED / DEBUTANIZER BTMS EXCHANGER : Shell 2

Rating - Horizontal Multipass Flow TEMA AEU Shell With Single-Segmental Baffles

Shellside condition	Sens. Liquid	(Level 2.3000)	
Axial stress loading (1000-psi)	0.000	Added mass factor	1.394
Beta	2.717		

Position In The Bundle	Inlet	Center	Outlet
Length for natural frequency (ft)	1.688	1.417	1.969
Length/TEMA maximum span (--)	0.338	0.283	0.394
Number of spans (--)	9	9	9
Tube natural frequency (Hz)	229.3	229.5	200.0 +
Shell acoustic frequency (Hz)			

Flow Velocities	Inlet	Center	Outlet
Window parallel velocity (ft/sec)	3.66	3.70	3.73
Bundle crossflow velocity (ft/sec)	2.90	4.13	2.29
Bundle/shell velocity (ft/sec)	2.17	2.19	1.21

Fluidelastic Instability Check	Inlet	Center	Outlet
Log decrement HTRI	0.038	0.038	0.038
Critical velocity (ft/sec)	22.67	32.28	16.79
Baffle tip cross velocity ratio (--)	0.1084	0.1086	0.1159
Average crossflow velocity ratio (--)	0.1277	0.1280	0.1366

Acoustic Vibration Check	Inlet	Center	Outlet
Vortex shedding ratio (--)			
Chen number (--)			
Turbulent buffeting ratio (--)			

Tube Vibration Check	Inlet	Center	Outlet
Vortex shedding ratio (--)	0.082	0.117	0.065
Parallel flow amplitude (inch)	0.0000	0.0000	0.0000
Crossflow amplitude (inch)	0.0002	0.0002	0.0002
Tube gap (inch)	0.2500	0.2500	0.2500
Crossflow RHO-V-SQ (lb/ft-sec2)	287.33	579.36	176.82

Bundle Entrance/Exit (analysis at first tube row)	Entrance	Exit
Fluidelastic instability ratio (--)	0.111	0.231
Vortex shedding ratio (--)	0.071	0.110
Crossflow amplitude (inch)	0.00013	0.00056
Crossflow velocity (ft/sec)	2.53	3.88
Tubesheet to inlet/outlet support (inch)	None	None

Shell Entrance/Exit Parameters	Entrance	Exit
Impingement device	Rods	--
Flow area (ft2)	0.246	0.107
Velocity (ft/sec)	3.39	7.99
RHO-V-SQ (lb/ft-sec2)	394.95	2143.6

Shell type	AEU	Baffle type	Single-Seg.
Tube type	Plain	Baffle layout	Parallel
Pitch ratio	1.3333	Tube diameter, (inch)	0.7500
Layout angle	90	Tube material	Carbon steel
Number U-Bend supports		Elastic modulus, (1000-psi)	29094
Use deresonating baffles	No	Supports/baffle space	

Program Messages

+ Frequency ratios are based upon lowest natural or acoustic frequency

* Items with asterisk exceed a conservative lower limit for vibration-free design. Review your case using the procedure described in Online Help; You may find that a vibration problem is unlikely.

HEAT EXCHANGER RATING DATA SHEET

Page 8

Released to the following HTRI Member Company:

US Units

ST

Al Nader

Service of Unit STRIPPER FEED / DEBUTANIZER BOTTOMS EXCH Item No. 18-X-372(CORN OIL JET- EOR)

Type AEU Orientation Horizontal Connected In 1 Parallel 1 Series

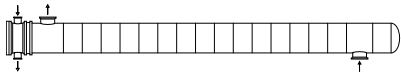
Surf/Unit (Gross/Eff) 306.31 / 301.27 ft2 Shell/Unit 1 Surf/Shell (Gross/Eff) 306.31 / 301.27 ft2

PERFORMANCE OF ONE UNIT

Fluid Allocation		Shell Side		Tube Side	
Fluid Name		STRIPPER FEED		DEBUANIZED NAPHTHA	
Fluid Quantity, Total	1000-lb/hr	103.25		49.482	
Vapor (In/Out)	wt%	0.00	0.00	0.00	0.00
Liquid	wt%	100.00	100.00	100.00	100.00
Temperature (In/Out)	F	110.70	129.45	185.61	145.00
Density	lb/ft3	34.280	33.618	35.792	37.450
Viscosity	cP	0.1360	0.1281	0.1456	0.1770
Specific Heat	Btu/lb-F	0.6200	0.6381	0.6283	0.5890
Thermal Conductivity	Btu/hr-ft-F	0.0520	0.0500	0.0506	0.0550
Critical Pressure	psia				
Inlet Pressure	psia	294.70		313.26	
Velocity	ft/sec	4.00		7.05	
Pressure Drop, Allow/Calc	psi	10.000	4.692	20.000	6.236
Average Film Coefficient	Btu/ft2-hr-F	393.64		509.75	
Fouling Resistance (min)	ft2-hr-F/Btu	0.00200		0.00200	
Heat Exchanged	1.2230 MM Btu/hr	MTD (Corrected)	41.4 F	Overdesign	1.88 %
Transfer Rate, Service	97.98 Btu/ft2-hr-F	Calculated	99.82 Btu/ft2-hr-F	Clean	185.81 Btu/ft2-hr-F

CONSTRUCTION OF ONE SHELL

Sketch (Bundle/Nozzle Orientation)

		Shell Side	Tube Side	
Design Pressure		375.00	400.00	
Design Temperature		300.00	330.00	
No Passes per Shell		1	4	
Flow Direction		Upward	Downward	
Connections	In inch	1 @ 5.7610	1 @ 2.9000	
Size &	Out inch	1 @ 5.7610	1 @ 2.9000	
Rating	Liq. Out inch	@	1 @	

Tube No.	120.00	OD	0.7500	inch	Thk(Avg)	0.0905	inch	Length	13.000	ft	Pitch	1.0000	inch	Tube pattern	90
Tube Type	Plain				Material	Carbon steel				Pairs seal strips		2			
Shell ID	15.250	inch			Kettle ID	inch				Passlane Seal Rod No.		6			
Cross Baffle Type	Parallel		Single-Seg.		%Cut (Diam		27		Impingement Plate		Rods				
Spacing(c/c)	8.5042	inch			Inlet	11.750		inch		No. of Crosspasses		17			
Rho-V2-Inlet Nozzle	732.29	lb/ft-sec2			Shell Entrance	394.95		lb/ft-sec2		Shell Exit	2143.6		lb/ft-sec2		
					Bundle Entrance	218.80		lb/ft-sec2		Bundle Exit	505.26		lb/ft-sec2		
Weight/Shell	2631.2	lb			Filled with Water	3742.2		lb		Bundle	1322.0		lb		

