

DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

Design Specifications

TEMA Class R		Shell Side	Tube Side	Tubesheets
Max Allow Working Pressure	psi	150	150	
Vacuum pressure	psi	-14.7	-14.7	
Test pressure	psi	195	195	
Design temperature / Min	F	400 / -20	400 / -20	400 / -20
Average metal temperature	F	273	298	298
Corrosion allowance	in	0.125	0.125	
Front tubesheet corrosion allow	in	0.125	0.125	
Rear tubesheet corrosion allow	in	0.125	0.125	
Radiographing		None	None	
Number of passes		1	1	
Nozzle flange rating		150	150	
Post weld heat treatment		No	No	
Code	ASME Section VIII Div.1 2004		TEMA Eighth Edition 1999	
Weights	Empty:4029	Full:5323	Bundle:2739	lbf

PROJECT NO: 58-CG87-60-P11-0014
 SERIAL NO: 9-1
 ITEM NO:
 SUPPLEMENT DATE:
 JACOBS ENGINEERING GROUP - CENTRAL REGION
 COMMENTS:
 A NO COMMENTS
 B COMMENTS NOTED - REVISE, RESUBMIT, PROCEED WITH FABRICATION
 C UNACCEPTABLE - DO NOT PROCEED WITH FABRICATION
 R FOR INFORMATION ONLY
 Review of this drawing by Jacobs Engineering Group does not relieve the supplier of his responsibility to supply the materials in accordance with the procurement documents.

Cylinders/Covers

	Front Head		Shell	Rear Head		Shell Cover		Tubes
	Cover	Cyl.	Cyl.	Cyl.	Cover	Cyl.	Cover	
Head type	Ellipsoidal			Ellipsoidal				
Outside diameter	in	24	24		24			0.75
Calculated thk.	in	0.2144	0.2768		0.2144			0.0046
TEMA minimum thk.	in	0.375	0.375		0.375			
Actual thickness	in	0.375	0.375		0.375			0.083
X-ray		None	None		None			
Joint efficiency		None	None		None			
Corrosion allowance	in	0.125	0.125		0.125			
External pressure	psi	15	15		15			164.7
Length Ext.Press.	in		96					96
Maximum Ext.Press.	psi	141.403	37.794		141.403			2061.904
Minimum thk. Ext.Press.	in	0.19	0.32		0.19			0.014
Max.length Ext.Press.	in		231.5					290

Nozzles

Nozzle designator		A	B	C	D	K
Vessel side		Tube	Tube	Shell	Shell	Shell
Outside diameter	in	4.5	3.5	6.625	6.625	2.375
Calculated thickness	in	0.2021	0.1381	0.213	0.213	0.1802
Code minimum thk	in	0.2144	0.2144	0.2299	0.2299	0.2299
Actual thickness	in	0.432	0.3	0.432	0.432	0.344
Reinf.pad OD	in					
Reinf.pad thickness	in					
Corrosion allowance	in	0.125	0.125	0.125	0.125	0.125
External pressure	psi	15	15	15	15	15
Length ext. press.	in	6	6	6	6	6.9235
Maximum ext. press.	psi	1229.327	1054.51	823.661	823.661	1571.761

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Nozzle Flanges

Nozzle designator		A	B	C	D	K
Flange type		Weld neck				
Flange rating		150	150	150	150	150
Flange OD	in	9	7.5	11	11	6
Bolt circle	in	7.5	6	9.5	9.5	4.75
Bolt diameter	in	0.625	0.625	0.75	0.75	0.625
Bolt number	in	8	4	8	8	4
Gasket OD	in	6.19	5	8.5	8.5	3.62
Gasket width	in	0.84	0.75	0.94	0.94	0.62
Gasket thickness	in	0.125	0.125	0.125	0.125	0.125
Flange calc. thk.	in					
Flange actual thk.	in	0.94	0.94	1	1	0.75
Lap jnt ring OD	in					
Hub length	in					
Hub slope	in					
Weld height	in					

Body Flanges

		Front Head		Shell		Rear Head		Shell
		Cover	at TbSh	Front	Rear	at TbSh	Cover	Cover
Flange type			Ring			Ring		
Flange OD	in		28.375			28.375		
Bolt circle	in		26.625			26.625		
Bolt diameter	in		0.75			0.75		
Bolt number			24			24		
Gasket OD	in		25.375			25.375		
Gasket width	in		0.375			0.375		
Gasket thk.	in		0.125			0.125		
Flange calc. thk.	in		1.875			1.875		
Flange overlay	in							
Recess	in		0.1875			0.1875		
Flange act. thk.	in		2.0625			2.0625		
Lap jnt ring OD	in							
Hub length	in							
Hub slope	in							
Weld height	in		0.375			0.375		

Tubesheets

		Front	Rear
Tubesheet diameter	in	28.375	28.375
TEMA minimum thickness	in	0.75	0.75
TEMA bending thickness	in	0.9835	0.9835
TEMA shear thickness	in	0.1292	0.1292
TEMA flange extension thk	in	0.7233	0.7233
TEMA effective thickness	in	1	1
Code thickness	in	1.1875	1.1875
Corrosion allowance - shell	in	0.125	0.125
Corrosion allowance - tube	in	0.125	0.125

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Recess	in	0.1875	0.1875
Actual thickness	in	1.3125	1.3125
Clad thickness (not included above)	in		

Tube Details

Tube type		Plain
Tube OD	in	0.75
Tube wall thickness	in	0.083
Number of tubes		487
Tube length	in	96
Tube pitch	in	0.9375
Tube pattern		30
Outer tube limit diameter	in	22.75

Materials of Construction

Component	Material
Shell Cylinder	SA-106 K03006 Grd B Smls. pipe
Front Head Cover	SA-516 K02700 Grd 70 Plate
Rear Head Cover	SA-516 K02700 Grd 70 Plate
Shell Lifting Lugs	SA-36 K02600 Plate
Front Tubesheet	SA-516 K02700 Grd 70 Plate
Rear Tubesheet	SA-516 K02700 Grd 70 Plate
Front Head Flng At TS	SA-266 K03506 Grd 2 Forgings
Rear Head Flng At TS	SA-266 K03506 Grd 2 Forgings
Front Head Gasket At TS	Spiral-Wound Metal Fiber Stainless
Rear Head Gasket At TS	Spiral-Wound Metal Fiber Stainless
Tubes	SA-179 K01200 Smls. tube
Baffles	SA-36 K02600 Plate
Tie Rods	SA-36 Bar
Spacers	SA-214 K01807 Wld. tube
Shell Support A	SA-516 K02700 Grd 70 Plate
Shell Support B	SA-516 K02700 Grd 70 Plate
Nozzle A	SA-106 K03006 Grd B Smls. pipe
Nozzle B	SA-105 K03504 Forgings
Nozzle C	SA-106 K03006 Grd B Smls. pipe
Nozzle D	SA-106 K03006 Grd B Smls. pipe
Nozzle K	SA-106 K03006 Grd B Smls. pipe
Nozzle Flng A	SA-105 K03504 Forgings
Nozzle Flng B	SA-105 K03504 Forgings
Nozzle Flng C	SA-105 K03504 Forgings
Nozzle Flng D	SA-105 K03504 Forgings
Nozzle Flng K	SA-105 K03504 Forgings
Front Hd Bolting At TS	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Rear Hd Bolting At TS	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)

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Component: Shell Cylinder

ASME Section VIII Div.1 2004 UG-27 Thickness of Shells under Int. Pressure

--- Calculations --- Cylinder Internal Pressure

Material: SA-106 K03006 Grd B Smls. pipe

Max Allow Working Pressure P = 150 psi Design temperature T = 400 F

Radiography = None Joint eff.circ str. E = 1

Design stress S = 17100 psi Joint eff.long str. E = 1

Design stress, long S = 17100 psi (circum. butt welds)

Inside corr.allow. CAI = 0.125 in Outside corr. all. CAO = 0 in

Material tolerance Tol = 0.0469 in TEMA min. thickness tm = 0.375 in

Outside diameter OD = 24 in Corroded radius OR = 12 in

Required wall thickness of the cylinder, greater of:

Circumferential stress

$$t = (P \cdot OR / (S \cdot E + 0.4 \cdot P)) + CAI + CAO + Tol = 0.2768 \text{ in} \quad \text{APP.1-1(A)}$$

Longitudinal stress

$$t = (P \cdot IR / (2 \cdot S \cdot E + 0.4 \cdot P)) + CAI + CAO + Tol = 0.1764 \text{ in} \quad \text{UG-27(c)(2)}$$

Actual wall thickness of cylinder: tnom = 0.375 in

(Required wall tks. for nozzle attachments, E=1, tri = 0.1049 in)

ASME Section VIII Div.1 2004 UG-28 Thickness of Shells under Ext. Pressure

--- Calculations --- Cylinder External Pressure

Material: SA-106 K03006 Grd B Smls. pipe

Max Allow Working Pressure PE = 14.7 psi Design temperature T = 400 F

Inside corr. allow. CAI = 0.125 in Corrosion allow. CAO = 0 in

Radiography = None Material tol. Tol = 0.0469 in

Cyl. outside dia. Do = 24 in Cylinder length EP L = 96 in

Nominal thickness tnom = 0.375 in (tnom-CAI-CAO-Tol) t = 0.2031 in

L/Do ratio Ldo = 4.0 Do/t Dot = 118.1538

(2*S) or (0.9*yield) SE = - Mod. of elasticity ME = 27500000 psi

A factor SII-D-FigG A = 0.000243 B factor CS-2 B = 3349

Max allowed external pressure: Pa = 4*B / (3*Dot) = 37.79 psi

Actual external Max Allow Working Pressure: PE = 14.7 psi

(Required cyl. tks. for nozzle attachments at PE, tre = 0.1481 in)

Component: Front Head Cover

ASME Section VIII Div.1 2004 UG-32 Formed Heads, and Sections,

Pressure on Concave Side

--- Calculations --- Ellipsoidal Cover Internal Pressure with t/L >= 0.002

Material: SA-516 K02700 Grd 70 Plate

Max Allow Working Pressure P = 150 psi Design temperature T = 400 F

Radiography = None Joint efficiency E = 1

Design stress S = 20000 psi TEMA min. thk tm = 0.375 in

Inside corr.all. CAI = 0.125 in Outside corr.all. CAO = 0 in

Major/minor rat. D/2h = 2.0 Forming tolerance Tol = 0 in

Corroded min. thk t = 0.0894 in Equiv.dish radius L = 21.15 in

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Ratio t/L = 0.00423 Material tol. Tol = 0 in
 Outside diameter OD = 24 in Corroded diameter OD = 24 in
 Proportion factor K = 0.1667*(2+(D/2h)**2) = 1.0002
 Required wall thickness of the cover:
 $t = (P*OD*K / (2*S*E+2*P*(K-0.1)))+CAI+CAO+Tol = 0.2144$ in App. 1-4(c)
 Actual wall thickness of cover: tnom = 0.375 in
 (Required wall tks. for nozzle attachments, E=1, tri = 0.0894 in)
 (If opening & reinf. are within 80% of head diameter, tri = 0.0808 in)
 ASME Section VIII Div.1 2004 UG-33 Formed Heads, Pressure on Convex Side
 --- Calculations --- Ellipsoidal Cover External Pressure
 Material: SA-516 K02700 Grd 70 Plate
 Max Allow Working Pressure PE = 14.7 psi Design temperature T = 400 F
 Inside corr. allow. CAI = 0.125 in Outside corr. all. CAO = 0 in
 Radiography = None Forming tolerance Tol = 0 in
 Material tolerance Tol = 0 in
 Cover outside dia. Do = 24 in Outside sph.radius Ro = 21.6 in
 Nominal thickness tnom = 0.375 in tnom-CAI-CAO-Tol t = 0.25 in
 Ko factor (UG-33.1) Ko = 0.9 Ro/t ratio Rot = 86.4
 UG-33(a) 424.63/1.67 = 254.27 psi Mod. of elasticity ME = 27500000 psi
 A factor = 0.125/Rot = 0.001447 B factor CS-2 B = 12217
 Maximum allowed external pressure: Pa = B / Rot = 141.4 psi
 Actual external Max Allow Working Pressure: PE = 14.7 psi
 (Required cov. tks. for nozzle attachments at PE, tre = 0.065 in)

Component: Rear Head Cover

ASME Section VIII Div.1 2004 UG-32 Formed Heads, and Sections,
 Pressure on Concave Side
 --- Calculations --- Ellipsoidal Cover Internal Pressure with t/L >= 0.002
 Material: SA-516 K02700 Grd 70 Plate
 Max Allow Working Pressure P = 150 psi Design temperature T = 400 F
 Radiography = None Joint efficiency E = 1
 Design stress S = 20000 psi TEMA min. thk tm = 0.375 in
 Inside corr.all. CAI = 0.125 in Outside corr.all. CAO = 0 in
 Major/minor rat. D/2h = 2.0 Forming tolerance Tol = 0 in
 Corroded min. thk t = 0.0894 in Equiv.dish radius L = 21.15 in
 Ratio t/L = 0.00423 Material tol. Tol = 0 in
 Outside diameter OD = 24 in Corroded diameter OD = 24 in
 Proportion factor K = 0.1667*(2+(D/2h)**2) = 1.0002
 Required wall thickness of the cover:
 $t = (P*OD*K / (2*S*E+2*P*(K-0.1)))+CAI+CAO+Tol = 0.2144$ in App. 1-4(c)
 Actual wall thickness of cover: tnom = 0.375 in
 (Required wall tks. for nozzle attachments, E=1, tri = 0.0894 in)
 (If opening & reinf. are within 80% of head diameter, tri = 0.0808 in)
 ASME Section VIII Div.1 2004 UG-33 Formed Heads, Pressure on Convex Side
 --- Calculations --- Ellipsoidal Cover External Pressure
 Material: SA-516 K02700 Grd 70 Plate
 Max Allow Working Pressure PE = 14.7 psi Design temperature T = 400 F
 Inside corr. allow. CAI = 0.125 in Outside corr. all. CAO = 0 in
 Radiography = None Forming tolerance Tol = 0 in
 Material tolerance Tol = 0 in
 Cover outside dia. Do = 24 in Outside sph.radius Ro = 21.6 in
 Nominal thickness tnom = 0.375 in tnom-CAI-CAO-Tol t = 0.25 in
 Ko factor (UG-33.1) Ko = 0.9 Ro/t ratio Rot = 86.4
 UG-33(a) 424.63/1.67 = 254.27 psi Mod. of elasticity ME = 27500000 psi
 A factor = 0.125/Rot = 0.001447 B factor CS-2 B = 12217
 Maximum allowed external pressure: Pa = B / Rot = 141.4 psi
 Actual external Max Allow Working Pressure: PE = 14.7 psi
 (Required cov. tks. for nozzle attachments at PE, tre = 0.065 in)

Component: Tubes

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ASME Section VIII Div.1 2004 UG-27 Thickness of Shells under Int. Pressure

--- Calculations --- Cylinder Internal Pressure

Material: SA-179 K01200 Smls. tube

Max Allow Working Pressure P = 164.7 psi Design temperature T = 400 F

Radiography = - Joint eff.circ str. E = 1

Design stress S = 13400 psi Joint eff.long str. E = -

Design stress, long S = - (circum. butt welds)

Inside corr.allow. CAI = 0 in Outside corr. all. CAO = 0 in

Material tolerance Tol = 0 in TEMA min. thickness tm = 0 in

Outside diameter OD = 0.75 in Corroded radius OR = 0.375 in

Required wall thickness of the cylinder, greater of:

Circumferential stress

$$t = (P \cdot OR / (S \cdot E + 0.4 \cdot P)) + CAI + CAO + Tol = 0.0046 \text{ in} \quad \text{APP.1-1(A)}$$

Longitudinal stress

$$t = (P \cdot IR / (2 \cdot S \cdot E + 0.4 \cdot P)) + CAI + CAO + Tol = - \quad \text{UG-27(c) (2)}$$

Actual wall thickness of cylinder: tnom = 0.083 in

(Required wall tks. for nozzle attachments, E=-, tri = -)

ASME Section VIII Div.1 2004 UG-28 Thickness of Shells under Ext. Pressure

--- Calculations --- Cylinder External Pressure

Material: SA-179 K01200 Smls. tube

Max Allow Working Pressure PE = 164.7 psi Design temperature T = 400 F

Inside corr. allow. CAI = 0 in Corrosion allow. CAO = 0 in

Radiography = Full Material tol. Tol = 0 in

Cyl. outside dia. Do = 0.75 in Cylinder length EP L = 96 in

Nominal thickness tnom = 0.083 in (tnom-CAI-CAO-Tol) t = 0.083 in

L/Do ratio Ldo = 128.0 Do/t Dot = 9.0361

(2*S) or (0.9*yield) SE = 24210 psi Mod. of elasticity ME = 27500000 psi

A factor SII-D-FigG A = 0.014136 B factor CS-1 B = 13174

Max allowed external pressure: Pa = B*((2.167/Dot)-0.0833) = 2061.9 psi

Actual external Max Allow Working Pressure: PE = 164.7 psi

(Required cyl. tks. for nozzle attachments at PE, tre = 0.014 in)

Component: Front Head Flng At TS

ASME Section VIII Div.1 2004 App. 2 Bolted Flange With Ring Type Gaskets

Flange:

Flange type: Optional type ring - code fig.2-4(8)

Flange material: SA-266 K03506 Grd 2 Forgings

Int. Max Allow Working Pressure PI = 150 psi Design temperature T = 400 F

Ext. Max Allow Working Pressure PE = -14.7 psi Bl = B+g1 or B+go Bl = -

Inside corr. allow CAI = 0.125 in Outside corr. all. CAO = 0.0 in

Stress (operating) SFO = 20000 psi Stress (atmos.) SFA = 20000 psi

Outside diameter A = 28.375 in Inside spherical rad. L = -

Inside diameter B = 23.5 in Hub thickness g1 = 0.625 in

Bolt circle diameter C = 26.625 in Hub tks. at attach. go = 0.25 in

Mean gasket diameter G = 25.0 in Weld leg/hub length h = 0.375 in

Hub to bolt circle R = 0.9375 in Bolt circle to OD E = 0.875 in

Flange thickness t = 1.875 in

Note: Optional Type Flanges use the smaller of integral or loose calculation.