Notes:		Thermal Resistance, %		Velocities, ft/sec		Flow Fractions	
		Shell	25.36	Shellside	4.00	A	0.109
		Tube	25.81	Tubeside	7.05	B	0.688
		Fouling	46.28	Crossflow	3.61	C	0.098
		Metal	2.56	Window	4.15	E	0.104
						F	0.001

HEAT EXCHANGER SPECIFICATION SHEET

Page 9

Released to the following HTRI Member Company:

US Units

ST

Al Nader

Job No. S-16030-8-18-X-372REV1XX

Customer AIR PRODUCTS (WORLD ENERGY PARAMOUNT)

Reference No. A8KM-4-402-RQ

Address

Proposal No. S-16030 REV1

Plant Location PARAMOUNT, CALIFORNIA

Date 7/4/2021

Rev C1

Service of Unit STRIPPER FEED / DEBUTANIZER BOTTOMS EXCHANGER

Item No. 18-X-372(CORN OIL JET- EOR)

Size 15.25 x 156 inch Type AEU Horizontal

Connected In 1 Parallel 1 Series

Surf/Unit (Gross/Eff) 306.31 / 301.27 ft2

Surf/Shell (Gross/Eff) 306.31 / 301.27 ft2

PERFORMANCE OF ONE UNIT

Fluid Allocation		Shell Side		Tube Side	
Fluid Name		STRIPPER FEED		DEBUANIZED NAPHTHA	
Fluid Quantity, Total lb/hr		103250		49482	
Vapor (In/Out)					
Liquid		103250	103250	49482	49482
Steam					
Water					
Noncondensables					
Temperature (In/Out) F		110.70	129.45	185.61	145.00
Specific Gravity		0.5494	0.5387	0.5736	0.6002
Viscosity cP		0.1360	0.1281	0.1456	0.1770
Molecular Weight, Vapor					
Molecular Weight, Noncondensables					
Specific Heat Btu/lb-F		0.6200	0.6381	0.6283	0.5890
Thermal Conductivity Btu/hr-ft-F		0.0520	0.0500	0.0506	0.0550
Latent Heat Btu/lb		86.271	158.85		
Inlet Pressure psia		294.70		313.26	
Velocity ft/sec		4.00		7.05	
Pressure Drop, Allow/Calc psi		10.000	4.692	20.000	6.236
Fouling Resistance (min) ft2-hr-F/Btu		0.00200		0.00200	
Heat Exchanged 1223011 Btu/hr				MTD (Corrected) 41.4 F	
Transfer Rate, Service 97.98 Btu/ft2-hr-F		Clean 185.81	Btu/ft2-hr-F	Actual 99.82	Btu/ft2-hr-F

CONSTRUCTION OF ONE SHELL

Sketch (Bundle/Nozzle Orientation)

		Shell Side		Tube Side	
Design/Test Pressure psig		375.00 /		400.00 /	
Design Temperature F		300.00		330.00	
No Passes per Shell		1		4	
Corrosion Allowance inch		0.0000		0.0000	
Connections Size & Rating	In inch	1 @ 5.7610		1 @ 2.9000	
	Out inch	1 @ 5.7610		1 @ 2.9000	
	Intermediate	@		@	



Tube No. 60U	OD 0.7500 inch	Thk(Avg) 0.0905 inch	Length 13.000 ft	Pitch 1.0000 inch
Tube Type Plain	Material Carbon steel			Tube pattern 90
Shell Chrome-moly steel (1 Cr, 0.5 Mo)	ID 15.250	OD 15.750 inch	Shell Cover SA-387 11 2 Pl. K11789	(Integ.)
Channel or Bonnet SA-387 11 2 Pl. K11789				Channel Cover SA-387 11 2 Pl. K11789
Tubesheet-Stationary Carbon steel				Tubesheet-Floating
Floating Head Cover				Impingement Plate Rods
Baffles-Cross Carbon steel	Type Single-Seg.	%Cut (Diam) 27	Spacing(c/c) 8.5042	Inlet 11.750 inch
Baffles-Long	Seal Type None			
Supports-Tube	U-Bend			Type Full support
Bypass Seal Arrangement 2 pairs seal strips	Tube-Tubesheet Joint Expanded (2 grooves)			
Expansion Joint	Type None			
Rho-V2-Inlet Nozzle 732.29 lb/ft-sec2	Bundle Entrance 218.80			Bundle Exit 505.26 lb/ft-sec2
Gaskets-Shell Side Mach. Mtl. (Kammprofile\Flex. Face)	Tube Side Mach. Mtl. (Kammprofile\Flex. Face)			
- Floating Head Mach. Mtl. (Kammprofile\Flex. Face)				
Code Requirements	TEMA Class R			
Weight/Shell 2631.2 lb	Filled with Water	3742.2 lb	Bundle 1322.0 lb	

Remarks:

Reprinted with Permission

G

 U RT-4			11283 CERTIFIED BY FABSCO SHELL & TUBE, LLC PLANT 2, SAPULPA, OKLAHOMA	
	MAWP		MAWT	
	SHELL	405	PSI AT	300 °F.
	MAEWP		MAWT	
	SHELL	15	PSI AT	300 °F.
	MDMT		MAWP	
	SHELL	5	°F. AT	405 PSI
	MAWP		MAWT	
	TUBES	405	PSI AT	330 °F.
	MAEWP		MAWT	
TUBES	15	PSI AT	300 °F.	
MDMT		MAWP		
TUBES	32	°F. AT	405 PSI	
SERIAL NUMBER		YEAR BUILT		ITEM/TAG NUMBER
S21-13258-10		2023		18-X-372B
PO #: 4505600057 HYDRO TEST DATE: 9/28/2023				
DEBUTANIZER BOTTOMS EXCHANGER				

INFORMATION NAMEPLATE	
HYDRO TEST PRESS. PSIG, TUBESIDE: SHOP: 631/FIELD-527	
HYDRO TEST PRESS. PSIG, SHELLSIDE: SHOP-631/FIELD-527	
DESIGN PRESS.: SHELLSIDE=375 PSIG; TUBESIDE=400 PSIG	
SECT. VIII, DIV. 1, 2021 ED; API-660; TEMA "R"	

*m
1/12/23*

Н

Flanged Joint Assembly Record and Tightening Sequence

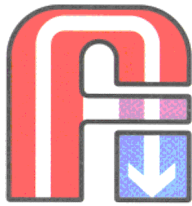


Project Name WORLD ENERGY RENEWABLES PROJECT		Project Number EN-20-7120	
Contact Name			Contact Phone Number
Unit or Equipment Item Number S21-13258-10 18-X-372B		Piping Isometric Number	
Flange Identification PARTS 1, 2, 3, 7	Flange Size and Rating	Flange Type (FF, RF, RTJ)	
Gasket Type SPIRAL WOUND	Gasket Material 316 SS	Lubricant Used EZ BREAK COMPOUND	
Number of Bolts 28	Bolt Material SA-193-B7	New Bolts Used? ☒ Yes ☐ No	
Bolt Length (1 & 2) 9 5/8", (3 & 7) 12 1/8"	Bolt Diameter 7/8" O.D.	Washers Used? ☒ Yes ☐ No	
Nut Material SA-194-2H		Target Torque (ft-lbs) 378.7	Target Stress (ksi)
Torque Wrench Manufacture HYTORC		Torque Wrench Model STEALTH 2	Calibration Certificate # 1233654853