Gasket material: Spiral-Wound Metal Fiber Stainless

Gasket outside dia. ODG = 25.375 in Gasket width Wth = 0.375 in

Gasket thickness tks = 0.125 in Gasket factor m = 3.0

Gasket seating stress y = 10000 psi Gasket eff. width b = 0.1875 in

Gasket rib length Rib = 0.0 in Seating width bo = 0.1875 in

Gasket rib eff width Br = 0.0 in (Table 2-5.2 facing 1a/1b Col. II)

Bolt material: SA-193 G41400 Grd B7 Bolt(<= 2 1/2)

Bolt diameter Dia = 0.75 in No. of bolts No. = 24

Bolt root area Area = 0.302 in2

Stress (operating) SB = 25000 psi Stress (atmos.) SA = 25000 psi

Joint-contact compr. load HP = 6.2832*b*G*PI*m+2*Br*m*PI*RIB = 13254 lbf

Hydrostatic end force H = 0.7854*G*G*PI = 73631 lbf

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Hydrostatic end force	He= 0.7854*G*G*PE	=	7216 lbf
Operating conditions:			
Min. calc. bolt load	WM1 = HP+H	=	86885 lbf
Min. used bolt load	WM1 = max of 2 mating flanges	=	86885 lbf
Bolting up conditions:			
Minimum bolt load	WM2 = b*3.1416*G*Y+Br*Y*RIB	=	147262 lbf
Min. used bolt load	WM2 = max of 2 mating flanges	=	147262 lbf
Required bolt area	AM = WM2/SA or WM1/SB	=	5.89 in2
Available bolt area	AB = No.Bolt*Area	=	7.25 in2
Design bolt load	W = 0.5*(AM+AB)*SA	=	164231 lbf
Minimum gasket width	NMIN = AB*SA/(6.283*y*G)	=	0.1154 in

Loads:

Integral Flange Calculations

Operating conditions:			
Hydrostatic end load	HD = 0.785*B*B*PI	=	65061 lbf
Hydrostatic end load	HDe= 0.785*B*B*PE	=	6376 lbf
Gasket load	HG = WM1-H	=	13254 lbf
Result. hydrostatic force	HT = H-HD	=	8571 lbf
Result. hydrostatic force	HTe= He-HDe	=	840 lbf
Bolting up conditions:			
Gasket load	HG = W	=	164231 lbf
Operating conditions:			
Hydrostatic lever arm	hd = R+0.5*g1	=	1.25 in
Gasket load lever arm	hg = (C-G)/2	=	0.8125 in
Result. hydro. lever arm	ht = (R+g1+hg)/2.0	=	1.1875 in
Bolting up conditions:			
Gasket load lever arm	hg = (C-G)/2	=	0.8125 in
Operating conditions:			
Hydrostatic moment	MD = HD*hd	=	81326 lbf*in
Gasket moment	MG = HG*hg	=	10769 lbf*in
Result. hydro. moment	MT = HT*ht	=	10178 lbf*in
Total operating moment	MOP = MD+MG+MT	=	102272 lbf*in
Total operating mom. MOPe=	HDe(hd-hg)+HTe(ht-hg)	=	3104 lbf*in
Bolting up conditions:			
Bolt up moment	MATM = W*hg	=	133438 lbf*in
Effective bolt moment	MB = MATM*SFO/SFA	=	133438 lbf*in
Total moment	MO = MOP or MB	=	133438 lbf*in
Bolt spacing correction	M = MO*Cf	=	133438 lbf*in

(TEMA 1999 RCB-11.23) Cf= 1

Flange shape constants:

K = A/B	= 1.2074	ho = SQ(B*G0)	= 2.4238
TF = Fig.2-7.1	= 1.836	h/ho = h/ho	= 0.1547
Z = Fig.2-7.1	= 5.3675	F = Fig.2-7.2	= 0.898
Y = Fig.2-7.1	= 10.4053	V = Fig.2-7.3	= 0.3716
U = Fig.2-7.1	= 11.4344	f = Fig.2-7.6	= 4.5671
G1/G0 = G1/Go	= 2.5	e = F/ho	= 0.3705
t =	= 1.875 in		
D = U*ho*g0*g0/V	= 4.6616	Alpha = t*e+1.0	= 1.6947
Beta = 1.333*t*e+1.0	= 1.926	Gamma = Alpha/TF	= 0.9231
Delta = t*t*t/D	= 1.4141	Lambda = Gamma+Delta	= 2.3371

Stress calculations:

Allowable stress:

Long. hub	SH = (f*M)/(Lambda*g1**2*B)	=	28406 psi	1.5*SFO =	30000 psi
Radial	SR = Beta*M/(Lambda*t**2*B)	=	1331 psi	SFO =	20000 psi
Tangential	ST1 = M*Y/(t**2*B) - (Z*SR)	=	9662 psi	SFO =	20000 psi
(greater)	ST2 = (SH+SR)/2 or (SH+ST1)/2	=	19034 psi	SFO =	20000 psi

Loads:

Loose Flange Calculations

Operating conditions:			
Hydrostatic end load	HD = 0.785*B*B*PI	=	68567 lbf
Hydrostatic end load	HDe= 0.785*B*B*PE	=	6720 lbf

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Gasket load	HG = WM1-H	= 13254 lbf
Result. hydrostatic force	HT = H-HD	= 5064 lbf
Result. hydrostatic force	HTE= He-HDE	= 496 lbf
Bolting up conditions:		
Gasket load	HG = W	= 164231 lbf
Operating conditions:		
Hydrostatic lever arm	hd = (C-B)/2.0	= 1.25 in
Gasket load lever arm	hg = (C-G)/2	= 0.8125 in
Result. hydro. lever arm	ht = (hd+hg)/2.0	= 1.0313 in
Bolting up conditions:		
Gasket load lever arm	hg = (C-G)/2	= 0.8125 in
Operating conditions:		
Hydrostatic moment	MD = HD*hd	= 85709 lbf*in
Gasket moment	MG = HG*hg	= 10769 lbf*in
Result. hydro. moment	MT = HT*ht	= 5222 lbf*in
Total operating moment	MOP = MD+MG+MT	= 101700 lbf*in
Total operating mom. MOPE=	HDE(hd-hg)+HTE(ht-hg)	= 3048 lbf*in
Bolting up conditions:		
Bolt up moment	MATM = W*hg	= 133438 lbf*in
Effective bolt moment	MB = MATM*SFO/SFA	= 133438 lbf*in
Total moment	MO = MOP or MB	= 133438 lbf*in
Bolt spacing correction	M = MO*Cf	= 133438 lbf*in
(TEMA 1999 RCB-11.23) Cf= 1		
Flange shape constants:		
B =	= 24.125 in	
K = A/B	= 1.1762	
Y = Fig.2-7.1	= 12.0464	
Flange calculated thickness:	t = (M*Y/SFO*B)**0.5	= 1.8252 in
Flange nominal thickness:	tnom	= 1.875 in
Stress calculations:		Allowable stress:
Tangential, ST = MO*Cf*Y/(B*tnom**2)	= 18952 psi	SFO = 20000 psi

Component: Front Head Flng At TS

ASME Section VIII Div.1 2004, Appendix S, S-2 Flange Rigidity

--- Calculations ---

Operating moment,	Mo = 102272 lbf*in	Gasket seat. moment	Ma = 133438 lbf*in
Factor V	V = 0.372	Factor L	L = 2.3371
Mod. elast.design T	Ed = 27500000 psi	Mod.elast.atm. temp	Ea = 29300000 psi
Thickness g0	g0 = 0.25 in	Factor h0	h0 = 2.4238 in
Factor KI	KI = 0.3	Factor KL	KL = 0.2
Corrosion allowance	ca = 0.125 in	Factor K	K = 1.2074
Thickness, T	T = 1.875 in		
Rigidity index, J, loose flange type			
Gasket seating	J = 109.4 * Ma / (E * T ** 3 * Log(K) * KL) = -		
Operating	J = 109.4 * Mo / (E * T ** 3 * Log(K) * KL) = -		
Rigidity index, J, integral flange type			
Gasket seating	J = 52.14 * Ma * V / (L*E *(G0+ca)**2 * ho * KI) = 0.37		
Operating	J = 52.14 * Mo * V / (L * E * G0 ** 2 * ho * KI) = 0.68		

Component: Rear Head Flng At TS

ASME Section VIII Div.1 2004 App. 2 Bolted Flange With Ring Type Gaskets

Flange:

Flange type: Optional type ring - code fig.2-4(8)

Flange material: SA-266 K03506 Grd 2 Forgings

Int. Max Allow Working Pressure	PI = 150 psi	Design temperature	T = 400 F
Ext. Max Allow Working Pressure	PE = -14.7 psi	B1 = B+g1 or B+go	B1 = -
Inside corr. allow	CAI = 0.125 in	Outside corr. all.	CAO = 0.0 in
Stress (operating)	SFO = 20000 psi	Stress (atmos.)	SFA = 20000 psi
Outside diameter	A = 28.375 in	Inside spherical rad.	L = -
Inside diameter	B = 23.5 in	Hub thickness	g1 = 0.625 in

DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

Bolt circle diameter	C = 26.625 in	Hub tks. at attach.	go = 0.25 in
Mean gasket diameter	G = 25.0 in	Weld leg/hub length	h = 0.375 in
Hub to bolt circle	R = 0.9375 in	Bolt circle to OD	E = 0.875 in
Flange thickness	t = 1.875 in		

Note: Optional Type Flanges use the smaller of integral or loose calculation.

Gasket material: Spiral-Wound Metal Fiber Stainless

Gasket outside dia.	ODG = 25.375 in	Gasket width	Wth = 0.375 in
Gasket thickness	tk = 0.125 in	Gasket factor	m = 3.0
Gasket seating stress	y = 10000 psi	Gasket eff. width	b = 0.1875 in
Gasket rib length	Rib = 0.0 in	Seating width	bo = 0.1875 in
Gasket rib eff width	Br = 0.0 in	(Table 2-5.2 facing 1a/lb Col. II)	

Bolt material: SA-193 G41400 Grd B7 Bolt (<= 2 1/2)

Bolt diameter	Dia = 0.75 in	No. of bolts	No. = 24
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Bolt root area	Area = 0.302 in ²
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Stress (operating)	SB = 25000 psi	Stress (atmos.)	SA = 25000 psi
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Joint-contact compr. load	HP = 6.2832*b*G*PI*m+2*Br*m*PI*RIB =	13254 lbf
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Hydrostatic end force	H = 0.7854*G*G*PI =	73631 lbf
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Hydrostatic end force	He = 0.7854*G*G*PE =	7216 lbf
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Operating conditions:

Min. calc. bolt load	WM1 = HP+H	=	86885 lbf
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Min. used bolt load	WM1 = max of 2 mating flanges	=	86885 lbf
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Bolting up conditions:

Minimum bolt load	WM2 = b*3.1416*G*Y+Br*Y*RIB	=	147262 lbf
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Min. used bolt load	WM2 = max of 2 mating flanges	=	147262 lbf
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Required bolt area	AM = WM2/SA or WM1/SB	=	5.89 in ²
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Available bolt area	AB = No.Bolt*Area	=	7.25 in ²
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Design bolt load	W = 0.5*(AM+AB)*SA	=	164231 lbf
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Minimum gasket width	NMIN = AB*SA/(6.283*y*G)	=	0.1154 in
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Loads:

Operating conditions:

Hydrostatic end load	HD = 0.785*B*B*PI	=	65061 lbf
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Hydrostatic end load	HDe = 0.785*B*B*PE	=	6376 lbf
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Gasket load	HG = WM1-H	=	13254 lbf
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Result. hydrostatic force	HT = H-HD	=	8571 lbf
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Result. hydrostatic force	HTe = He-HDe	=	840 lbf
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Bolting up conditions:

Gasket load	HG = W	=	164231 lbf
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Operating conditions:

Hydrostatic lever arm	hd = R+0.5*g1	=	1.25 in
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Gasket load lever arm	hg = (C-G)/2	=	0.8125 in
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Result. hydro. lever arm	ht = (R+g1+hg)/2.0	=	1.1875 in
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Bolting up conditions:

Gasket load lever arm	hg = (C-G)/2	=	0.8125 in
-----------------------	--------------	---	-----------

Operating conditions:

Hydrostatic moment	MD = HD*hd	=	81326 lbf*in
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Gasket moment	MG = HG*hg	=	10769 lbf*in
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Result. hydro. moment	MT = HT*ht	=	10178 lbf*in
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Total operating moment	MOP = MD+MG+MT	=	102272 lbf*in
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Total operating mom. MOPe	HDe(hd-hg)+HTe(ht-hg)	=	3104 lbf*in
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Bolting up conditions:

Bolt up moment	MATM = W*hg	=	133438 lbf*in
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Effective bolt moment	MB = MATM*SFO/SFA	=	133438 lbf*in
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Total moment	MO = MOP or MB	=	133438 lbf*in
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Bolt spacing correction	M = MO*Cf	=	133438 lbf*in
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(TEMA 1999 RCB-11.23) Cf = 1

Flange shape constants:

K = A/B	= 1.2074	ho = SQ(B*G0)	= 2.4238
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TF = Fig.2-7.1	= 1.836	h/ho = h/ho	= 0.1547
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Z = Fig.2-7.1	= 5.3675	F = Fig.2-7.2	= 0.898
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Y = Fig.2-7.1	= 10.4053	V = Fig.2-7.3	= 0.3716
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DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

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Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

U = Fig.2-7.1	= 11.4344	f = Fig.2-7.6	= 4.5671
G1/G0 = G1/G0	= 2.5	e = F/ho	= 0.3705
t =	= 1.875 in		
D = U*ho*g0*g0/V	= 4.6616	Alpha = t*e+1.0	= 1.6947
Beta = 1.333*t*e+1.0	= 1.926	Gamma = Alpha/TF	= 0.9231
Delta = t*t*t/D	= 1.4141	Lambda = Gamma+Delta	= 2.3371

Stress calculations:		Allowable stress:	
Long. hub SH = (f*M)/(Lambda*g1**2*B)	= 28406 psi	1.5*SFO =	30000 psi
Radial SR = Beta*M/(Lambda*t**2*B)	= 1331 psi	SFO =	20000 psi
Tangential ST1 = M*Y/(t**2*B) - (Z*SR)	= 9662 psi	SFO =	20000 psi
(greater) ST2 = (SH+SR)/2 or (SH+ST1)/2	= 19034 psi	SFO =	20000 psi

Loads:

Loose Flange Calculations

Operating conditions:

Hydrostatic end load	HD = 0.785*B*B*PI	= 68567 lbf
Hydrostatic end load	HDe = 0.785*B*B*PE	= 6720 lbf
Gasket load	HG = WM1-H	= 13254 lbf
Result. hydrostatic force	HT = H-HD	= 5064 lbf
Result. hydrostatic force	HTe = He-HDe	= 496 lbf

Bolting up conditions:

Gasket load	HG = W	= 164231 lbf
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Operating conditions:

Hydrostatic lever arm	hd = (C-B)/2.0	= 1.25 in
Gasket load lever arm	hg = (C-G)/2	= 0.8125 in
Result. hydro. lever arm	ht = (hd+hg)/2.0	= 1.0313 in

Bolting up conditions:

Gasket load lever arm	hg = (C-G)/2	= 0.8125 in
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Operating conditions:

Hydrostatic moment	MD = HD*hd	= 85709 lbf*in
Gasket moment	MG = HG*hg	= 10769 lbf*in
Result. hydro. moment	MT = HT*ht	= 5222 lbf*in
Total operating moment	MOP = MD+MG+MT	= 101700 lbf*in
Total operating mom. MOPe =	HDe(hd-hg)+HTe(ht-hg)	= 3048 lbf*in

Bolting up conditions:

Bolt up moment	MATM = W*hg	= 133438 lbf*in
Effective bolt moment	MB = MATM*SFO/SFA	= 133438 lbf*in
Total moment	MO = MOP or MB	= 133438 lbf*in
Bolt spacing correction	M = MO*Cf	= 133438 lbf*in

(TEMA 1999 RCB-11.23) Cf = 1

Flange shape constants:

B =	= 24.125 in
K = A/B	= 1.1762
Y = Fig.2-7.1	= 12.0464

Flange calculated thickness: t = (M*Y/SFO*B)**0.5 = 1.8252 in

Flange nominal thickness: tnom = 1.875 in

Stress calculations:

Tangential, ST = MO*Cf*Y/(B*tnom**2)	= 18952 psi	Allowable stress:	SFO = 20000 psi
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Component: Rear Head Flng At TS

ASME Section VIII Div.1 2004, Appendix S, S-2 Flange Rigidity

--- Calculations ---

Operating moment, Mo =	102272 lbf*in	Gasket seat. moment Ma =	133438 lbf*in
Factor V	V = 0.372	Factor L	L = 2.3371
Mod. elast.design T Ed =	27500000 psi	Mod.elast.atm. temp Ea =	29300000 psi
Thickness g0	g0 = 0.25 in	Factor h0	h0 = 2.4238 in
Factor KI	KI = 0.3	Factor KL	KL = 0.2
Corrosion allowance ca =	0.125 in	Factor K	K = 1.2074
Thickness, T	T = 1.875 in		
Rigidity index, J, loose flange type			
Gasket seating J =	109.4 * Ma / (E * T ** 3 * Log(K) * KL)	=	-

DOYLE & ROTH MFG COMPANY, INC

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Calculated By: Haresh Sevak

Checked By: Rohit Patel

Operating $J = 109.4 * Mo / (E * T ** 3 * Log(K) * KL) = -$
 Rigidity index, J, integral flange type
 Gasket seating $J = 52.14 * Ma * V / (L * E * (G0+ca)**2 * ho * KI) = 0.37$
 Operating $J = 52.14 * Mo * V / (L * E * G0 ** 2 * ho * KI) = 0.68$

Component: Tubesheets

Tubesheet Details - TEMA 1999 Design

Materials of construction

Shell: SA-106 K03006 Grd B Smls. pipe
 Channel: SA-516 K02700 Grd 70 Plate
 Tubesheet: SA-516 K02700 Grd 70 Plate
 Tubes: SA-179 K01200 Smls. tube

Design conditions	Shell	Channel	Tubesheet	Tubes
Max Allow Working Pressure	psi	164.7	164.7	
Design temperature	F	400	400	400
Allowable stress	psi	17100	20000	13400
Mean metal temp.	F	273	298	298
Mod.of elas/M.M.T.	psi	28235000	28110000	28110000
Coef.th.exp/M.M.T. in/in/F		0.0000068		0.0000068
Corrosion allowance	in	0.125	0.125	
Yield stress, Sy	psi			22200

RCB-7.134 Tubesheet Formula - Tubesheet Flange Extension

RCB-7.1341 Fixed Tubesheet or Floating Tubesheet Exchangers

Design temperature TS = 400 F TS allowable stress S = 20000 psi

Tubesheet OD A = 28.375 in Reaction diameter G = 23.5 in

Ratio A/G r = 1.2074

Equivalent diameter DL = 18.874 in Flange moment M = 133438 lbf*in

($M * (r**2 - 1 + 3.71 * r**2 * Ln(r)) ** 1/2$)

Tr = 0.98 * (-----) = 0.7233 in

($S * (A - G) * (1 + 1.86 * r**2)$)

Relative expansion between shell and tubes (TEMA T-4.5)

Shell metal temp. Thetas = 203 F Tube metal temp. Thetat = 228 F

Tube length L = 96.0 in

DeltaL = (Alphas*Thetas-Alphat*Thetat)*L = -0.0175 in

Component: Tubesheets

Tubesheet Details - TEMA 1999 Design

RCB-7.13 Required Effective Tubesheet Thickness

Tubesheet details with effective thicknesses (no corrosion added), in

Effective thickness definition as per TEMA 1999 RCB-7.12

Corroded conditions refer to head and shell dimensions only

Bending : T = (F*G/3)*Sqrt(P/Eta*S) Factor Eta = 0.4195

Shear : T = 0.31*DL*(P/S)/(1-do/Pitch)

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded

User specified thickness

Effective thickness, T : 1.0 1.0 0.0 0.0

Req. tks. shell side (bending): 0.7951 0.7362 0.0 0.0

Req. tks. tube side (bending): 0.9594 0.9835 0.0 0.0

Req. tks. shell side (shear): 0.1292 0.1084 0.0 0.0

Req. tks. tube side (shear): 0.1143 0.122 0.0 0.0

Shell and tube stresses, tube-to-TS loads and effective pressures

Stresses, psi (* means stress exceeds allowable)

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded

Shell longitudinal stress = 2187 3220 0 0

Shell compressive stress = 0 0 0 0

Tube longitudinal stress = 1467 2034 0 0

Tube compressive stress = -4202 -4239 0 0

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Calculated By: Haresh Sevak

Checked By: Rohit Patel

Tube-to-tubesheet load, lbf				
Tube-to-tubesheet load Wj =	255	354	0	0
Effective pressures P, psi				
Eff.pres.shell side (bend.)=	88.3	74.1	0	0
Eff.pres.tube side (bend.) =	128.6	132.3	0	0
Eff.pres.shell side (shear)=	88.3	74.1	0	0
Eff.pres.tube side (shear) =	78.1	83.4	0	0

Component: Tubesheets

Tubesheet Details - TEMA 1999 Design

RCB-7.161 Equivalent Differential Expansion Pressure, Pd, psi

Tube OD	do = 0.75 in	Tube thickness	tt = 0.083 in
Tube Number	N = 487	Tube pitch	pitch = 0.9375 in
Tube Length	Lt = 96.0 in	Mod.of Elasticity	E = 28110000 psi
Mod.of Elasticity	Es = 28235000 psi	Mod.of Elasticity	Et = 28110000 psi
Pd = 4*J*Es*ts*(DeltaL/Lt)/(Do-3*ts)*(1+J*K*Fq)			
J = Sj*L/Sj*L+Pi*(Do-ts)*ts*Es K = Es*ts*(Do-ts)/Et*tt*N*(do-tt)			
Fq = 0.25+(F-0.6)*((300*ts*Es/K*L*E)*(G/T)**3)**0.25			

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded

Units: in

Factor F shell side F = Fs =	1.0	1.0	1.0	1.0
Factor F tube side F = Ft =	1.0	1.0	1.0	1.0
Dia. G shell side G = Gs =	23.25	23.5	23.25	23.5
Dia. G tube side G = Gt =	23.25	23.5	23.25	23.5
Shell OD Do =	24.0	24.0	24.0	24.0
Shell thickness ts =	0.375	0.25	0.375	0.25
Spring rate, lbf/in Sj =	-	-	0	0
Stiffness multiplier K =	-	-	0	0
Effective tube length L =	93.5	93.8	0	0
J=1;w/o Exp.Joint J =	1.0	1.0	0.0	0.0
J=0;Sj< (Do-ts)*ts*Es/10*L =	0	0	0	0
Rigidity factor K K =	0.3301	0.2212	0.3301	0.2212
Fq =	5.2058	6.1441	0.0	0.0
Pd =	-124.3	-94	0	0

Component: Tubesheets

Tubesheet Details - TEMA 1999 Design

RCB-7.162 Equivalent Bolting Pressure, Pb, psi

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
Equiv. bolting pressure Pbt =	50.5	48.9	50.5	48.9
Equiv. bolting pressure Pbs =	65.8	63.7	65.8	63.7
Operating moment M1 = 102272 lbf*in	Bolting-up moment M2 = 133438 lbf*in			
6.2 * M1	6.2 * M2			
Operating - Pbt = -----	Bolting up - Pbs = -----			
F**2 * Gs**3	F**2 * Gs**3			

RCB-7.163 Effective Shell Side Max Allow Working Pressure, P, psi

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
P = (Ps'-Pd)/2	88.3	74.1	0	0
P = Ps'	52.3	54.3	0	0
P = PBs	65.8	63.7	0	0
P = (Ps'-Pd-PBs)/2	55.4	42.2	0	0
P = (PBs+Pd)/2	-29.3	-15.1	0	0
P = Ps'-PBs	-13.5	-9.5	0	0
G = Gs = Shell I.D., in	23.25	23.5	23.25	23.5
fs = 1-N*(do/G)**2	0.4932	0.504	0.4932	0.504
Dj = expansion joint ID, in	23.25	23.5	0.0	0.0
Ps' =	52.3	54.3	0	0

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Calculated By: Haresh Sevak

Checked By: Rohit Patel

$$Ps' = Ps * \frac{0.4 * J * (1.5 + K * (1.5 + fs)) - ((1 - J) / 2) * (Dj ** 2 / G ** 2 - 1)}{1 + J * K * Fq}$$

Component: Tubesheets

Tubesheet Details - TEMA 1999 Design

RCB-7.164 Effective Tube Side Max Allow Working Pressure, P, psi

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
If Ps' is positive:				
P = (Pt'+PBt+Pd)/2	2.1	19.1	0	0
P = Pt'+PBt	128.6	132.3	0	0
If Ps' is negative:				
P = (Pt'-Ps'+PBt+Pd)/2	-24	-8	0	0
P = Pt'-Ps'+PBt	76.3	78	0	0
When J=0 and Ps and Pt are both positive:				
P = Pt+(Ps/2)*((Dj/G)**2-1)+PBt	0	0	0	0
G = Gs = shell I.D., in	23.25	23.5	23.25	23.5
ft = 1-N*((do-2*tt)/G)**2	0.6927	0.6992	0.6927	0.6992
Pt' =	78.1	83.4	0	0

$$Pt' = Pt * \frac{1 + 0.4 * J * K * (1.5 + ft)}{1 + J * K * Fq}$$

RCB-7.22 Shell Longitudinal Stress, Ss, psi

$$Ss = (Cs * (Do - ts) * (Ps*)) / 4 * ts$$

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
Tensile stress (shell), psi				
Allowable stress	17100	17100	17100	17100
Tensile stress Ss =	2187	3220	0	0
Compressive stress (shell), psi				
Allowable stress	13930	14805	13930	14805
Compressive stress Ss =	0	0	0	0
Effective pressure, Ps*, psi				
Ps* = Pt-Pt'	86.6	81.3	0	0
Ps* = Ps'	52.3	54.3	0	0
Ps* = -Pd	124.3	94	0	0
Ps* = Pt-Pt'+Ps'	138.9	135.6	0	0
Ps* = Pt-Pt'-Pd	210.9	175.3	0	0
Ps* = Ps'-Pd	176.6	148.2	0	0
Ps* = Pt-Pt'+Ps'-Pd	263.2	229.5	0	0

Component: Tubesheets

Tubesheet Details - TEMA 1999 Design

RCB-7.23 Tube Longitudinal Stress-Periphery of Bundle, St, psi

$$St = (Ct * Fq * (Pt*) * G**2) / 4 * N * tt * (do-tt)$$

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
G = Gs = Shell I.D., in	23.25	23.5	23.25	23.5
Fs = 3.25-0.5*Fq	1.25	1.25	0	0
Tensile stress (tubes), psi				
Allowable stress	13400	13400	13400	13400
Tensile stress St =	1466.9	2034.3	0	0
Compressive stress (tubes), psi				
Allowable stress Sc =	13400	13400	0	0
Compressive stress St =	-4202	-4239	0	0
Intermediate pressures, P2 and P3, psi				
P2 = Pt'-(ft*Pt/Fq)	56.2	64.7	0	0
P3 = Ps'-(fs*Ps/Fq)	36.7	40.8	0	0

RCB-7.23 Tube Longitudinal Stress-Periphery of Bundle (Continued), St, psi

	-Without exp.joint-	-- With exp.joint --
--	---------------------	----------------------

DOYLE & ROTH MFG COMPANY, INC

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PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

Effective pressure, Pt*, psi	Uncorroded	Corroded	Uncorroded	Corroded
Pt* = P2	56.2	64.7	0	0
Pt* = -P3	-36.7	-40.8	0	0
Pt* = Pd	-124.3	-94	0	0
Pt* = P2-P3	19.5	23.9	0	0
Pt* = P2+Pd	-68.1	-29.3	0	0
Pt* = -P3+Pd	-161	-134.7	0	0
Pt* = P2-P3+Pd	-104.8	-70.1	0	0

RCB-7.24 Allowable Tube Compressive Stress-Periphery of Bundle, Sc, psi

$$Sc = \pi^{**2} * Et / (Fs * (kl/r)**2) \text{ when } Cc \leq kl/r \quad k = 0.80$$

$$Sc = (Sy/Fs) * (1 - (kl/r) / (2 * Cc)) \text{ when } Cc > kl/r \quad l = 21.75 \text{ in}$$

$$Cc = \text{Sqrt}(2 * \pi^{**2} * Et / Sy) \quad Cc = 158.1 \quad kl/r = 73.22$$

$$r = 0.25 * \text{Sqrt}(do^{**2} + (do - 2 * tt)**2) = 0.2376 \text{ in}$$

Component: Tubesheets

Tubesheet Details - TEMA 1999 Design

RCB-7.25 Tube-to-Tubesheet Joint Loads-Periphery of Bundle, Wj, lbf

$$Wj = \pi * Fq * (Pt*) G^{**2} / (4 * N)$$

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
G = Gs = Shell I.D., in	23.25	23.5	23.25	23.5
Tube-to-tubesheet load, Wj	255.1	353.8	0	0
Effective pressure, Pt*, psi				
Pt* = P2	56.2	64.7	0	0
Pt* = -P3	-36.7	-40.8	0	0
Pt* = P2-P3	19.5	23.9	0	0

RCB-7.25 Tube-to-Tubesheet Joint Loads-Periphery of Bundle (cont.), Wj, lbf

Allowable Loads per ASME Section VIII Div. 1 2004 Appendix A

Type	Joint description	No Test		Test	
		fr	Lmax	fr	Lmax
a	Strength welded only	0.8	1864	1	2331
b	Seal welded only	0.55	1282	0.7	1631
e	Strength welded and expanded	0.8	1864	1	2331
f	Seal welded and exp.with 2 grooves	0.75	1748	0.95	2214
g	Seal welded and exp.with 1 groove	0.65	1515	0.85	1981
h	Seal welded and exp.with no grooves	0.5	1165	0.7	1631
i	Expanded with 2 grooves	0.7	1631	0.9	2098
j	Expanded with 1 groove	0.65	1515	0.8	1864
k	Expanded with no grooves	0.5	1165	0.6	1398

* = Wj calculated exceeds code allowable for this joint type.