Torque Settings	Torque (ft-lbs)	Regulator Pressure (psi)
1st Pass @ 30%	113.61	100
2nd Pass @ 70%	265.09	100
3rd Pass @ 100%	378.7	100
4th Pass @ 100%	378.7	100
5th Pass (when specified) @ 100% (4 to 24 hours after 4th Pass)	378.7	100
	Date	Time
Initial Flg. Alignment Checked	10/12/2022	
4th Pass Torque Completed		
5th Pass Torque Completed		
Final Flange Gap Checked	9/26/2023	

Notes

QA/QC Supervisor's Signature Mike Olson	12/13/2023



FABSCO

SHELL & TUBE. LLC

2410 Industrial Road
P.O. Box 988
Sapulpa, OK 74066
918/224-7550 Fax 918/224-3564

CERTIFICATE OF COMPLIANCE

**To: AIR PRODUCTS
1940 AIR PRODUCTS BLVD
ALLENTOWN, PA 18106**

**Equipment Name: STRIPPER FEED /
DEBUTANIZER BOTTOMS EXCHANGER**

Purchase Order No.: 4505600057

Item#: 18-X-372B

Drawing No.: S21-13258-10-1

Rev. No.: 8

Fabsco Shell & Tube LLC Job No.: S21-13258-10

Fabsco Shell & Tube, L.L.C. certified that the above Purchase Agreement/Item Numbers meet the requirements of ASME Code & applicable Purchase Agreement/Customer Requirements.

Signature: Mike Olson

9/28/2023

Mike Olson, QC Manager

Date:

I



INSTALLATION, OPERATION & MAINTENANCE MANUAL

for

SHELL AND TUBE HEAT EXCHANGERS

INSTALLATION, OPERATION & MAINTENANCE MANUAL – Shell & Tube Heat Exchangers

FABSCO
SHELL & TUBE, LLC

P.O. Box 988
Sapulpa, Oklahoma 74066
918/224-7550

FORWARD

Included in this manual are Tables and Figures which are reprinted in their entirety from the Standards of the Tubular Exchanger Manufacturers Association Tenth Edition (2019). Pages containing such material contain a citation to that publication.

Additionally, there are extensive extracts of text reprinted from the 10th Edition TEMA Standards. Pages containing such excerpts contain a footnote to that effect.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise.

The information in this publication is based on the collective experience of Industry engineers and technicians. While the information is intended to be comprehensive and thorough, it is subject to change based on particular applications, field experience and technological developments. The Tube Exchanger Manufacturers Association expressly disclaims any warranty of fitness for a particular application, as well as any claims for compensatory, consequential or other damages arising out of or related to the use of this publication.

TABLE OF CONTENTS

	Page
SAFETY CONSIDERATIONS	4
SECTION 1 HEAT EXCHANGER NOMENCLATURE..... Paragraphs N-1 and N-2	5
SECTION 2 IDENTIFICATION AND DEFINITIONS Paragraphs D-2.1 through D-2.28	8
SECTION 3 INSTALLATION OF HEAT EXCHANGERS Paragraphs E-3 through E-3.3	9
SECTION 4 OPERATION OF HEAT EXCHANGERS Paragraphs E-4 through E-4.4.2	11
SECTION 5 MAINTENANCE OF HEAT EXCHANGERS Paragraphs E-5 through E-5.10	14

GENERAL INSTUCTIONS FOR INSTALLATION, OPERATION AND MAINTENANCE OF SHELL AND TUBE HEAT EXCHANGERS

SAFETY CONSIDERATIONS

LIFTING DEVICES

When eyebolts, lugs, clips or other devices are installed by the manufacturer, it is intended that these lifting devices are to lift only the empty components to which they are attached and not the assembled heat exchanger, unless explicitly specified otherwise.

Proper rigging must be used in lifting assembled heat exchangers. Exchangers are usually much heavier than pressure vessels of comparable dimensions; therefore, weights should be carefully evaluated. Where available, determinations should include reference to manufacturers drawings, added components, bill of lading, etc. Special care must be exercised in handling exchangers with expansion joints.

ROUTING PRECAUTIONARY PROCEDURES

A heat exchanger is a multi-chamber pressure vessel designed at specific limits of pressure, temperature and fluid flow conditions as shown on the exchanger specification sheet and heat exchanger nameplate(s). The process system, which includes the heat exchanger, must be safeguarded so that the heat exchanger design conditions and operating limits are not exceeded. All operating and maintenance personnel should be made aware of specific limitations including pressures and temperatures flow rates, start-up/shut-down procedures and cleaning procedures.

Do not remove channel covers, shell covers, floating head covers, bonnets or connecting piping until all pressure has been relieved and both shell and tube sides are completely drained. Exceptions are permissible when design permits independent pressure testing of shell or tube sides.

Plugged tubes and double tubesheets, unless vented, may remain pressurized after shell and tube side are depressurized. Caution may be exercised in loosening of tube plugs or opening of vents to avoid sudden release of pressure or harmful fluids.

Many heat exchangers circulate fluids, which are toxic, lethal or flammable and dangerous to the human system. These fluids could cause problems if bolted or threaded joints are not maintained in leak-tight condition under operating or no-flow ambient conditions. Proper precautions, such as effective draining and purging, must be taken in handling and decontamination when exchangers are opened for any reason. It is essential that the user advises maintenance or repair personnel, including outside contractors, when toxic, lethal, or flammable conditions exist.

When heat exchangers are cleaned, it is important that full characteristics of the circulating fluids, fouling material, and the cleaning agent be known and care exercised in handling them. Use eye protection, a respirator, or other appropriate protective devices.

Do not blow out heat exchangers with air when the process fluids or the cleaning fluids being handled are flammable or reactive.

SECTION 1 HEAT EXCHANGER NOMENCLATURE

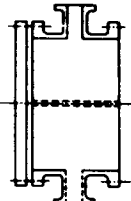
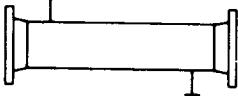
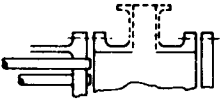
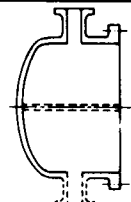
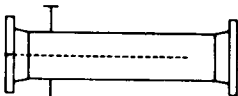
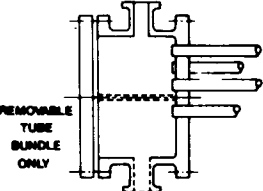
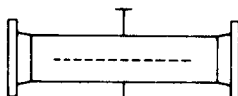
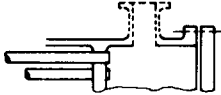
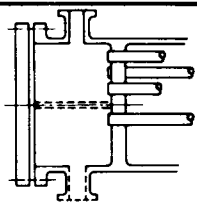
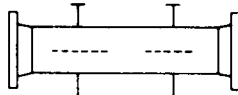
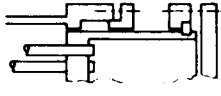
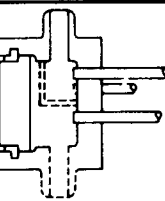
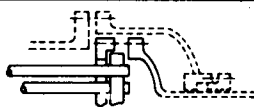
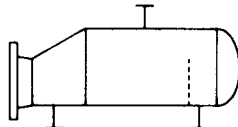
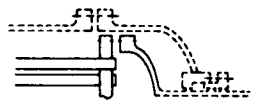
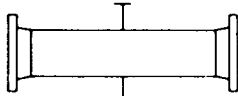
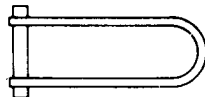
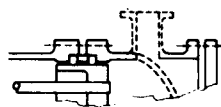
N-1 TYPE DESIGNATION-RECOMMENDED PRACTICE

It is recommended that heat exchanger type be designated by letters as described below.

N-1.1 TYPE

Type designation shall be by letters describing stationary head, shell (omitted for bundles only), and rear head, in that order, as indicated in Figure N-1.1.

FIGURE N-1.1

	FRONT END STATIONARY HEAD TYPES		SHELL TYPES		REAR END HEAD TYPES
A	 CHANNEL AND REMOVABLE COVER	E	 ONE PASS SHELL	L	 FIXED TUBESHEET LIKE "A" STATIONARY HEAD
B	 BONNET (INTEGRAL COVER)	F	 TWO PASS SHELL WITH LONGITUDINAL BAFFLE	M	 FIXED TUBESHEET LIKE "B" STATIONARY HEAD
C	 REMOVABLE TUBE BUNDLE ONLY CHANNEL INTEGRAL WITH TUBE- SHEET AND REMOVABLE COVER	G	 SPLIT FLOW	N	 FIXED TUBESHEET LIKE "N" STATIONARY HEAD
N	 CHANNEL INTEGRAL WITH TUBE- SHEET AND REMOVABLE COVER	H	 DOUBLE SPLIT FLOW	P	 OUTSIDE PACKED FLOATING HEAD
D	 SPECIAL HIGH PRESSURE CLOSURE	J	 DIVIDED FLOW	S	 FLOATING HEAD WITH BACKING DEVICE
		K	 KETTLE TYPE REBOILER	T	 PULL THROUGH FLOATING HEAD
		X	 CROSS FLOW	U	 U-TUBE BUNDLE
				W	 EXTERNALLY SEALED FLOATING TUBESHEET

SECTION 1

HEAT EXCHANGER NOMENCLATURE

N-2 NOMENCLATURE OF HEAT EXCHANGER COMPONENTS

For the purpose of establishing standard terminology, Figure N-2 illustrates various types of heat exchangers. Typical parts and connections, for illustrative purposes only, are numbered for identification in Table N-2. (See Note).

TABLE N-2

1. Stationary Head – Channel	20. Slip-on Backing Flanges
2. Stationary Head – Bonnet	21. Floating Head Cover – External
3. Stationary Head Flange – Channel or Bonnet	22. Floating Tubesheet Skirt
4. Channel Cover	23. Packing Box
5. Stationary Head Nozzle	24. Packing
6. Stationary Tubesheet	25. Packing Gland
7. Tubes	26. Lantern Ring
8. Shell	27. Tie rods and Spacers
9. Shell Cover	28. Transverse Baffles or Support Plates
10. Shell Flange – Stationary Head End	29. Impingement Plate
11. Shell Flange – Rear Head End	30. Longitudinal Baffle
12. Shell Nozzle	31. Pass Partition
13. Shell Cover Flange	32. Vent Connection
14. Expansion Joint	33. Drain Connection
15. Floating Tubesheet	34. Instrument Connection
16. Floating Head Cover	35. Support Saddle
17. Floating Head Flange	36. Lifting Lug
18. Floating Head Backing Device	37. Support Bracket
19. Split Shear Ring	38. Weir
	39. Liquid Level Connection

NOTE: Manufacturers may identify corresponding parts
Using numbers differing from the above.

Figure N-2

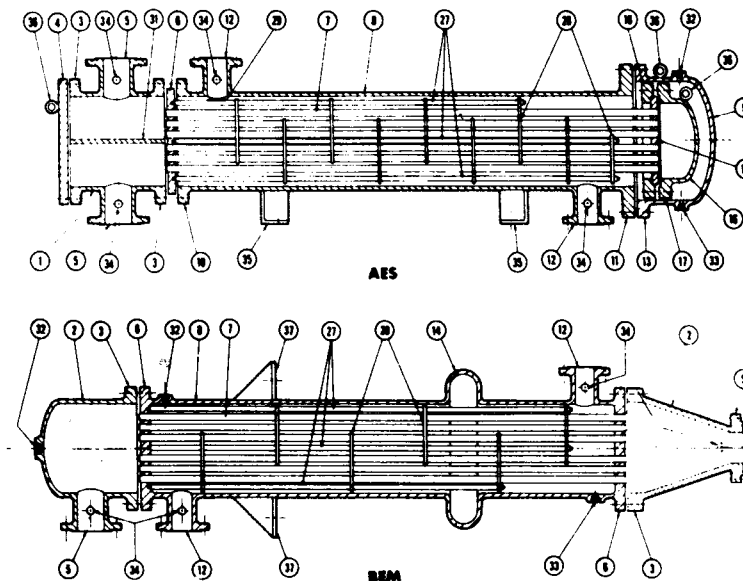
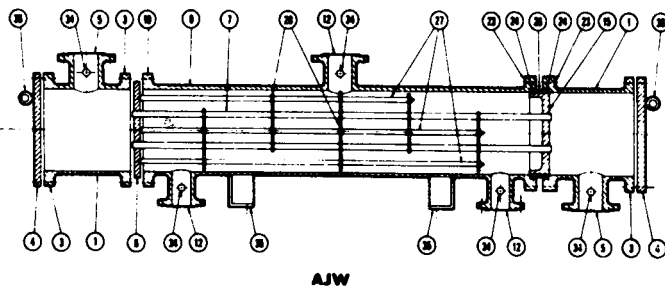


Figure N-2 (Continued)



SECTION 2

HEAT EXCHANGER IDENTIFICATION AND DEFINITIONS

D-2.1 EXCHANGER IDENTIFICATION

D-2.11 COMPLETE EXCHANGER

Manufacturers normally assigned on a serial number, which is unique and permanently identifies each exchanger. Inquiries to the manufacturer should reference this number when it is shown on the nameplate and manufacturer's drawings. Additional useful information normally shown includes size, type, and item number.