For joints types a,b,b-1,c,d,e : Lmax = At*Sa*fr

For joints types f,g,h, : Lmax = At*Sa*fe*fr*fy

For joints types i,j,k : Lmax = At*Sa*fe*fr*fy,ft

Cross-sectional area At = 0.1739 in² Tube allowable stress Sa = 13400 psi

Factor fe (1/do or 1) fe = 1 Ratio fy fy = 1

ft = (Po+Pt)/Po ft = 1 Min Yield Str SigmaM = 26000 psi

(ft = 1 if max exceeded)

Tube OD do = 0.75 in Tube thickness tt = 0.083 in

Tubes yield str(min) st = 26000 psi Joint operating Temp T = 298 F

Tubes Mod.Elasticity EtT = 28110000 psi TubSh Mod.Elast. EsT = 28110000 psi

Tubes Coef.Th.Exp. at = 0.000068 TubSh Coef.Th.Exp. as = 0.000068

Po = (4*(do*t-t**2)*st)/do**2 Po = 10236 psi

Pt = ((T-Tamb)*(at-as)*(EtT*EsT)/(EtT+EsT) Pt = 0 psi

For joint types i, j, k:

$$Po + Pt \leq 0.58 * \text{SigmaM}$$

$$10236 \text{ psi} \leq 15080 \text{ psi}$$

Component: Tubesheets

ASME VIII-1 2004 UHX-13 Rules for the Design of Fixed Tubesheets

Fig.UHX-13.1(b) Controlling Case: UHX-13.4(a)(3)

Tubesheet material: SA-516 K02700 Grd.70 Plate

DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

Tube material:	SA-179 K01200 Smls. tube		
Shell material:	SA-106 K03006 Grd B Smls. pipe		
Channel material:	SA-516 K02700 Grd 70 Plate		
Adjacent shell material:	-		
Design temp. tubesheet T =	400 F	Design temp. tubes	Tt = 400 F
Design temp. shell Ts =	400 F	Design temp. channel Tc =	400 F
Shell mean metal tmp Tsm =	273 F	Tubes mean metal tmp Ttm =	298 F
Shell metal tmp/TubS T's =	273 F	Channel metal tmp TS T'c =	298 F
TubSh metal tmp at rim T' =	298 F	Tubesheet OD	A = 28.375 in
TubSh mod.elasticity E =	27500000 psi	Shell mod.elasticity Es =	27500000 psi
Channel mod.elast. Ec =	27500000 psi	Tube mod.elas. at Tt Et =	27500000 psi
TubSh allowable stress S =	20000 psi	Tube mod.elas. at T Ett =	27500000 psi
Tube exp.depth ratio rho =	0.895	Tube allow.Str. at Tt St =	13400 psi
Tube pitch p =	0.9375 in	Tube allow.Str. at T Stt =	13400 psi
Center-to-center dis UL =	0.0 in	Tube outside diam. dt =	0.75 in
Tube yield stress Syt =	22200 psi	Unsupp.length lt=k*1 lt =	17.4 in
Tube buckling factor k =	0.8	Unsupported tube span l =	21.75 in
Outermost tube rad. ro =	11.0 in	Tube thickness tt =	0.083 in
Shell all. stress Ss =	17100 psi	Channel all. stress Sc =	20000 psi
Adj Shell all. str. Ss,1 =	-	Gasket diam G =	25.0 in
Shell gasket diam. Gs =	-	Channel gasket diam. Gc =	25.0 in
Shell radius as =	11.75 in	Channel radius ac =	12.5 in
Shell thickness ts =	0.25 in	Channel thickness tc =	0.25 in
Adjacent shell thk ts,1 =	-	Channel ID Dc =	23.5 in
Shell ID Ds =	23.5 in	Tube length L =	93.375 in
Number of tubes Nt =	487	Tube length Lt =	95.75 in
Pass partition groove hg =	0.0 in	Tube side cor.allow. ct =	0.125 in
Bolt circle diam. C =	26.625 in	Shell side cor.allow. cs =	0.125 in
Flange load W =	164231 lbf	Gasket reaction diam. G1 =	25.0 in
Tubesheet thickness h =	1.1875 in		
Shell Max Allow Working Pressure Ps =	164.7 psi	Tube Max Allow Working Pressure Pt =	164.7 psi
*Shell th.ex.coe.alphasm =	6.846	*Tube th.ex.coe.alphatm =	6.896
*Shell th.ex.coe.alpha's =	6.846	*Chan.th.ex.coe.alpha'c =	6.896
*Shell th.ex.coe.alpha's1 =	0.0	*TubSh th.ex.coe.alpha' =	6.896
*TubSh th.ex.coe.alpha'sm1 =	0.0	*(th.exp.coef * 10**6)	
Poisson's ratio shell vs =	0.3	Poisson's rat. tubes vt =	0.3
Poisson's rat.channel vc =	0.3	Poisson's rat. tubSh v =	0.3
Exp.joint spring rate kj =	0 lbf/in	Exp.joint diameter Dj =	0.0 in

Component: Tubesheets

Fig.UHX-13.1(b) Controlling Case: UHX-13.4(a)(3)

UHX-13.5.1 Step 1. Determine Do, Mu, Mu* and h'g from UHX-11.5.1.

Do =	2 * ro + dt	Do =	22.75 in
mu =	(p - dt) / p	mu =	0.2
d* =	MAX(dt-2*tt*(Ett/E)*(Stt/S)*Rho), (dt-2*tt)	d* =	0.6505 in
Pass lane area limit		4*Do*p =	85.31 in2
Actual pass lane area, AL		AL =	0 in2
Effective pitch = p/SQRT(1-(4*MIN[AL,4*Do*p]/Pi*Do**2))		p* =	0.9375 in
mu* = (p* - d*) / p*		mu* =	0.3061
h'g = MAX[(hg-ct), (0)]		h'g =	0.0 in
Calculate ao, rhos, rhoc, xs and xt			
ao = radius of the perforated region = Do / 2		ao =	11.375 in
rhos = as/ao		rhos =	1.033
rhoc = ac/ao		rhoc =	1.0989
xs = 1 - Nt(dt/(2*ao))**2		xs =	0.4707
xt = 1 - Nt((dt-2*tt)/(2*ao))**2		xt =	0.6791
stiffness Kt, and stiffness factors Ks,t and J			
Shell axial stiffness, Ks = PI*ts(Ds+ts)*Es/L		Ks =	5493582 lbf/in
Ks* = PI*(Ds+ts)/((L-2*11)/(Es*ts)+(2*11/(Es,1*ts,1)))		Ks* =	-
Tube axial stiffness, Kt = PI*tt(dt-tt)*Et/L		Kt =	51222 lbf/in

DOYLE & ROTH MFG COMPANY, INC

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Calculated By: Haresh Sevak

Checked By: Rohit Patel

Factor $K_{s,t} = K_s / (N_t * K_t)$ or $K_s / (N_t * K_t)$

$K_{s,t} = 0.2202$

$J = 1 / (1 + (K_s / K_j))$

$J = 1.0$

Calculate shell coefficients betas, k_s , lambdas and deltas

$betas = (12 * (1 - v_s^{**2}))^{**0.25} / ((D_s + t_s) * t_s)^{**0.5}$

$betas = 0.746$

$k_s = betas * (E_s * t_s^{**3}) / (6 * (1 - v_s^{**2}))$

$k_s = 58710$

$lambdas = (6 * D_s / h^{**3}) * k_s * (1 + h * betas + (h^{**2} * betas^{**2}) / 2)$

$lambdas = 11262814$

$deltas = (D_s^{**2} / (4 * E_s * t_s)) * (1 - v_s / 2)$

$deltas = 0.000017$

Calculate channel coefficients betac, k_c , lambdac and deltac

$betac = (12 * (1 - v_c^{**2}))^{**0.25} / ((D_c + t_c) * t_c)^{**0.5}$

$betac = 0$

$k_c = betac * (E_c * t_c^{**3}) / (6 * (1 - v_c^{**2}))$

$k_c = 0$

$lambdac = (6 * D_c / h^{**3}) * k_c * (1 + h * betac + (h^{**2} * betac^{**2}) / 2)$

$lambdac = 0$

$deltac = (D_c^{**2} / (4 * E_c * t_c)) * (1 - v_c / 2)$

$deltac = 0$

NOTE: If the effect of plasticity used, E_s or E_c will be E_s^* or E_c^*

Component: Tubesheets

Fig.UHX-13.1(b) Controlling Case: UHX-13.4(a)(3)

UHX-13.5.3 Step 3. Calculate h/p. If rho changes, recalculate d^* and μ^*

from UHX-11.5.1. Determine E^*/E and v^* relative to h/p from UHX-11.5.2

Layout: Triangular

Tubesheet thickness $h = 1.1875$ in

From fig. UHX-11.2 or UHX-11.3 - $E^*/E = 0.3162$

$v^* = 0.324$

$h/p = 1.2667$

$\mu^* = 0.3061$

Effective Tubesheet Mod.Elasticity $E^* = 8694288$ psi

Parameter $X_a = (24 * (1 - v^{**2})) * N_t * (E_t * t_t * (d_t - t_t) * a_o^{**2}) / ((E^*) * L * h^{**3})^{**0.25}$

$X_a = 6.240$

UHX-13.5.4 Step 4. Calculate diameter ratio K and coefficient F.

$K = A / D_o$

$K = 1.247$

$F = ((1 - v^*) / E^*) * (lambdas + lambdac + E * \ln(K))$

$F = 1.348$

Parameters Z_d , Z_v and Z_m from Table UHX-13.1

$\Psi_{i1}(X_a) = \text{bei}(X_a) + (1 - v^*) / X_a * \text{ber}'(X_a)$

$\Psi_{i1}(X_a) = -9.9431$

$\Psi_{i2}(X_a) = \text{ber}(X_a) - (1 - v^*) / X_a * \text{bei}'(X_a)$

$\Psi_{i2}(X_a) = -7.3392$

$Z_a = \text{bei}'(X_a) * \Psi_{i2}(X_a) - \text{ber}'(X_a) * \Psi_{i1}(X_a)$

$Z_a = 109.3128$

$Z_d = (\text{ber}(X_a) * \Psi_{i2}(X_a) + \text{bei}(X_a) * \Psi_{i1}(X_a)) / (X_a^{**3} * Z_a)$

$Z_d = 0.0062$

$Z_v = (\text{ber}'(X_a) * \Psi_{i2}(X_a) + \text{bei}'(X_a) * \Psi_{i1}(X_a)) / (X_a^{**2} * Z_a)$

$Z_v = 0.0262$

$Z_m = (\text{ber}'(X_a)^{**2} + \text{bei}'(X_a)^{**2}) / (X_a * Z_a)$

$Z_m = 0.2337$

Calculate Q_1 , Q_{z1} , Q_{z2} and U

$\Phi = (1 + v^*) * F$

$\Phi = 1.7849$

$Q_1 = (\rho_{hos} - 1 - \Phi * Z_v) / (1 + \Phi * Z_m)$

$Q_1 = -0.0097$

$Q_{z1} = ((Z_d + Q_1 * Z_v) * X_a^{**4}) / 2$

$Q_{z1} = 4.5048$

$Q_{z2} = ((Z_v + Q_1 * Z_m) * X_a^{**4}) / 2$

$Q_{z2} = 18.1131$

$U = ((Z_v + (\rho_{hos} - 1) * Z_m) * X_a^{**4}) / (1 + \Phi * Z_m)$

$U = 36.2263$

UHX-13.5.5 Step 5.

UHX-13.5.5(a) Calculate gamma

$\gamma = (\alpha_{tm} * (T_{tm} - T_{amb}) - \alpha_{sm} * (T_{sm} - T_{amb})) * L$
(=0 for load cases 1, 2, 3)

$\gamma = 0.0$ in

UHX-13.5.5(b) Calculate omegas, omegas*, omegac, omegac*

$\omega_{egas} = \rho_{hos} * k_s * betas * deltas * (1 + h * betas)$

$\omega_{egas} = 1.4565$

$\omega_{egas}^* = a_o^{**2} * ((\rho_{hos}^{**2} - 1) * (\rho_{hos} - 1)) / 4 - \omega_{egas}$

$\omega_{egas}^* = -1.385$

$\omega_{egac} = \rho_{hoc} * k_c * betac * deltac * (1 + h * betac)$

$\omega_{egac} = 0.0$

$\omega_{egac}^* = a_o^{**2} * ((\rho_{hoc}^{**2} + 1) * (\rho_{hoc} - 1)) / 4 - (\rho_{hos} - 1) / 2 - \omega_{egac}$

$\omega_{egac}^* = 4.9297$

UHX-13.5.5(c) Calculate gammab

$\gamma_{mab} = (G_c - C) / D_o$

$\gamma_{mab} = -0.0714$

Component: Tubesheets

Fig.UHX-13.1(b) Controlling Case: UHX-13.4(a)(3)

UHX-13.5.6 Step 6. For each loading case calculate P_s' , P_t' , P_{γ} , P_w , P_{prim} , and effective pressure P_e .

$P_s' = (x_s + 2 * (1 - x_s) * v_t + (2 / K_{st}) * (D_s / D_o)^{**2} * v_s - (\rho_{hos}^{**2} - 1) / (J * K_{st}) - ((1 - J) / (2 * J * K_{st})) * (D_j^{**2} - (2 * a_s)^{**2}) / D_o^{**2}) * P_s$

$P_s' = 558.5$ psi

DOYLE & ROTH MFG COMPANY, INC

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Calculated By: Haresh Sevak

Checked By: Rohit Patel

$Pt' = (xt+2*(1-xt)*vt+1/(J*Kst))*Pt$	$Pt' = 891.42 \text{ psi}$
$Pgamma = (Nt*Kt/(Pi*ao**2))*gamma$	$Pgamma = 0 \text{ psi}$
$PW = -(U/ao**2)*(gammab/(2*Pi))*W$	$PW = 522.72 \text{ psi}$
$Prim = -(U/ao**2)*((omegas*(Ps)-(omegac*(Pt)))$	$Prim = 291.18 \text{ psi}$
Effective pressure, Pe	
$Pe = (J*Kst/(1+J*Kst(Qz1+(rhos-1)Qz2))$	
$* (Ps'-Pt'+Pgamma+Pomega+PW+Prim)$	$Pe = 49.88 \text{ psi}$

UHX-13.5.7 Step 7. For each loading case calculate Q2 and Q3.

$Q2 = ((omegas*(Ps)-(omegac*(Pt)) - ((omegas*(Ps)-omegac*(Pc)) + (gammab/(2*Pi))*W)/(1+Phi*Zm)$	$Q2 = -2051.2815$
$Q3 = Q1 + 2*Q2 / Pe*ao**2$	$Q3 = -0.6453$

Using Xa and Q3, determine coefficient Fm for each loading case from either Table UHX-13.1 or Figs. UHX-13.3.-1 and UHX-13.3.-2.

Controlling x = 6.2397 in

Calculate functions Psi1 and Psi2 relative to x

$Psi1(x) = bei(x) + (1-v*)/x * ber'(x)$	$Psi1(x) = -9.9432$
$Psi2(x) = ber(x) - (1-v*)/x * bei'(x)$	$Psi2(x) = -7.3392$

Calculate functions Qm, Qv and Fm relative to x

$Qm(x) = (bei'(Xa)*Psi2(x) - ber'(Xa)*Psi1(x))/Za$	$Qm(x) = 1.0$
$Qv(x) = (Psi1(Xa)*Psi2(x) - Psi2(Xa)*Psi1(x))/(Xa*Za)$	$Qv(x) = -0.0$

Controlling Fm relative to x

$Fm(x) = (Qv(x) + Q3 * Qm(x)) / 2$	$Fm(x) = -0.3227$
$Fm = MAX Fm(x) $	$Fm = 0.3227$

For each loading case, calculate the bending stress in the tubesheet

$sigma = (1.5*Fm/mu)*(2*ao/(h-h'g))**2 * Pe$	$sigma = 28943 \text{ psi}$
	$ sigma <= 1.5*S$
	$28943 \text{ psi} <= 30000 \text{ psi}$

UHX-13.5.8 Step 8. For each loading case, calculate the average shear stress in the tubesheet at the outer edge of the perforated region
Shear stress in the tubesheet, tau

$tau = (1/(2*m))*(ao/h) * Pe$	$m = (p-dt)/p = 0.2$
	$tau = 1194 \text{ psi}$
	$ tau <= 0.8*S$
	$1194 \text{ psi} <= 16000 \text{ psi}$

UHX-13.5.9 Step 9. Perform this step for each loading case.

UHX-13.5.9(a) Calculate coefficient Fq and the axial tube stress sigmat,o in the outermost tube row

$Factor Fq = (Zd + Q3*Zv)*Xa**4/2$	$= -8.1001$
$sigma_to = ((Ps*xs-Ptxt) - Pe*Fq)/(xt-xs)$	$= 1774 \text{ psi}$
	$ sigma_to <= St$
	$1774 \text{ psi} <= 13400 \text{ psi}$

UHX-13.5.9(b) Check the tubes for buckling.

$Ct = SQRT(2*PI**2*(Et/Syt))$	$Ct = 156.3705$
$rt = SQRT(dt**2+(dt-2*tt)**2)/4$	$rt = 0.2376 \text{ in}$
$Ft = lt/rt$	$Ft = 91.5254$
$Fs = MAX((1.25, (3.25-0.5*Fq), 2)$	$Fs = 0.0$
For Ct <= Ft Stb = MIN[(1/Fs)*(PI**2*Et/(Ft**2)), St]	Stb = -
For Ct > Ft Stb = MIN[(Syt/Fs)*(1-(Ft/2*Ct)), St]	Stb = -
	$ sigma_to <= Stb$
	$1774 \text{ psi} <= -$

UHX-13.5.10 Step 10. For each loading case, calculate the stresses in the shell and /or channel integral with the tubesheet.

Calculate the axial membrane stress sigmasm, axial bending stress sigmasb and total axial stress sigmas in the shell at its junction to the tubesheet

$sigmasm = ao**2/2*(as*ts)*ts*[Pe+(rhos-1)*(Ps-Pt)]$	
$+ as**2/2*(as+ts)*ts*Pt$	$sigmasm = 4865 \text{ psi}$
$sigmasb = 6/ts**2*ks[betas*(deltas*Ps+(as**2/$	

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$$\text{sigmas} = |\text{sigmasm}| + |\text{sigmasb}|$$

$$\text{sigmasb} = -18258 \text{ psi}$$

$$\text{sigmas} = 23123 \text{ psi}$$

$$\text{sigmas} \leq Ss \cdot 1.5$$

$$23123 \text{ psi} \leq 25650 \text{ psi}$$

ASME VIII-1 2004 UHX-13 - Rules for the Design of Fixed Tubesheets

ASME Fig.UHX-13.1(b) All Load Cases

Controlling case: ***

Load case:	1	2	3	4	5	6	7
Tube-side press, Pt	164.7	0	164.7	0	164.7	0	164.7
Shell-side press, Ps	0	164.7	164.7	0	0	164.7	164.7
Axial diff.Th.Exp	0.0	0.0	0.0	0.017	0.017	0.017	0.017
TubSh Bending stress	-26436	21581	28943	19881	27267	22707	30093
Max TubSh Bending st	30000	30000	30000	65000	65000	65000	65000
Min TubSh thk	1.1199	1.0072	1.1664	0.6567	0.7691	0.7019	0.808
TubSh Shear stress	-333	2844	1194	3962	2320	5506	3863
Max TubSh Shear str	16000	16000	16000	16000	16000	16000	16000
Min TubSh thk	0.0247	0.2111	0.0887	0.2941	0.1722	0.4086	0.2867
Tubesheet thickness	1.1875	1.1875	1.1875	1.1875	1.1875	1.1875	1.1875

Elastic-Plastic analysis results:

Load case: 1 2 3

TubSh Bending stress	-26683	21581	28943
Max TubSh Bending st	30000	30000	30000

Component: Tubesheets

ASME Fig.UHX-13.1(b) All Load Cases

Controlling case: ***

Load case:	1	2	3	4	5	6	7
Tubes stress	2561	-21	1774	-1640	152	-2425	-634
Max Tubes stress	13400	13400	13400	26800	26800	26800	26800
Max buckling stress	-	7852	-	7852	-	7922	7852
Total shell stress	36679	3537	23123	9106	28791	14858	15219
Max shell stress	25650	25650	25650	59800	59800	59800	59800
Max shell stress EP	59800	59800	59800				
Total channel stress	4037	0	4037	0	4037	0	4037
Max channel stress	30000	30000	30000	65000	65000	65000	65000
Max channel str. EP	65000	65000	65000				
EP factor - Facts(*)	0.9526	1.0	1.0				
EP factor - Factc(*)	1.0	1.0	1.0				

(*) <= 1 used in calculations

ASME VIII-1 2004 UHX-13 - Fixed Tubesheets - All Cases

Load case	Ps psi	Pt psi	Gamma* in	Pomega psi	Pc* psi
- 1 -	0	164.7	0	0	0
- 2 -	164.7	0	0	0	0
- 3 -	164.7	164.7	0	0	0
- 4 -	0	0	0.017	0	0
- 5 -	0	164.7	0.017	0	0
- 6 -	164.7	0	0.017	0	0
- 7 -	164.7	164.7	0.017	0	0

Load case	P's psi	P't psi	Pgamma psi	Pomega psi	Pw psi	Prim psi	Pe psi
- 1 -	0	891.4	0	0	522.7	227.3	-14.7
- 2 -	558.5	0	0	0	522.7	63.9	118.8
- 3 -	558.5	891.4	0	0	522.7	291.2	49.9
- 4 -	0	0	1069.2	0	523.7	0	165.4
- 5 -	0	888.1	1069.2	0	523.7	227.8	96.9
- 6 -	556.6	0	1069.2	0	523.7	64	229.9
- 7 -	556.6	888.1	1069.2	0	523.7	291.8	161.3

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Calculated By: Haresh Sevak

Checked By: Rohit Patel

Component: Nozzle A

ASME VIII Div.1 2004 UG-27 Thickness of Cylinders under Internal Pressure

--- Calculations --- Cylinder Internal Pressure

Material: SA-106 K03006 Grd B Smls. pipe

Max Allow Working Pressure P = 150 psi Design temperature T = 400 F

Radiography = None Joint efficiency E = 0.85

Design stress S = 17100 psi

Inside corr.allow. CAI = 0.125 in Outside corr. all. CAO = 0 in

Material tolerance Tol = 0.054 in Minimum thickness tmin = 0.2144 in

Outside diameter OD = 4.5 in Corroded radius OR = 2.25 in

- Minimum thickness greater than:

- UG-45(a) Required wall thickness of the cylinder:

$$t = (P \cdot OR / (S \cdot E + 0.4 \cdot P)) + CAI + CAO + Tol = 0.2021 \text{ in} \quad \text{APP.1-1(A)}$$

- UG-45(b) Smallest of:

UG-45(b) (1) or (2) required thickness: t = 0.2144 in

UG-45(b) (4) required thickness: t = 0.3324 in

Minimum thickness: tmin = 0.2144 in

Nominal thickness: tnom = 0.432 in

ASME Section VIII Div.1 2004 UG-28 Thickness of Shells under Ext. Pressure

--- Calculations --- Cylinder External Pressure

Material: SA-106 K03006 Grd B Smls. pipe

Max Allow Working Pressure PE = 14.7 psi Design temperature T = 400 F

Inside corr. allow. CAI = 0.125 in Corrosion allow. CAO = 0 in

Radiography = None Material tol. Tol = 0.054 in

Cyl. outside dia. Do = 4.5 in Cylinder length EP L = 6 in

Nominal thickness tnom = 0.432 in (tnom-CAI-CAO-Tol) t = 0.253 in

L/Do ratio Ldo = 1.3333 Do/t Dot = 17.7866

(2*S) or (0.9*yield) SE = - Mod. of elasticity ME = 27500000 psi

A factor SII-D-FigG A = 0.014002 B factor CS-2 B = 16399

Max allowed external pressure: Pa = 4*B / (3*Dot) = 1229.33 psi

Actual external Max Allow Working Pressure: PE = 14.7 psi

(Required cyl. tks. for nozzle attachments at PE, tre = 0.017 in)

Component: Reinforcement Nozzle A

ASME Section VIII Div.1 2004 UG-37 Reinforcement Required for Openings in Shells and Formed Heads

--- Design Conditions:

Int. Max Allow Working Pressure PI = 150 psi Ext. design press. PE = -15 psi

Design temperature T = 400 F Fig.UW-16.1 Sketch (c)

Vessel material: SA-516 K02700 Grd 70 Plate

Inside corr. allow. CAI = 0.125 in Outside corr.allow.CAO = 0.0 in

Vessel design stress Sv = 20000 psi Joint efficiency E = 1

Vessel outside dia Do = 24.0 in Corroded radius OR = 12.0 in

Nominal thickness tnom = 0.375 in Reinforcement limit lp = 3.886 in

Req. tks. int.pres. tr = 0.0808 in Req. tks.ext.pres. tre = 0.065 in

Corroded thickness t = 0.25 in Reinf. efficiency E1 = 1.0

Attachment Material: SA-106 K03006 Grd B Smls. pipe

Inside corr. allow. CAI = 0.125 in Outside corr.allow.CAO = 0.0 in

Nozzle design stress Sn = 17100 psi Joint efficiency E = 1

Nozzle outside dia. Don = 4.5 in Corroded radius OR = 2.25 in

Nominal thickness tnom = 0.432 in Reinforcement limit ln = 0.625 in

Req.tks. int.pres. trn = 0.0197 in Req.tks.ext.pres. trne = 0.071 in

Corroded thickness tn = 0.307 in Nozzle Projection h = 0.0 in

Reinforcement element material:

Outside diameter Dp = 0.0 in Nominal thickness te = 0.0 in

Outside corr. all. CAO = 0.0 in Design stress Se = 0 psi

Minimum weld size tmin = 0.25 in Leg size (1/2*tmin) (Act) = 0.0 in

1/2 * tmin (minimum) = 0.0 in 1/2 * tmin (actual) = 0.0 in

Weld tw (minimum) = 0.175 in Weld tw (actual) = 0.0 in

Weld tc (minimum) = 0.175 in Weld tc (actual) = 0.175 in

DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

smaller	0.25 in		Leg size tw (actual)	= 0.0 in
tc of	0.7 * tmin		Leg size tc (actual)	= 0.25 in
Outward nozzle weld	L1 = 0.25 in		fr1 = Sn/Sv	= 0.855
Outer element weld	L2 = 0.0 in		fr2 = Sn/Sv	= 0.855
Inward nozzle weld	L3 = 0.0 in		fr3 = Sn/Sv or Se/Sv	= 0.855
Inward nozzle weld new	= 0.0 in		fr4 = Se/Sv	= 1.0
Corroded int.proj.thk ti	= 0.0 in			

Component: Reinforcement Nozzle A

Corroded inside diameter or controlling parallel limit d = 3.886 in

Plane correction factor (Fig.UG-37) F = 1.0

Offset distance from centerline doff = 0.0 in

Reinforcement areas (internal pressure condition) ASME 2004 UG-37

A1 = Vessel wall. Larger of:

$$\left| \frac{d*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)}{2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)} \right| = 0.6426 \text{ in2}$$

$$\left| \frac{d*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)}{2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)} \right| = 0.1735 \text{ in2}$$

A1 = 0.6426 in2

A2 = Nozzle wall outward

$$\left| \frac{5*(tn-trn)*fr2*t}{5*(tn-trn)*fr2*tn} \right| = 0.3071 \text{ in2}$$

Smaller of:

$$\left| \frac{5*(tn-trn)*fr2*t}{5*(tn-trn)*fr2*tn} \right| = 0.3771 \text{ in2}$$

A2 = 0.3071 in2

A3 = Nozzle wall inward

$$\left| \frac{5*t*ti*fr2}{5*ti*ti*fr2} \right| = 0.0 \text{ in2}$$

Smallest of:

$$\left| \frac{5*t*ti*fr2}{5*ti*ti*fr2} \right| = 0.0 \text{ in2}$$

$$\left| \frac{2*h*ti*fr2}{2*h*ti*fr2} \right| = 0.0 \text{ in2}$$

A3 = 0.0 in2

Component: Reinforcement Nozzle A

A41 = Outward nozzle weld = (L1**2)*fr3 = 0.0534 in2

A42 = Outer element weld = (L2**2)*fr4 = 0.0 in2

A43 = Inward nozzle weld = (L3**2)*fr2 = 0.0 in2

A4 = 0.0534 in2

A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4

A5 = 0.0 in2

Aa = Area Available = A1+A2+A3+A4+A5

Aa = 1.0031 in2

A = Area required = (d*tr*F)+2*tn*tr*F*(1-f1)

A = 0.321 in2

ASME VIII Div.1 2004 Reinforcement areas (external pressure) UG-37(d)

A1 = Vessel wall. Larger of:

$$\left| \frac{d*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)}{2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)} \right| = 0.7024 \text{ in2}$$

$$\left| \frac{d*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)}{2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)} \right| = 0.1896 \text{ in2}$$

A1 = 0.7024 in2

A2 = Nozzle wall outward

$$\left| \frac{5*(tn-trne)*fr2*t}{5*(tn-trne)*fr2*tn} \right| = 0.2522 \text{ in2}$$

Smaller of:

$$\left| \frac{5*(tn-trne)*fr2*t}{5*(tn-trne)*fr2*tn} \right| = 0.3097 \text{ in2}$$

A2 = 0.2522 in2

A3 = Nozzle wall inward

$$\left| \frac{5*t*ti*fr2}{5*ti*ti*fr2} \right| = 0.0 \text{ in2}$$

Smallest of:

$$\left| \frac{5*t*ti*fr2}{5*ti*ti*fr2} \right| = 0.0 \text{ in2}$$

$$\left| \frac{2*h*ti*fr2}{2*h*ti*fr2} \right| = 0.0 \text{ in2}$$

A3 = 0.0 in2

A41 = Outward nozzle weld = (L1**2)*fr3 = 0.0534 in2

A42 = Outer element weld = (L2**2)*fr4 = 0.0 in2

A43 = Inward nozzle weld = (L3**2)*fr2 = 0.0 in2

A4 = 0.0534 in2

A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4

A5 = 0.0 in2

Aa = Area Available = A1+A2+A3+A4+A5

Aa = 1.0081 in2

A = Area required = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))

A = 0.1292 in2

Component: Reinforcement Nozzle A

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

ASME - Weld strength calculations not required per UW-15(b).