D-2.12 EXCHANGER PARTS

Exchanger parts should be identified by the exchanger serial number and by the name and part number corresponding to those shown in Section 1, Table N-2, or as shown on the manufacturer's drawings.

D-2.2 DEFINITIONS

D-2.21 EXCHANGER UNIT

One or more exchangers designed for a specific service.

D-2.22 ITEM NUMBER

The purchaser's identification number for an exchanger unit.

D-2.23 NORMAL OPERATING CONDITIONS

The thermal and hydraulic performance requirements generally specified for designing the heat exchanger.

D-2.24 UPSET CONDITIONS

A departure from specified operating conditions.

D-2.25 PULSATING FLUID CONDITIONS

Conditions of flow generally characterized by rapid fluctuations in pressure and flow rate resulting from sources outside of the heat exchanger such as: pumps, compressors, blowers, etc.

D-2.26 START-UP CONDITIONS

The condition of operation, which exist from the time that flow of either or both process streams, is initiated to the time that steady-state operating conditions are achieved.

D-2.27 SHUTDOWN CONDITIONS

The conditions of operation, which exist, form the time of steady-state operating conditions to the time that flow of both process streams has ceased.

D.2.28 CODE

All references to Code herein mean the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Pressure Vessels.

SECTION 3

INSTALLATION OF HEAT EXCHANGERS

E-3 INSTALLATION

E-3.1 INSTALLATION PLANNING

E-3.11 CLEARANCE FOR DISMANTLING

For straight tube exchangers fitting with removable bundles, provide sufficient clearance at the stationary head end to permit removal of the bundle from the shell and provide adequate space beyond the rear head and to permit removal of the shell cover and/or floating head cover.

For fixed tubesheet exchangers, provide sufficient clearance at one end to permit withdrawal and replacement of the tubes and enough space beyond the head at the opposite end to permit removal of the bonnet or channel cover.

For U-tube heat exchangers, provide sufficient clearance at the stationary head end to permit withdrawal of the tube bundle, or at the opposite end to permit removal of the shell.

E-3.12 FOUNDATIONS

Foundations must be adequate so that exchangers will not settle and impose excessive strains on the exchanger. Foundation bolts should be set to allow for setting inaccuracies. In concrete footings, pipe sleeves at least one size larger than bolt diameter slipped over the bolt and cast in place are best for this purpose, as they allow the bolt center to be adjusted after the foundation has set.

E-3.13 PIPING

E-1.131 THERMAL EXPANSION

It is essential that adequate provisions be made in the connecting piping to allow for thermal expansion without imposing unspecified piping loads on the exchanger. This is particularly important for single pass internal floating head designs, outside packed floating heads, and fixed tubesheet types with shell expansion joints. Unless precautions are taken, leakage or damage may result.

E-3.132 PULSATION AND VIBRATION

In all installations, care must be taken to eliminate or minimize transmission of fluid pulsations and mechanical vibrations to the heat exchangers.

E-3.14 CLEANING

Convenient means should be provided for cleaning the unit as suggested under "Maintenance." (Section 5).

E-3.15 LEVELING

Exchangers must be installed so that pipe connections are made without forcing, disassembling or loosening of flanged assemblies.

E-3.16 STACKED HEAT EXCHANGERS

The manufacturer normally stacks exchangers prior to completion of fabrication to insure proper alignment of interconnecting nozzles. Shims separating the intermediate shell supports are normally used. Therefore, it is important that shims, if used, match the thicknesses and locations used by the manufacturer.

SECTION 3

INSTALLATION OF HEAT EXCHANGERS

E-3.17 CONNECTION PROTECTORS

Remove shipping covers and plugs immediately prior to installation. Before connecting to piping, inspect all openings in the heat exchanger or foreign material. The entire system should be clean and free of foreign objects before starting operation. Do not expose heat exchanger internals to moisture or harmful contaminants.

E-3.18 PIPE CONNECTIONS

Pipe connections must be in accordance with the manufacturer's dimensional outline drawing.

E-3.19 FOUNDATION BOLTS

Foundation bolts should be loosened at one end of the unit to allow free expansion of shells. Slotted holes in supports are provide for this purpose.

E-3.20 If the heat exchanger is equipped with a bellows type expansion joint, the expansion joint must be adequately protected during shipping and setting. Shipping supports must be removed in accordance with instructions.

E-3.3 HEAT EXCHANGER STORAGE

Heat exchangers normally are not protected for storage. If storage is necessary, a covered location at uniform temperature is preferable and provisions must be made to protect the heat exchanger interior from moisture, freezing, or harmful contaminants.

SECTION 4

OPERATION OF HEAT EXCHANGERS

E-4 OPERATION

E-4.1 PERFORMANCE OF HEAT EXCHANGERS

Satisfactory performance and service life can be expected only from heat exchangers which are properly installed, operated in accordance with design conditions, and receive preventative maintenance and cleaning on an appropriate schedule. These requirements are the responsibility of the user.

E-4.11 PERFORMANCE FAILURES

The failure of heat exchanger equipment to perform satisfactorily may be caused by one or more factors, such as:

- (1) Excessive fouling.
- (2) Air or gas binding resulting from improper piping installation or lack of suitable vents.
- (3) Operating conditions differing from design conditions.
- (4) Mal-distribution of flow in the unit.
- (5) Excessive clearances between the baffles and shell and/or tubes, due to corrosion.
- (6) Improper thermal design.
- (7) Flooding resulting from inadequate drainage of condensate.

E-4.2 OPERATION OF HEAT EXCHANGERS

E-4.21 OPERATING PROCEDURES – NORMAL

Before placing any exchanger in operating, reference should be made to the exchanger drawings, specification sheet(s), and name plate(s) for any special instructions. Local safety and health regulations must be considered. Improper start-up or shutdown sequences, particularly of fixed tubesheet units, may cause leaking of tube-to-tubesheet and/or bolted flanged joints.

E-4.22 START-UP OPERATION

Most exchangers with removable tube bundles may be placed in service by first establishing circulation of the cold medium, followed by the gradual introduction of the hot medium. During start-up all vent valves should be opened and left open until all passages have been purged of air and are completely filled with fluid. For fixed tubesheet exchangers, fluids must be introduced in a manner to minimize differential expansion between the shell and tubes. (Refer E-4.24).

E-4.23 SHUT-DOWN OPERATION

For exchangers with removable bundles, the units may be shut down by first gradually stopping the flow of the hot medium and then stopping the flow of the cold medium. If it is necessary to stop the flow of cold medium, the circulation of hot medium through the exchanger should also be stopped. For fixed tubesheet exchangers the unit must be shut down in a manner to minimize differential expansion.

E-4.24 START-UP AND SHUT-DOWN PROCEDURES FOR FIXED TUBESHEET EXCHANGERS

When start-up and shutdown instructions are furnished, they must be followed. When specific instructions are not supplied, the recommended procedure is to start, or stop, the circulation of both shell and tube side fluids gradually and at the same time.

SECTION 4

OPERATION OF HEAT EXCHANGERS

E-4.3 OPERATING LIMITATIONS

E-4.31 NORMAL OPERATING CONDITIONS

Equipment must not be operated at conditions more severe than those specified on the heat exchanger specification sheet, and/or nameplates. A change in service or deviation from the specified operating conditions may require that a mechanical design check be made in order to avoid possible damage to the heat exchanger.

E-4.32 SUPPLEMENTAL NAME PLATE DATA

The manufacturer may supply supplemental data where it is pertinent to the operation or testing of the exchanger. This may include information pertaining to differential design and test pressure conditions, restrictions on operating conditions for fixed tubesheet type exchangers, or other restrictive conditions applicable to the design and/or operation of the unit or its components. Such information may be noted on the standard nameplate or on a supplemental plate attached to the exchanger at the nameplate location.

E-4.33 FLOW RATE

Heat exchangers are not to be operated at flow rates greater than those shown on the heat exchanger specification sheet. Excessive flow rates can cause vibration and/or erosion and severely damage the heat exchanger.

E-4.34 HYDRAULIC HAMMER

Exchangers should not be subjected to pulsating, slugging, or unstable flow conditions, which may impair performance or result in destructive hydraulic hammer. Adequate condensate drainage is essential for steam heaters and similar apparatus.

E-4.35 TEMPERATURE SHOCKS

Exchangers normally should not be subjected to abrupt temperature fluctuations. Hot fluid must not be suddenly introduced when the unit is cold, nor cold fluid when the unit is hot.

E-4.36 FLUID TEMPERATURE LIMITS

E-4.361 Heat exchangers are not to be operated at fluid temperature more severe than those shown on the heat exchanger specification sheet.

E-4.362 For fixed tubesheet exchanger's fluid inlet temperatures may be severely limited when there is no fluid on the opposite side. Operation with fluid circulation on one side only should be avoided, unless specifically provided for in the design of the heat exchanger.

E-4.4 BOLTED JOINTS

E-4.41 RECOMMENDATIONS FOR RETIGHTENING

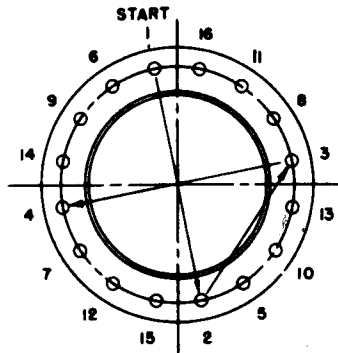
Heat exchangers are pressure tested before leaving the manufacturer's shop in accordance with ASME Code requirements. However, normal yielding of gasket joints may occur in the interval between testing in the manufacturer's shop and installation at the job site. Therefore, all external bolted joints may require retightening after installation and, if necessary, after the exchanger has reached operating temperature.

SECTION 4

E-4.42 RECOMMENDED BOLT TIGHTENING PROCEDURE

It is important that all bolted joints be tightened uniformly and in a diametrically staggered pattern as illustrated in Figure E-4.42 except for special high pressure closures when the instructions of the manufacturer should be followed.

Figure E-4.42



F-4.43 BOLTED JOINT MAINTENANCE

F-4.43.1 The flange joint, should be retightened using the sequence listed in the accompanying Maintenance Manual, paragraph E-4.42.

Note all exchanger are tested in Fabsco's shop, at a pressure equal to 1.3 times the design pressure Stamped on the name plate. The test media is water at ambient temperature. These test must be leak free for 1-hour (min.) and are witness by the Authorized Inspection Agency before the U-1 data reports are signed and the ASME stamp is allowed to be applied to the name plate.

If exchangers are allowed to start up without re-tightening, leaks can occur. We cannot emphasize the importance of this pre-loading, re-torquing of Stud Bolts to ensure leak free gasketed joints. Field crews should be cautioned against torque values listed in most design manuals. Many times these values are for the designer of the equipment, and may not be high enough to properly "Pre-Load" the gasket to account for relaxation of the gasket and operating temperature effects on the joint.

During Hydro-test in Fabsco shop the target bolt torque is approximately 40% of the stud yield (45,000 psi). This is normally sufficient to provide a leak free joint for testing at ambient temperature. This same bolt stress should be sufficient to maintain a leak free joint once the exchanger reaches operating temperature and pressure.

Before start-up, all bolted joints should be re-checked to see if the bolts have remained stressed to a minimum of 40% of yield after transporting, and handling. Upon start-up these joints should be observed for leakage as the temperature rises to operating temperature. The start-up procedure alone can cause relaxation of bolts and cause leaks which have to be addressed. Once again after reaching temperature cycle these bolts should be checked to see if relaxing has occurred.

Even though the Torque required to reach 45,000 psi bolt stress should in most cases be sufficient, it is sometimes necessary to apply more torque in order to achieve a pre-load that will result in a leak free joint. Bolt Stress and torque values can vary so much due to the many variables, Such as thread lube, condition of threads, gasket types ect'. that a higher torque value may be needed to achieve a tight joint. Therefore if after trying values in column 1 below, it may be necessary to apply torque values high enough to produce 80% of yield. After exchangers are in operation and bolting is no longer NEW, the efficiency of the Bolts has declined and therefore higher torque values will be necessary to achieve a preload bolt stress. We suggest step tightening as necessary until the torque values in column 2 are reached. If leaks are still present, likely gasket surfaces have been damaged and will need to be addressed.

Bolt Dia.	Torque (45,000 PSI	Torque (60,000 PSI
3/4 ”	150	200
7/8”	240	320
1”	368	490
1 1/8”	533	710
1 1/4 ”	750	1000
1 3/8”	1020	1360
1 1/2"	1200	1600

Torque values are in ft. lbs. And based on a “Well Lubricated Stud” , and nut bearing surfaces in good condition.

SECTION 5

MAINTENANCE OF HEAT EXCHANGERS

E-5 MAINTENANCE

E-5.1 INSPECTION OF UNIT

At regular intervals and as frequently as experience indicates, an examination should be made of the interior and exterior condition of the unit. Neglect in keeping all tubes clean may result in complete stoppage of flow through some tubes, which could cause severe thermal strains, leaking tube joints, or structural damage to other components. Sacrificial anodes, when provided, should be inspected to determine whether they should be cleaned or replaced.