Total weld load (UG-41(b) (2))

$$W = (A-A1+2*tn*fr1*(E1*t-F*tr))*Sv \quad W = -$$

Weld load for strength path 1-1 (UG-41(b) (1))

$$W(1-1) = (A2+A5+A41+A42)*Sv \quad W(1-1) = 7210 \text{ lbf}$$

Weld load for strength path 2-2 (UG-41(b) (1))

DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

$W(2-2) = (A2+A3+A41+A43+2*tn*t*fr1)*Sv$ W(2-2) = 9835 lbf
 Weld load for strength path 3-3 (UG-41(b)(1))
 $W(3-3) = (A2+A3+A5+A41+A42+A43+2*tn*t*fr1)*Sv$ W(3-3) = -
 Reinforcing element strength = $A5 * Se$ = -
 Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement
 Unit stresses - UW15(c) and UG-45(c)
 Inner fillet weld shear = 8379 psi
 Outer fillet weld shear = -
 Groove weld tension = 12654 psi
 Groove weld shear = -
 Nozzle wall shear = 11970 psi
 Strength of connection elements
 Inner fillet weld shear = 14800 lbf
 Nozzle wall shear = 24192 lbf
 Groove weld tension = 22351 lbf
 Outer fillet weld shear = -
 Possible paths of failure
 1-1 24192 + 14800 = 38992 lbf
 2-2 14800 + 22351 = 37151 lbf
 3-3 - + - = -

Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement
 Welds strong enough if path greater than the smaller of W or W(path)
 Path 1-1 > W or W11
 38992 lbf > 7210 lbf OK
 Path 2-2 > W or W22
 37151 lbf > 9835 lbf OK
 Path 3-3 > W or W33
 - > -

Component: Nozzle B

ASME VIII Div.1 2004 UG-27 Thickness of Cylinders under Internal Pressure
 --- Calculations --- Cylinder Internal Pressure
 Material: SA-105 K03504 Forgings
 Max Allow Working Pressure $P = 150$ psi Design temperature $T = 400$ F
 Radiography = None Joint efficiency $E = 1$
 Design stress $S = 20000$ psi
 Inside corr. allow. $CAI = 0.125$ in Outside corr. all. $CAO = 0$ in
 Material tolerance $Tol = 0$ in Minimum thickness $t_{min} = 0.2144$ in
 Outside diameter $OD = 3.5$ in Corroded radius $OR = 1.75$ in
 - Minimum thickness greater than:
 - UG-45(a) Required wall thickness of the cylinder:
 $t = (P*OR / (S*E+0.4*P)) + CAI + CAO + Tol = 0.1381$ in APP.1-1(A)
 - UG-45(b) Smallest of:
 UG-45(b)(1) or (2) required thickness: $t = 0.2144$ in
 UG-45(b)(4) required thickness: $t = 0.314$ in
 Minimum thickness: $t_{min} = 0.2144$ in
 Nominal thickness: $t_{nom} = 0.3$ in

ASME Section VIII Div.1 2004 UG-28 Thickness of Shells under Ext. Pressure
 --- Calculations --- Cylinder External Pressure
 Material: SA-105 K03504 Forgings
 Max Allow Working Pressure $PE = 14.7$ psi Design temperature $T = 400$ F
 Inside corr. allow. $CAI = 0.125$ in Corrosion allow. $CAO = 0$ in
 Radiography = None Material tol. $Tol = 0$ in
 Cyl. outside dia. $Do = 3.5$ in Cylinder length EP $L = 6$ in
 Nominal thickness $t_{nom} = 0.3$ in $(t_{nom} - CAI - CAO - Tol)$ $t = 0.175$ in
 L/Do ratio $Ldo = 1.7143$ Do/t Dot = 20.0
 $(2*S)$ or $(0.9*yield)$ $SE = -$ Mod. of elasticity $ME = 27500000$ psi
 A factor SII-D-FigG $A = 0.008487$ B factor CS-2 $B = 15818$
 Max allowed external pressure: $Pa = 4*B / (3*Dot)$ = 1054.51 psi
 Actual external Max Allow Working Pressure: PE = 14.7 psi
 (Required cyl. tks. for nozzle attachments at PE, $t_{re} = 0.015$ in)

DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

Component: Reinforcement Nozzle B

ASME Section VIII Div.1 2004 UG-37 Reinforcement Required for Openings in Shells and Formed Heads

--- Design Conditions:

Int. Max Allow Working Pressure PI = 150 psi Ext. design press. PE = -15 psi

Design temperature T = 400 F Fig.UW-16.1 Sketch (c)

Vessel material: SA-516 K02700 Grd 70 Plate

Inside corr. allow. CAI = 0.125 in Outside corr.allow.CAO = 0.0 in

Vessel design stress Sv = 20000 psi Joint efficiency E = 1

Vessel outside dia^o Do = 24.0 in Corroded radius OR = 12.0 in

Nominal thickness tnom = 0.375 in Reinforcement limit lp = 3.15 in

Req. tks. int.pres. tr = 0.0808 in Req. tks.ext.pres. tre = 0.065 in

Corroded thickness t = 0.25 in Reinf. efficiency E1 = 1.0

Attachment Material: SA-105 K03504 Forgings

Inside corr. allow. CAI = 0.125 in Outside corr.allow.CAO = 0.0 in

Nozzle design stress Sn = 20000 psi Joint efficiency E = 1

Nozzle outside dia. Don = 3.5 in Corroded radius OR = 1.75 in

Nominal thickness tnom = 0.3 in Reinforcement limit ln = 0.4375 in

Req.tks. int.pres. trn = 0.0131 in Req.tks.ext.pres. trne = 0.015 in

Corroded thickness tn = 0.175 in Nozzle Projection h = 0.0 in

Reinforcement element material:

Outside diameter Dp = 0.0 in Nominal thickness te = 0.0 in

Outside corr. all. CAO = 0.0 in Design stress Se = 0 psi

Minimum weld size tmin = 0.175 in Leg size (1/2*tmin) (Act) = 0.0 in

1/2 * tmin (minimum) = 0.0 in 1/2 * tmin (actual) = 0.0 in

Weld tw (minimum) = 0.1225 in Weld tw (actual) = 0.0 in

Weld tc (minimum) = 0.1225 in Weld tc (actual) = 0.1225 in

smaller | 0.25 in | Leg size tw (actual) = 0.0 in

tc of | 0.7 * tmin | Leg size tc (actual) = 0.175 in

Outward nozzle weld L1 = 0.175 in fr1 = Sn/Sv = 1.0

Outer element weld L2 = 0.0 in fr2 = Sn/Sv = 1.0

Inward nozzle weld L3 = 0.0 in fr3 = Sn/Sv or Se/Sv = 1.0

Inward nozzle weld new = 0.0 in fr4 = Se/Sv = 1.0

Corroded int.proj.thk ti = 0.0 in

Component: Reinforcement Nozzle B

Corroded inside diameter or controlling parallel limit d = 3.15 in

Plane correction factor (Fig.UG-37) F = 1.0

Offset distance from centerline doff = 0.0 in

Reinforcement areas (internal pressure condition) ASME 2004 UG-37

A1 = Vessel wall. Larger of:

$$\left| d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1) \right| = 0.5331 \text{ in}^2$$

$$\left| 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1) \right| = 0.1439 \text{ in}^2$$

$$A1 = 0.5331 \text{ in}^2$$

$$A2 = \text{Nozzle wall outward} \left| 5*(tn-trn)*fr2*t \right| = 0.2024 \text{ in}^2$$

$$\text{Smaller of:} \left| 5*(tn-trn)*fr2*tn \right| = 0.1417 \text{ in}^2$$

$$A2 = 0.1417 \text{ in}^2$$

$$A3 = \text{Nozzle wall inward} \left| 5*t*ti*fr2 \right| = 0.0 \text{ in}^2$$

$$\text{Smallest of:} \left| 5*ti*ti*fr2 \right| = 0.0 \text{ in}^2$$

$$\left| 2*h*ti*fr2 \right| = 0.0 \text{ in}^2$$

$$A3 = 0.0 \text{ in}^2$$

Component: Reinforcement Nozzle B

$$A41 = \text{Outward nozzle weld} = (L1**2)*fr3 = 0.0306 \text{ in}^2$$

$$A42 = \text{Outer element weld} = (L2**2)*fr4 = 0.0 \text{ in}^2$$

$$A43 = \text{Inward nozzle weld} = (L3**2)*fr2 = 0.0 \text{ in}^2$$

$$A4 = 0.0306 \text{ in}^2$$

$$A5 = \text{Reinforcement pad Area} = (Dp-d-2*tn)*te*fr4$$

$$A5 = 0.0 \text{ in}^2$$

$$Aa = \text{Area Available} = A1+A2+A3+A4+A5$$

$$Aa = 0.7054 \text{ in}^2$$

$$A = \text{Area required} = (d*tr*F) + 2*tn*tr*F*(1-f1)$$

$$A = 0.2544 \text{ in}^2$$

DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

Note: Reinforcing not required for this nozzle per ASME code rules.

ASME VIII Div.1 2004 Reinforcement areas (external pressure) UG-37(d)

A1 = Vessel wall. Larger of:

$$\begin{aligned} |d*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| &= 0.5828 \text{ in}^2 \\ |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| &= 0.1573 \text{ in}^2 \\ A1 &= 0.5828 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A2 = \text{Nozzle wall outward} & \quad |5*(tn-trne)*fr2*t| = 0.2 \text{ in}^2 \\ \text{Smaller of:} & \quad |5*(tn-trne)*fr2*tn| = 0.14 \text{ in}^2 \\ A2 &= 0.14 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A3 = \text{Nozzle wall inward} & \quad |5*t*ti*fr2| = 0.0 \text{ in}^2 \\ \text{Smallest of:} & \quad |5*ti*ti*fr2| = 0.0 \text{ in}^2 \\ & \quad |2*h*ti*fr2| = 0.0 \text{ in}^2 \\ A3 &= 0.0 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A41 = \text{Outward nozzle weld} &= (L1**2)*fr3 = 0.0306 \text{ in}^2 \\ A42 = \text{Outer element weld} &= (L2**2)*fr4 = 0.0 \text{ in}^2 \\ A43 = \text{Inward nozzle weld} &= (L3**2)*fr2 = 0.0 \text{ in}^2 \\ A4 &= 0.0306 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A5 = \text{Reinforcement pad Area} &= (Dp-d-2*tn)*te*fr4 \\ Aa = \text{Area Available} &= A1+A2+A3+A4+A5 \\ A &= \text{Area required} = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1)) \end{aligned}$$

Component: Reinforcement Nozzle B

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

ASME - Weld strength calculations not required per UW-15(b).

Total weld load (UG-41(b)(2))

$$W = (A-A1+2*tn*fr1*(E1*t-F*tr))*Sv \quad W = -$$

Weld load for strength path 1-1 (UG-41(b)(1))

$$W(1-1) = (A2+A5+A41+A42)*Sv \quad W(1-1) = 3446 \text{ lbf}$$

Weld load for strength path 2-2 (UG-41(b)(1))

$$W(2-2) = (A2+A3+A41+A43+2*tn*t*fr1)*Sv \quad W(2-2) = 5196 \text{ lbf}$$

Weld load for strength path 3-3 (UG-41(b)(1))

$$W(3-3) = (A2+A3+A5+A41+A42+A43+2*tn*t*fr1)*Sv \quad W(3-3) = -$$

Reinforcing element strength = A5 * Se = -

Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement

Unit stresses - UW15(c) and UG-45(c)

Inner fillet weld shear	=	9800 psi
Outer fillet weld shear	=	-
Groove weld tension	=	14800 psi
Groove weld shear	=	-
Nozzle wall shear	=	14000 psi

Strength of connection elements

Inner fillet weld shear	=	9424 lbf
Nozzle wall shear	=	12790 lbf
Groove weld tension	=	14233 lbf
Outer fillet weld shear	=	-

Possible paths of failure

1-1	12790 + 9424	=	22214 lbf
2-2	9424 + 14233	=	23657 lbf
3-3	- + -	=	-

Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement

Welds strong enough if path greater than the smaller of W or W(path)

Path 1-1 > W or W11	
22214 lbf > 3446 lbf	OK
Path 2-2 > W or W22	
23657 lbf > 5196 lbf	OK
Path 3-3 > W or W33	
- > -	

Component: Nozzle C

ASME VIII Div.1 2004 UG-27 Thickness of Cylinders under Internal Pressure

DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

--- Calculations --- Cylinder Internal Pressure

Material: SA-106 K03006 Grd B Smls. pipe

Max Allow Working Pressure P = 150 psi Design temperature T = 400 F

Radiography = None Joint efficiency E = 0.85

Design stress S = 17100 psi

Inside corr.allow. CAI = 0.125 in Outside corr. all. CAO = 0 in

Material tolerance Tol = 0.054 in Minimum thickness tmin = 0.2299 in

Outside diameter OD = 6.625 in Corroded radius OR = 3.3125 in

- Minimum thickness greater than:

- UG-45(a) Required wall thickness of the cylinder:

$$t = (P \cdot OR / (S \cdot E + 0.4 \cdot P)) + CAI + CAO + Tol = 0.213 \text{ in} \quad \text{APP.1-1(A)}$$

- UG-45(b) Smallest of:

UG-45(b) (1) or (2) required thickness: t = 0.2299 in

UG-45(b) (4) required thickness: t = 0.37 in

Minimum thickness: tmin = 0.2299 in

Nominal thickness: tnom = 0.432 in

ASME Section VIII Div.1 2004 UG-28 Thickness of Shells under Ext. Pressure

--- Calculations --- Cylinder External Pressure

Material: SA-106 K03006 Grd B Smls. pipe

Max Allow Working Pressure PE = 14.7 psi Design temperature T = 400 F

Inside corr. allow. CAI = 0.125 in Corrosion allow. CAO = 0 in

Radiography = None Material tol. Tol = 0.054 in

Cyl. outside dia. Do = 6.625 in Cylinder length EP L = 6 in

Nominal thickness tnom = 0.432 in (tnom - CAI - CAO - Tol) t = 0.253 in

L/Do ratio Ldo = 0.9057 Do/t Dot = 26.1858

(2*S) or (0.9*yield) SE = - Mod. of elasticity ME = 27500000 psi

A factor SII-D-FigG A = 0.0117 B factor CS-2 B = 16176

Max allowed external pressure: Pa = 4*B / (3*Dot) = 823.66 psi

Actual external Max Allow Working Pressure: PE = 14.7 psi

(Required cyl. tks. for nozzle attachments at PE, tre = 0.021 in)

Component: Reinforcement Nozzle C

ASME Section VIII Div.1 2004 UG-37 Reinforcement Required for Openings in Shells and Formed Heads

--- Design Conditions:

Int. Max Allow Working Pressure PI = 150 psi Ext. design press. PE = -15 psi

Design temperature T = 400 F Fig.UW-16.1 Sketch (c)

Vessel material: SA-106 K03006 Grd B Smls. pipe

Inside corr. allow. CAI = 0.125 in Outside corr.allow.CAO = 0.0 in

Vessel design stress Sv = 17100 psi Joint efficiency E = 1

Vessel outside dia Do = 24.0 in Corroded radius OR = 12.0 in

Nominal thickness tnom = 0.375 in Reinforcement limit lp = 6.011 in

Req. tks. int.pres. tr = 0.1049 in Req. tks.ext.pres. tre = 0.1481 in

Corroded thickness t = 0.2031 in Reinf. efficiency E1 = 1.0

Attachment Material: SA-106 K03006 Grd B Smls. pipe

Inside corr. allow. CAI = 0.125 in Outside corr.allow.CAO = 0.0 in

Nozzle design stress Sn = 17100 psi Joint efficiency E = 1

Nozzle outside dia. Don = 6.625 in Corroded radius OR = 3.3125 in

Nominal thickness tnom = 0.432 in Reinforcement limit ln = 0.5078 in

Req.tks. int.pres. trn = 0.029 in Req.tks.ext.pres. trne = 0.075 in

Corroded thickness tn = 0.307 in Nozzle Projection h = 0.0 in

Reinforcement element material:

Outside diameter Dp = 0.0 in Nominal thickness te = 0.0 in

Outside corr. all. CAO = 0.0 in Design stress Se = 0 psi

Minimum weld size tmin = 0.2031 in Leg size (1/2*tmin) (Act) = 0.0 in

1/2 * tmin (minimum) = 0.0 in 1/2 * tmin (actual) = 0.0 in

Weld tw (minimum) = 0.1422 in Weld tw (actual) = 0.0 in

Weld tc (minimum) = 0.1422 in Weld tc (actual) = 0.1422 in

smaller | 0.25 in | Leg size tw (actual) = 0.0 in

tc of | 0.7 * tmin | Leg size tc (actual) = 0.2031 in

Outward nozzle weld L1 = 0.2031 in fr1 = Sn/Sv = 1.0

DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

Outer element weld L2 = 0.0 in fr2 = Sn/Sv = 1.0
 Inward nozzle weld L3 = 0.0 in fr3 = Sn/Sv or Se/Sv = 1.0
 Inward nozzle weld new = 0.0 in fr4 = Se/Sv = 1.0
 Corroded int.proj.thk ti = 0.0 in

Component: Reinforcement Nozzle C

Corroded inside diameter or controlling parallel limit d = 6.011 in

Plane correction factor (Fig.UG-37) F = 1.0

Offset distance from centerline doff = 0.0 in

Reinforcement areas (internal pressure condition) ASME 2004 UG-37

A1 = Vessel wall. Larger of:

$$\left| \begin{array}{l} d*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1) \\ 2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1) \end{array} \right| = 0.5905 \text{ in2}$$

$$\left| \begin{array}{l} 5*(tn-trn)*fr2*t \\ 5*(tn-trn)*fr2*tn \end{array} \right| = 0.1002 \text{ in2}$$

A1 = 0.5905 in2

A2 = Nozzle wall outward

$$\left| \begin{array}{l} 5*(tn-trn)*fr2*t \\ 5*(tn-trn)*fr2*tn \end{array} \right| = 0.2824 \text{ in2}$$

Smaller of:

$$\left| \begin{array}{l} 5*(tn-trn)*fr2*t \\ 5*(tn-trn)*fr2*tn \end{array} \right| = 0.4268 \text{ in2}$$

A2 = 0.2824 in2

A3 = Nozzle wall inward

$$\left| \begin{array}{l} 5*t*ti*fr2 \\ 5*ti*ti*fr2 \end{array} \right| = 0.0 \text{ in2}$$

Smallest of:

$$\left| \begin{array}{l} 5*ti*ti*fr2 \\ 2*h*ti*fr2 \end{array} \right| = 0.0 \text{ in2}$$

A3 = 0.0 in2

Component: Reinforcement Nozzle C

A41 = Outward nozzle weld = (L1**2)*fr3 = 0.0413 in2

A42 = Outer element weld = (L2**2)*fr4 = 0.0 in2

A43 = Inward nozzle weld = (L3**2)*fr2 = 0.0 in2

A4 = 0.0413 in2

A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4

A5 = 0.0 in2

Aa = Area Available = A1+A2+A3+A4+A5

Aa = 0.9141 in2

A = Area required = (d*tr*F)+2*tn*tr*F*(1-f1)

A = 0.6305 in2

ASME VIII Div.1 2004 Reinforcement areas (external pressure) UG-37(d)

A1 = Vessel wall. Larger of:

$$\left| \begin{array}{l} d*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1) \\ 2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1) \end{array} \right| = 0.3306 \text{ in2}$$

$$\left| \begin{array}{l} 5*(tn-trne)*fr2*t \\ 5*(tn-trne)*fr2*tn \end{array} \right| = 0.0561 \text{ in2}$$

A1 = 0.3306 in2

A2 = Nozzle wall outward

$$\left| \begin{array}{l} 5*(tn-trne)*fr2*t \\ 5*(tn-trne)*fr2*tn \end{array} \right| = 0.2356 \text{ in2}$$

Smaller of:

$$\left| \begin{array}{l} 5*(tn-trne)*fr2*t \\ 5*(tn-trne)*fr2*tn \end{array} \right| = 0.3561 \text{ in2}$$

A2 = 0.2356 in2

A3 = Nozzle wall inward

$$\left| \begin{array}{l} 5*t*ti*fr2 \\ 5*ti*ti*fr2 \end{array} \right| = 0.0 \text{ in2}$$

Smallest of:

$$\left| \begin{array}{l} 5*ti*ti*fr2 \\ 2*h*ti*fr2 \end{array} \right| = 0.0 \text{ in2}$$

A3 = 0.0 in2

A41 = Outward nozzle weld = (L1**2)*fr3 = 0.0413 in2

A42 = Outer element weld = (L2**2)*fr4 = 0.0 in2

A43 = Inward nozzle weld = (L3**2)*fr2 = 0.0 in2

A4 = 0.0413 in2

A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4

A5 = 0.0 in2

Aa = Area Available = A1+A2+A3+A4+A5

Aa = 0.6075 in2

A = Area required = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))

A = 0.4452 in2

Component: Reinforcement Nozzle C

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

ASME - Weld strength calculations not required per UW-15(b).

Total weld load (UG-41(b)(2))

$$W = (A-A1+2*tn*fr1(E1*t-F*tr))*Sv \quad W = 1716 \text{ lbf}$$

Weld load for strength path 1-1 (UG-41(b)(1))

$$W(1-1) = (A2+A5+A41+A42)*Sv \quad W(1-1) = 5534 \text{ lbf}$$

Weld load for strength path 2-2 (UG-41(b)(1))

$$W(2-2) = (A2+A3+A41+A43+2*tn*t*fr1)*Sv \quad W(2-2) = 7667 \text{ lbf}$$

Weld load for strength path 3-3 (UG-41(b)(1))

$$W(3-3) = (A2+A3+A5+A41+A42+A43+2*tn*t*fr1)*Sv \quad W(3-3) = -$$

DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

Reinforcing element strength = $A5 * Se$ = -

Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement

Unit stresses - UW15(c) and UG-45(c)

Inner fillet weld shear = 8379 psi
 Outer fillet weld shear = -
 Groove weld tension = 12654 psi
 Groove weld shear = -
 Nozzle wall shear = 11970 psi

Strength of connection elements

Inner fillet weld shear = 17703 lbf
 Nozzle wall shear = 36452 lbf
 Groove weld tension = 26735 lbf
 Outer fillet weld shear = -

Possible paths of failure

1-1 36452 + 17703 = 54155 lbf
 2-2 17703 + 26735 = 44438 lbf
 3-3 - + - = -

Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement

Welds strong enough if path greater than the smaller of W or W(path)

Path 1-1 > W or W11
 54155 lbf > 1716 lbf OK
 Path 2-2 > W or W22
 44438 lbf > 1716 lbf OK
 Path 3-3 > W or W33
 - > -

Component: Nozzle D

ASME VIII Div.1 2004 UG-27 Thickness of Cylinders under Internal Pressure

--- Calculations --- Cylinder Internal Pressure

Material: SA-106 K03006 Grd B Smls. pipe

Max Allow Working Pressure P = 150 psi Design temperature T = 400 F
 Radiography = None Joint efficiency E = 0.85

Design stress S = 17100 psi

Inside corr.allow. CAI = 0.125 in Outside corr. all. CAO = 0 in

Material tolerance Tol = 0.054 in Minimum thickness t_{min} = 0.2299 in

Outside diameter OD = 6.625 in Corroded radius OR = 3.3125 in

- Minimum thickness greater than:

- UG-45(a) Required wall thickness of the cylinder:

$$t = (P \cdot OR / (S \cdot E + 0.4 \cdot P)) + CAI + CAO + Tol = 0.213 \text{ in} \quad \text{APP.1-1(A)}$$

- UG-45(b) Smallest of:

UG-45(b) (1) or (2) required thickness: $t = 0.2299 \text{ in}$

UG-45(b) (4) required thickness: $t = 0.37 \text{ in}$

Minimum thickness: $t_{min} = 0.2299 \text{ in}$

Nominal thickness: $t_{nom} = 0.432 \text{ in}$

ASME Section VIII Div.1 2004 UG-28 Thickness of Shells under Ext. Pressure

--- Calculations --- Cylinder External Pressure

Material: SA-106 K03006 Grd B Smls. pipe

Max Allow Working Pressure PE = 14.7 psi Design temperature T = 400 F

Inside corr. allow. CAI = 0.125 in Corrosion allow. CAO = 0 in

Radiography = None Material tol. Tol = 0.054 in

Cyl. outside dia. Do = 6.625 in Cylinder length EP L = 6 in

Nominal thickness $t_{nom} = 0.432 \text{ in}$ ($t_{nom} - CAI - CAO - Tol$) $t = 0.253 \text{ in}$

L/Do ratio Ldo = 0.9057 Do/t Dot = 26.1858

(2*S) or (0.9*yield) SE = - Mod. of elasticity ME = 27500000 psi

A factor SII-D-FigG A = 0.0117 B factor CS-2 B = 16176

Max allowed external pressure: Pa = $4 \cdot B / (3 \cdot Dot)$ = 823.66 psi

Actual external Max Allow Working Pressure: PE = 14.7 psi

(Required cyl. tks. for nozzle attachments at PE, $t_{re} = 0.021 \text{ in}$)

Component: Reinforcement Nozzle D

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Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

$$|2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.0561 \text{ in}^2$$

$$A1 = 0.3306 \text{ in}^2$$

$$A2 = \text{Nozzle wall outward} \quad | \quad 5*(tn-trne)*fr2*t \quad | = 0.2356 \text{ in}^2$$

$$\text{Smaller of:} \quad | \quad 5*(tn-trne)*fr2*tn \quad | = 0.3561 \text{ in}^2$$

$$A2 = 0.2356 \text{ in}^2$$

$$A3 = \text{Nozzle wall inward} \quad | \quad 5*t*ti*fr2 \quad | = 0.0 \text{ in}^2$$

$$\text{Smallest of:} \quad | \quad 5*ti*ti*fr2 \quad | = 0.0 \text{ in}^2$$

$$\quad \quad \quad | \quad 2*h*ti*fr2 \quad | = 0.0 \text{ in}^2$$

$$A3 = 0.0 \text{ in}^2$$

$$A41 = \text{Outward nozzle weld} = (L1**2)*fr3 = 0.0413 \text{ in}^2$$

$$A42 = \text{Outer element weld} = (L2**2)*fr4 = 0.0 \text{ in}^2$$

$$A43 = \text{Inward nozzle weld} = (L3**2)*fr2 = 0.0 \text{ in}^2$$

$$A4 = 0.0413 \text{ in}^2$$

$$A5 = \text{Reinforcement pad Area} = (Dp-d-2*tn)*te*fr4 \quad A5 = 0.0 \text{ in}^2$$

$$Aa = \text{Area Available} = A1+A2+A3+A4+A5 \quad Aa = 0.6075 \text{ in}^2$$

$$A = \text{Area required} = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1)) \quad A = 0.4452 \text{ in}^2$$

Component: Reinforcement Nozzle D

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

ASME - Weld strength calculations not required per UW-15(b).

Total weld load (UG-41(b)(2))

$$W = (A-A1+2*tn*fr1*(E1*t-F*tr))*Sv \quad W = 1716 \text{ lbf}$$

Weld load for strength path 1-1 (UG-41(b)(1))

$$W(1-1) = (A2+A5+A41+A42)*Sv \quad W(1-1) = 5534 \text{ lbf}$$

Weld load for strength path 2-2 (UG-41(b)(1))

$$W(2-2) = (A2+A3+A41+A43+2*tn*t*fr1)*Sv \quad W(2-2) = 7667 \text{ lbf}$$

Weld load for strength path 3-3 (UG-41(b)(1))

$$W(3-3) = (A2+A3+A5+A41+A42+A43+2*tn*t*fr1)*Sv \quad W(3-3) = -$$

Reinforcing element strength = A5 * Se = -

Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement

Unit stresses - UW15(c) and UG-45(c)

Inner fillet weld shear	=	8379 psi
Outer fillet weld shear	=	-
Groove weld tension	=	12654 psi
Groove weld shear	=	-
Nozzle wall shear	=	11970 psi

Strength of connection elements

Inner fillet weld shear	=	17703 lbf
Nozzle wall shear	=	36452 lbf
Groove weld tension	=	26735 lbf
Outer fillet weld shear	=	-

Possible paths of failure

1-1	36452 + 17703	=	54155 lbf
2-2	17703 + 26735	=	44438 lbf
3-3	- + -	=	-

Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement

Welds strong enough if path greater than the smaller of W or W(path) ---

Path 1-1 > W or W11	
54155 lbf > 1716 lbf	OK
Path 2-2 > W or W22	
44438 lbf > 1716 lbf	OK
Path 3-3 > W or W33	
- > -	

Component: Nozzle K

ASME VIII Div.1 2004 UG-27 Thickness of Cylinders under Internal Pressure

--- Calculations --- Cylinder Internal Pressure

Material: SA-106 K03006 Grd B Smls. pipe

Max Allow Working Pressure P = 150 psi Design temperature T = 400 F

Radiography = None Joint efficiency E = 0.85

DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

Design stress S = 17100 psi
 Inside corr.allow. CAI = 0.125 in Outside corr. all. CAO = 0 in
 Material tolerance Tol = 0.043 in Minimum thickness tmin = 0.2299 in
 Outside diameter OD = 2.375 in Corroded radius OR = 1.1875 in
 - Minimum thickness greater than:
 - UG-45(a) Required wall thickness of the cylinder:
 $t = (P \cdot OR / (S \cdot E + 0.4 \cdot P)) + CAI + CAO + Tol = 0.1802 \text{ in APP.1-1(A)}$
 - UG-45(b) Smallest of:
 UG-45(b) (1) or (2) required thickness: t = 0.2299 in
 UG-45(b) (4) required thickness: t = 0.2598 in
 Minimum thickness: tmin = 0.2299 in
 Nominal thickness: tnom = 0.344 in

ASME Section VIII Div.1 2004 UG-28 Thickness of Shells under Ext. Pressure

--- Calculations --- Cylinder External Pressure

Material: SA-106 K03006 Grd B Smls. pipe

Max Allow Working Pressure PE = 14.7 psi Design temperature T = 400 F
 Inside corr. allow. CAI = 0.125 in Corrosion allow. CAO = 0 in
 Radiography = None Material tol. Tol = 0.043 in
 Cyl. outside dia. Do = 2.375 in Cylinder length EP L = 6.9235 in
 Nominal thickness tnom = 0.344 in (tnom-CAI-CAO-Tol) t = 0.176 in
 L/Do ratio Ldo = 2.9152 Do/t Dot = 13.4943
 (2*S) or (0.9*yield) SE = - Mod. of elasticity ME = 27500000 psi
 A factor SII-D-FigG A = 0.009268 B factor CS-2 B = 15907
 Max allowed external pressure: Pa = 4*B / (3*Dot) = 1571.76 psi
 Actual external Max Allow Working Pressure: PE = 14.7 psi
 (Required cyl. tks. for nozzle attachments at PE, tre = 0.013 in)

Component: Reinforcement Nozzle K

ASME Section VIII Div.1 2004 UG-37 Reinforcement Required for Openings in Shells and Formed Heads

--- Design Conditions:

Int. Max Allow Working Pressure PI = 150 psi Ext. design press. PE = -15 psi
 Design temperature T = 400 F Fig.UW-16.1 Sketch (c)
 Vessel material: SA-106 K03006 Grd B Smls. pipe
 Inside corr. allow. CAI = 0.125 in Outside corr.allow.CAO = 0.0 in
 Vessel design stress Sv = 17100 psi Joint efficiency E = 1
 Vessel outside dia Do = 24.0 in Corroded radius OR = 12.0 in
 Nominal thickness tnom = 0.375 in Reinforcement limit lp = 1.937 in
 Req. tks. int.pres. tr = 0.1049 in Req. tks.ext.pres. tre = 0.1481 in
 Corroded thickness t = 0.2031 in Reinf. efficiency E1 = 1.0
 Attachment Material: SA-106 K03006 Grd B Smls. pipe
 Inside corr. allow. CAI = 0.125 in Outside corr.allow.CAO = 0.0 in
 Nozzle design stress Sn = 17100 psi Joint efficiency E = 1
 Nozzle outside dia. Don = 2.375 in Corroded radius OR = 1.1875 in
 Nominal thickness tnom = 0.344 in Reinforcement limit ln = 0.5078 in
 Req.tks. int.pres. trn = 0.0104 in Req.tks.ext.pres. trne = 0.056 in
 Corroded thickness tn = 0.219 in Nozzle Projection h = 0.0 in
 Reinforcement element material:
 Outside diameter Dp = 0.0 in Nominal thickness te = 0.0 in
 Outside corr. all. CAO = 0.0 in Design stress Se = 0 psi
 Minimum weld size tmin = 0.2031 in Leg size (1/2*tmin) (Act) = 0.0 in
 1/2 * tmin (minimum) = 0.0 in 1/2 * tmin (actual) = 0.0 in
 Weld tw (minimum) = 0.1422 in Weld tw (actual) = 0.0 in
 Weld tc (minimum) = 0.1422 in Weld tc (actual) = 0.1422 in
 smaller | 0.25 in | Leg size tw (actual) = 0.0 in
 tc of | 0.7 * tmin | Leg size tc (actual) = 0.2031 in
 Outward nozzle weld L1 = 0.2031 in fr1 = Sn/Sv = 1.0
 Outer element weld L2 = 0.0 in fr2 = Sn/Sv = 1.0
 Inward nozzle weld L3 = 0.0 in fr3 = Sn/Sv or Se/Sv = 1.0
 Inward nozzle weld new = 0.0 in fr4 = Se/Sv = 1.0
 Corroded int.proj.thk ti = 0.0 in

DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

Reinforcement areas (internal pressure) Offset distance doff = 6.0 in

A1 = Vessel wall. Larger of:
 $\left| \frac{d*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)}{2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)} \right|$

A2 = Nozzle wall outward $\left| \frac{5*(tn-trn)*fr2*t}{5*(tn-trn)*fr2*tn} \right|$ A2 = 0.2119 in2
 Smaller of:

A3 = Nozzle wall inward $\left| \frac{5*t*ti*fr2}{5*ti*ti*fr2} \right|$ A3 = 0.0 in2
 Smallest of: $\left| \frac{2*h*ti*fr2}{2*h*ti*fr2} \right|$

A41 = Outward nozzle weld = (L1**2)*fr3 A41 = 0.0413 in2
 A42 = Outer element weld = (L2**2)*fr4 A42 = 0.0 in2
 A43 = Inward nozzle weld = (L3**2)*fr2 A43 = 0.0 in2
 A5 = Re-pad Area = (Dp-d-2*tn)*te*fr4 A5 = 0.0 in2

Plane Direction: Circumferential Longitudinal
 Diameter d = 2.4998 in d = 1.937 in
 Factor F = 0.5 F = 1.0

A1 = Vessel wall A1 = 0.3767 in2 A1 = 0.1903 in2
 Aa = Area Available = A1+A2+A3+A4+A5 Aa = 0.6298 in2 Aa = 0.4434 in2
 A = Required = d*tr*F+2*tn*tr*F*(1-fr1) Ar = 0.1311 in2 Ar = 0.2032 in2
 Per UG-36(c)(3)(a), this opening does NOT required additional reinforcement other than the inherent in the construction.