E-5.11 INDICATIONS OF FOULING

Exchangers subject to fouling or scaling should be cleaned periodically. A light sludge or scale coating on the tube greatly reduces its efficiency. A marked increase in pressure drop and/or reduction in performance usually indicate cleaning is necessary. The unit should first be checked for air or vapor binding to confirm that this is not the cause for the reduction in performance. Since the difficulty of cleaning increases rapidly as the scale thickness or deposit increases, the intervals between cleanings should not be excessive.

E-5.12 PREVENTATIVE MAINTENANCE

Additional important reasons for inspections include:

- (1) Corrosion and erosion may weaken various parts of an exchanger and may eventually cause mechanical failure, or impaired performance.
- (2) Determination of fouling and corrosion rates for prediction of service life scheduling downtime.
- (3) Implementation of preventive maintenance procedures, which reduce rates of fouling and general deterioration, or eliminate leaks.

E-5.13 ACCESS TO TUBES

Before disassembly, the user must assure himself that the unit has been depressurized, vented and drained, neutralized and/or purged of hazardous materials.

To inspect the inside of the tubes and also make them accessible for cleaning, the following procedures should be used:

- (1) Stationary Head End
 - (a) Type A, C, & D, removes cover only.
 - (b) Type B, remove bonnet.
- (2) Rear Head End
 - (a) Type L, N, & P, remove cover only.
 - (b) Type M, remove bonnet.
 - (c) Type S & T, remove shell cover and floating head cover.
 - (d) Type W, remove channel cover or bonnet.

SECTION 5

MAINTENANCE OF HEAT EXCHANGERS

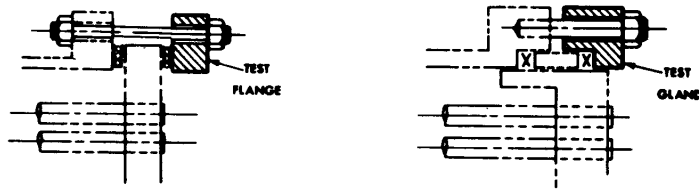
E-5.14 LOCATING LEAKS IN TUBES

The following procedures may be used to locate perforated or split tubes and leaking joints between tubes and tubesheets. In most cases, the entire front face of each tubesheet will be accessible for inspection. The point where water escapes indicates a defective tube or tube-to-tubesheet joint.

- (1) Units with removable channel cover:
Remove channel cover and apply hydraulic pressure in the shell.
- (2) Units with bonnet type head:
 - (a) On fixed tubesheet units where tubesheets are an integral part of the shell, remove bonnet and apply hydraulic pressure in the shell.
 - (b) On fixed tubesheet units where tubesheets are not an integral part of the shell and on units with removable bundles, remove bonnet, re-bolt tubesheet to shell or install test flange or gland, whichever is applicable, and apply hydraulic pressure in the shell.
See Figure E-5.14-1 for typical test flange and test gland.

CAUTION: Bolting directly to the edges of the tubesheets may result in overstress unless it was considered in the design of the tubesheets.

Figure E-5.14-1

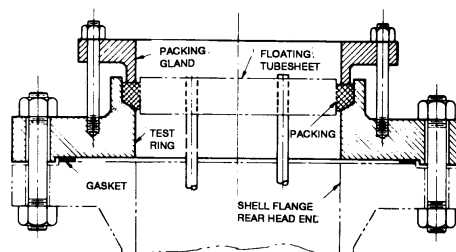


- (3) Units with type S or T floating head:
Remove channel cover or bonnet, shell cover and floating head cover. Install test ring and bolt in place with gasket and packing. Apply hydraulic pressure in the shell. A typical test ring is shown in Figure E-5.14-2. When a test ring is not available it is possible to locate leaks in the floating head end by removing the shell cover and applying hydraulic pressure in the tubes. Leaking tube joints may then be located by sighting through the tube lanes.

NOTE: Care must be exercised when testing partially assembled exchangers to prevent over extension of expansion joints or overloading of tubes and/or tube-to-tube-to-tubesheet joints.

Hydrostatic test should be performed so that the temperature of the metal is at least 30°F above the minimum design metal temperature, MDMT.

Figure E-5.14-2



SECTION 5

MAINTENANCE OF HEAT EXCHANGERS

E-5.2 TUBE BUNDLE REMOVAL

Bundles must be withdrawn from the stationary end as noted on the drawing. All parts such as glands, retainer rings, split shear rings and closure packing must be removed before attempting to remove bundle. Threaded eyebolts may be attached to the stationary tubesheet when tapped holes have been provided for this purpose. When eyebolt tappings are not provided, rods may be passed through two or more tubes and attached to a steel bearing plate over the floating tubesheet. Provide a protective spacer between the bearing plate and tubesheet to protect the tube ends.

E-5.21 HANDLING TUBE BUNDLES

Tube bundles should not be handled with hooks or other devices, which might damage the tubes. Bundles should be supported on cradles or skids. Horizontal tube bundles should be lifted by means of suitable slings. Baffles can be bent and damaged by dragging a bundle over a rough surface. All gasket and packing contact surfaces should be protected from accidental damage since these areas are generally difficult to repair.

E-5.3 CLEANING TUBE BUNDLES

E-5.31 CLEANING METHODS

The heat transfer surfaces of heat exchangers should be kept reasonably clean to assure satisfactory performance. Convenient means for cleaning should be made available.

Heat exchangers may be cleaned by either chemical or mechanical methods. The method selected must be the choice of the operator of the plant and will depend on the type of deposit and the facilities available in the plant. Following are several cleaning procedures that may be considered:

- (1) Circulating hot wash oil or light distillate through tubes or shell at high velocity may effectively remove sludge or similar soft deposits.
- (2) Some salt deposits may be washed out by circulating hot fresh water.
- (3) Some commercial cleaning compounds are available for removing sludge or scale provided hot wash oil or water is not available or does not give satisfactory results.
- (4) High pressure water jet cleaning.
- (5) Scrapers, rotating wire brushes, and other mechanical means for removing hard scale, coke, or other deposits.
- (6) Employ services of a qualified organization that provides cleaning services. These organizations will check the nature of the deposits to be removed, furnish proper solvents and/or acid solutions containing inhibitors, and provide equipment and personnel for a complete cleaning job.

E-5.32 CLEANING PRECAUTIONS

- (1) Tubes should not be cleaned by blowing steam through individual tubes since this heats the tube and may result in severe expansion strain, deformation of the tube, or loosening of the tube-to-tubesheet joint.
- (2) When mechanically cleaning a tube bundle, care should be exercised to avoid damaging the tubes.
- (3) Cleaning compounds must be compatible with the metallurgy of the exchanger.

SECTION 5

MAINTENANCE OF HEAT EXCHANGERS

- (4) Cleaning procedures, especially those which circulate hot fluids through the tubes, can cause significant temperature differentials between the shell and tubes. Such cleaning procedures can cause damage to fixed tubesheet heat exchangers and should be avoided unless specifically provided of in the design of the heat exchanger.

E-5.4 GASKET REPLACEMENT

Gasket and gasket surfaces should be thoroughly cleaned and should be free of scratches and other defects. Gaskets should be properly positioned before attempting to retighten bolts. It is recommended that when a heat exchanger is dismantled for any cause, it's to be reassembled with new gaskets. This will tend to prevent future leaks and/or damage to the gasket seating surfaces of the heat exchanger. Composition gaskets become dried out and brittle so that they do not always provide an effective seal when reused. Metal or metal-jacketed gaskets, when compressed initially, flow to match their contact surfaces. In so doing they are work hardened and, if reused, may provide an imperfect seal or result in deformation and damage to the gasket contact surfaces of exchanger.

Bolted joints and flanges are designed for use with the particular type of gasket specified. Substitution of a gasket of different construction or improper dimensions may result in leakage and damage to gasket surfaces. Therefore, any gasket substitutions should be of compatible design.

Any leakage at a gasketed joint should be rectified and not permitted to persist as it may result in damage to the gasket surfaces.

When metal jacketed filled type gaskets are used with a tongue and groove joint without a nubbin, the gasket should be installed so that the tongue bears on the seamless side of the gasket jacket. When a nubbin is used, the nubbin should bear on the seamless side.

E-5.5 SPARE AND REPLACEMENT PARTS

The procurement of spare or replacement parts from the manufacturer will be facilitated if the correct name for the part, as shown in Section 1, Table N-2, of this manual is given, together with the serial number, type, size, and other information from the nameplate. Replacement parts should be purchased from the original manufacturer.

E-5.6 EXPANDED TUBE JOINTS

E-5.61 TUBE HOLE FINISH

Tube hole finish affects the mechanical strength and leak tightness of an expanded tube-to-tubesheet joint. In general:

- (1) A rough tube hole provides more mechanical strength than a smooth tube hole. This is influenced by a complex relationship of modulus of elasticity; yield strength, and hardness of the materials being used.
- (2) A smooth tube hole does not provide the mechanical strength that a rough tube hole does, but it can provide a pressure tight joint at a lower level of tube wall reduction.
- (3) Very light wall tubes require a smother tube hole finish than heavier wall tubes.
- (4) Significant longitudinal scratches can provide leak paths through an expanded tube-to-tubesheet joint and should therefore be removed.

SECTION 5

MAINTENANCE OF HEAT EXCHANGERS

E-5.62 TUBE WALL REDUCTION

The optimum tube wall reduction for an expanded tube-to-tubesheet joint depends on a number of factors, some of which are:

- (1) Tube hole finish.
- (2) The presence or absence of the tube hole serrations (grooves).
- (3) The tube hole size and tolerance.
- (4) Tubesheet ligament width and its relation to tube diameter and thickness.
- (5) Tube wall thickness.
- (6) Tube hardness and change in hardness during cold working.
- (7) Tube O.D. tolerance.
- (8) Type of expander used.
- (9) Type of torque control or final tube thickness control.
- (10) Function of tube joint, i.e., strength in resistance to pulling out, minimum cold work for corrosion purposes, freedom from leaks, ease of replacement, etc.
- (11) Length of expanded joint.
- (12) Compatibility of tube and tubesheet materials.

E-5.63 TUBE EXPANDING

A suitable tube expander should be used to tighten a leaking tube joint. Care should be taken to insure that tubes are not over expanded. Do not re-expand tubes, which are not leaking. Do not expand tubes beyond 1/8" from the back face of the tubesheet.

E-5.64 TYPICAL COMPUTATION OF TUBE WALL REDUCTION

EXAMPLE OF DETERMINING THE EXPANDED TUBE INSIDE DIAMETER FOR A SPECIFIED AMOUNT OF WALL REDUCTION

GIVEN:	TUBE DIAMETER	=	0.750
	TUBE HOLE DIAMETER	=	0.760
	TUBE WALL THICKNESS	=	0.065
	SPECIFIED WALL REDUCTION	=	5%

SOLUTION:	WALL REDUCTION	=	$0.065 \times 0.05 = 0.00325$
	FINAL WALL THICKNESS	=	$0.065 - 0.00325 = 0.06175$
	FINAL EXPANDED TUBE I.D.	=	$0.760 - 2(0.06175) = 0.6365$

CAUTION: *THE USE OF NOMINAL DIMENSIONS, WITHOUT ATTENTION TO PERMISSIBLE TOLERANCES CAN LEAD TO INCORRECT CONCLUSIONS.*

EXPANDING PROCEDURES SHOULD BE BASED ON MEASURED DIMENSIONS, NOT NOMINAL DIMENSIONS.

SECTION 5

MAINTENANCE OF HEAT EXCHANGERS

E-5.65 PLUGGING TUBES IN TUBE BUNDLES

In U-tube heat exchangers, and other exchangers of special design, it may not be feasible to remove and replace defective tubes. Defective tubes may be plugged using commercially available tapered plugs with ferrules or tapered only plugs, which may or may not be seal welded. Excessive tube plugging may result in reduced thermal performance, higher-pressure drop, and/or mechanical damage.

E-5.7 WELDED TUBE JOINTS

Welding procedure and testing techniques for either seal welded or strength welded tube joints normally are by agreement between manufacturer and purchaser and therefore should be considered prior to welded tube joints or tube replacements.

E-5.8 END FLANGES AND BOLTING

The purpose of this section is to alert the users, and provide basic data for consideration in assembly and maintenance of bolted flanged joints. Controlling the torque applied in tightening threaded bolts is the most economical and commonly used method for the control of initial tension. There are several factors, which affect the relationship between torque and tension of threaded bolts. A few of the factors are the type of lubricant and/or plating, if any, used on the threads and the materials from which the bolt and nut are manufactured.

In assembling gasketed joints it is essential that the gasket first be seated uniformly by initial tightening of studs using a staggered quarterly pattern. After the gasket is seated, torquing may be completed stepwise to the final desired value, following a staggered or sequential pattern.

The following may be used as references and aids when assembling bolted flanged joints:

1. Recommended assembly and maintenance of flanged joints as shown in the Crane Company Catalog #60, Engineering Data Section.
2. Torque Control, Sixth Edition, Sturtevant Company.
3. ASME Code, Appendix S.
4. See also Paragraph F-4.4 above.

E-5.9 SPECIAL HIGH PRESSURE CLOSURES

E-5.10 REPAIRS, ALTERATION, RERATING, AND REPLACEMENT PARTS.

In order to maintain the Code integrity of the vessel, any repairs by welding, subsequent heat-treating, alterations, replacement pressure parts, or re-rating must be done in accordance with the National Board Inspection Code.

Potentially toxic or harmful contaminants must be neutralized prior to repairs.

Following repair by welding, post weld heat treatment may be a requirement for preservation of resistance to corrosion.