ASME VIII Div.1 2004 Reinforcement areas (external pressure) UG-37(d)

A1 = Vessel wall. Larger of:
 $\left| \frac{d*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)}{2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)} \right|$

A2 = Nozzle wall outward $\left| \frac{5*(tn-trne)*fr2*t}{5*(tn-trne)*fr2*tn} \right|$ A2 = 0.1655 in2
 Smaller of:

A3 = Nozzle wall inward $\left| \frac{5*t*ti*fr2}{5*ti*ti*fr2} \right|$ A3 = 0.0 in2
 Smallest of: $\left| \frac{2*h*ti*fr2}{2*h*ti*fr2} \right|$

A41 = Outward nozzle weld = (L1**2)*fr3 A41 = 0.0413 in2
 A42 = Outer element weld = (L2**2)*fr4 A42 = 0.0 in2
 A43 = Inward nozzle weld = (L3**2)*fr2 A43 = 0.0 in2
 A5 = Re-pad Area = (Dp-d-2*tn)*te*fr4 A5 = 0.0 in2

Plane Direction: Circumferential Longitudinal
 Diameter d = 2.4998 in d = 1.937 in
 Factor F = 1.0 F = 1.0

A1 = Vessel wall A1 = 0.1375 in2 A1 = 0.1065 in2
 Aa = Area Available = A1+A2+A3+A4+A5 Aa = 0.3443 in2 Aa = 0.3133 in2
 A = Req=0.5*(d*tre*F+2*tn*tre*F*(1-fr1)) Ar = 0.1851 in2 Ar = 0.1435 in2

Component: Reinforcement Nozzle K

Nozzle attachment weld loads - UG-41 - Strength of reinforcement
 ASME - Weld strength calculations not required per UW-15(b).
 Total weld load (UG-41(b)(2))
 $W = (A-A1+2*tn*fr1*(E1*t-F*tr))*Sv$ W = 956 lbf

Weld load for strength path 1-1 (UG-41(b)(1))
 $W(1-1) = (A2+A5+A41+A42)*Sv$ W(1-1) = 4329 lbf

Weld load for strength path 2-2 (UG-41(b)(1))
 $W(2-2) = (A2+A3+A41+A43+2*tn*t*fr1)*Sv$ W(2-2) = 5850 lbf

Weld load for strength path 3-3 (UG-41(b)(1))
 $W(3-3) = (A2+A3+A5+A41+A42+A43+2*tn*t*fr1)*Sv$ W(3-3) = -

Reinforcing element strength = A5 * Se = -

Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement
 Unit stresses - UW15(c) and UG-45(c)
 Inner fillet weld shear = 8379 psi
 Outer fillet weld shear = -
 Groove weld tension = 12654 psi
 Groove weld shear = -

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Calculated By: Haresh Sevak

Checked By: Rohit Patel

Nozzle wall shear = 11970 psi
 Strength of connection elements
 Inner fillet weld shear = 6347 lbf
 Nozzle wall shear = 8874 lbf
 Groove weld tension = 9585 lbf
 Outer fillet weld shear = -
 Possible paths of failure
 1-1 8874 + 6347 = 15221 lbf
 2-2 6347 + 9585 = 15932 lbf
 3-3 - + - = -

Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement

Welds strong enough if path greater than the smaller of W or W(path)

Path 1-1 > W or W11
 15221 lbf > 956 lbf OK
 Path 2-2 > W or W22
 15932 lbf > 956 lbf OK
 Path 3-3 > W or W33
 - > -

Component: Nozzle C

Method: Local Stresses in Cylindrical Shell Due to External Loadings per
 Heat Exchange Institute (HEI 'Std For Power Plant Hx', First Edition)

Vessel: Shell Cylinder SA-106 K03006 Grd B Smls. pipe
 Max Allow Working Pressure Pr = 150 psi Design temperature T = 400 F
 Joint efficiency E = 1.00

Vessel design stress S = 17100 psi Vessel yield stress Sy = 29900 psi
 Inside corr. allow. CAI = 0.125 in Outside corr. all. CAO = 0.0 in
 Vessel outside dia. OD = 24.0 in Vessel mean radius Rm = 11.8984 in
 Vessel thickness tnom = 0.3281 in

Nozzle:
 Nozzle outside dia. ODN = 6.625 in Nozzle outside rad. ro = 3.3125 in
 Reinf. pad:
 Pad thickness Prtk = 0.0 in Vessel + pad tks. T = 0.2031 in

Shape factors and Coefficients:
 Gamma = Rm/T = 58.5769 Beta = 0.875*ro/Rm = 0.2436
 Alpha = 1002.67 Sigma = 1505.58 Delta = 634.55
 Conversion factor Cf = 1

Maximum load & moment
 S = 2*pr*(Rm-T/2)/t = 17423 psi
 Sa = shell allowable stress = 17100 psi
 Sig = minimum of S & Sa = 17100 psi
 Frrf = Rm*Rm*(sy-sig)/alpha = 1807 lbf
 Mrcm = Rm*Rm*ro*sy*cf/sigma = 9313 lbf*in
 Mrlm = Rm*Rm*ro*(sy-sig)*cf/delta = 9460 lbf*in
 Frf = maximum resultant force = 1807 lbf
 Mrm = maximum resultant moment = 9313 lbf*in

- Interaction diagram:



Applied loads:
 Radial load P = 0 lbf
 Circ. moment Mc = 0 lbf*in
 Long. moment Ml = 0 lbf*in
 Maximum allowable loads:
 Radial Load P, Mc = 1807 lbf
 Radial Load P, Ml = 1807 lbf
 Mc or Ml (from P) = 9313 lbf*in

Note: Couples (P,Mc) & (P,Ml)
 must be located within
 the triangle limited by
 0, FRF, MRM.

DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

-----+-----
 0 MRM
 9313

Component: Nozzle D

Method: Local Stresses in Cylindrical Shell Due to External Loadings per
 Heat Exchange Institute (HEI 'Std For Power Plant Hx', First Edition)

Vessel: Shell Cylinder SA-106 K03006 Grd B Smls. pipe
 Max Allow Working Pressure Pr = 150 psi Design temperature T = 400 F

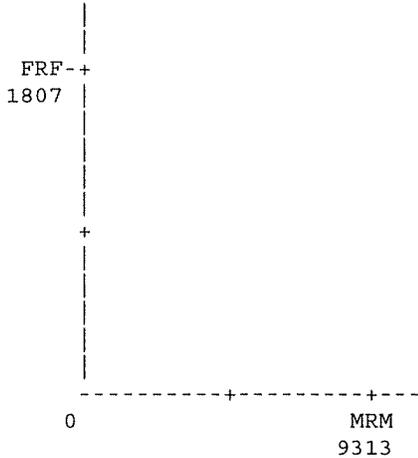
Joint efficiency E = 1.00
 Vessel design stress S = 17100 psi Vessel yield stress Sy = 29900 psi
 Inside corr. allow. CAI = 0.125 in Outside corr. all. CAO = 0.0 in
 Vessel outside dia. OD = 24.0 in Vessel mean radius Rm = 11.8984 in
 Vessel thickness tnom = 0.3281 in

Nozzle:
 Nozzle outside dia. ODN = 6.625 in Nozzle outside rad. ro = 3.3125 in
 Reinf. pad:
 Pad thickness Prtk = 0.0 in Vessel + pad tks. T = 0.2031 in

Shape factors and Coefficients:
 Gamma = Rm/T = 58.5769 Beta = 0.875*ro/Rm = 0.2436
 Alpha = 1002.67 Sigma = 1505.58 Delta = 634.55
 Conversion factor Cf = 1

Maximum load & moment
 S = 2*pr*(Rm-T/2)/t = 17423 psi
 Sa = shell allowable stress = 17100 psi
 Sig = minimum of S & Sa = 17100 psi
 Frrf = Rm*Rm*(sy-sig)/alpha = 1807 lbf
 Mrcm = Rm*Rm*ro*sy*cf/sigma = 9313 lbf*in
 Mrlm = Rm*Rm*ro*(sy-sig)*cf/delta = 9460 lbf*in
 Frf = maximum resultant force = 1807 lbf
 Mrm = maximum resultant moment = 9313 lbf*in

- Interaction diagram:



Applied loads:
 Radial load P = 0 lbf
 Circ. moment Mc = 0 lbf*in
 Long. moment Ml = 0 lbf*in
 Maximum allowable loads:
 Radial Load P, Mc = 1807 lbf
 Radial Load P, Ml = 1807 lbf
 Mc or Ml (from P) = 9313 lbf*in

Note: Couples (P, Mc) & (P, Ml)
 must be located within
 the triangle limited by
 0, FRF, MRM.

Component: Nozzle K

Method: Local Stresses in Cylindrical Shell Due to External Loadings per
 Heat Exchange Institute (HEI 'Std For Power Plant Hx', First Edition)

Vessel: Shell Cylinder SA-106 K03006 Grd B Smls. pipe
 Max Allow Working Pressure Pr = 150 psi Design temperature T = 400 F

Joint efficiency E = 1.00
 Vessel design stress S = 17100 psi Vessel yield stress Sy = 29900 psi
 Inside corr. allow. CAI = 0.125 in Outside corr. all. CAO = 0.0 in
 Vessel outside dia. OD = 24.0 in Vessel mean radius Rm = 11.8984 in
 Vessel thickness tnom = 0.3281 in

DOYLE & ROTH MFG COMPANY, INC

Customer: Jacobs Engineering For Nova Chemicals

PO No.: 58-CG87-60-P11-0014

Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

Nozzle:

Nozzle outside dia. ODN = 3.1878 in Nozzle outside rad. ro = 1.5939 in

Reinf. pad:

Pad thickness Prtk = 0.0 in Vessel + pad tks. T = 0.2031 in

Shape factors and Coefficients:

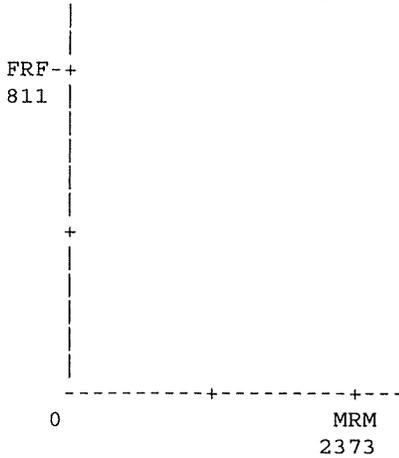
Gamma = Rm/T = 58.5769 Beta = 0.875*ro/Rm = 0.1172
 Alpha = 2233.90 Sigma = 2030.38 Delta = 1217.24

Conversion factor Cf = 1

Maximum load & moment

S = 2*pr*(Rm-T/2)/t = 17423 psi
 Sa = shell allowable stress = 17100 psi
 Sig = minimum of S & Sa = 17100 psi
 Frf = Rm*Rm*(sy-sig)/alpha = 811 lbf
 Mrcm = Rm*Rm*ro*sy*cf/sigma = 3323 lbf*in
 Mrlm = Rm*Rm*ro*(sy-sig)*cf/delta = 2373 lbf*in
 Frf = maximum resultant force = 811 lbf
 Mrm = maximum resultant moment = 2373 lbf*in

Interaction diagram:



Applied loads:

Radial load P = 0 lbf
 Circ. moment Mc = 0 lbf*in
 Long. moment Ml = 0 lbf*in

Maximum allowable loads:

Radial Load P, Mc = 811 lbf
 Radial Load P, Ml = 811 lbf
 Mc or Ml (from P) = 2373 lbf*in

Note: Couples (P, Mc) & (P, Ml) must be located within the triangle limited by 0, FRF, MRM.

Component: Nozzle Flange Details

Flange, Gasket and Bolting Details

Dimensional data in

Nozzle	Flg Type	Flg Dia.(*)	Flg Rating	Neck tks	Flg tks	Bolt Cir.	Gaskets O.D.	Gaskets Width	Bolts No	Bolts Dia.
A	ANSI WN	4.5	150	0.432	0.94	7.5	6.19	0.84	8	0.625
B	ANSI WN	3.5	150	0.3	0.94	6.0	5.0	0.75	4	0.625
C	ANSI WN	6.625	150	0.432	1.0	9.5	8.5	0.94	8	0.75
D	ANSI WN	6.625	150	0.432	1.0	9.5	8.5	0.94	8	0.75
K	ANSI WN	2.375	150	0.344	0.75	4.75	3.62	0.62	4	0.625

* Dia. = Nozzle O.D. if ANSI flange
 = Flange O.D. if non-ANSI flange

Component: Vertical Vessel Supports

Support material: SA-516 K02700 Grd 70 Plate

Shell material: SA-106 K03006 Grd B Smls. pipe

Max Allow Working Pressure P = 150 psi Design temperature T = 400 F

Shell radius R = 12.0 in Bracket mat.all.str. Sl = 20000 psi
 Shell OD D = 24.0 in Shell mat.all.stress S = 17100 psi
 Shell thickness ts = 0.25 in Moment coefficient Mc = 0.04431
 Vessel weight W = 7100 lbf Gusset thickness t = 0.375 in
 Actual height h = 7.0 in Base plate thickness t = 0.375 in
 Number of supports N = 2 Reinforcing pad tks. R = 0.375 in

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Equipment Nos.: E-2206 Thru E-2208, E-2219 "REACTOR JACKET HEATERS"

Calculated By: Haresh Sevak

Checked By: Rohit Patel

Bracket eccentricity $E = 3.875$ in Bracket width = 6.0 in
 Distance between gussets = 3.25 in Bracket mat yield str $y = 32500$ psi
 Distance from outside of bracket to vessel OD $d = 6.0$ in
 Distance from vessel OD to bolt hole $Q = 5.0$ in
 Hoop stress = $P \cdot R / t_s$ $H_s = 7200$ psi
 Minimum height $hR = \text{Sqrt}(6 \cdot D \cdot W \cdot E \cdot M_c / ((1.25 \cdot S - H_s) \cdot t_s^2)) = 14.076$ in
 Shell stress $S_{str} = ((6 \cdot D \cdot W \cdot E \cdot M_c) / (h^2 \cdot t_s^2) + H_s) / 1.25 = 51614$ psi
 Minimum height

Without reinforcing pad With reinforcing pad

Two brackets 16.768 in 14.076 in
 Four brackets 6.6432 in 5.9706 in

Minimum gusset and base plate thickness

Required thickness for shear $t_{gs} = 0.625 \cdot W / (h \cdot S_1 \cdot N)$ $t_{gs} = 0.0158$ in
 Required thickness for bending $t_{gb} = 2 \cdot W \cdot E / (N \cdot S_1 \cdot h^2)$ $t_{gb} = 0.0281$ in
 Required thickness for crushing $t_{gc} = 0.5 \cdot W / (d \cdot S_1 \cdot N)$ $t_{gc} = 0.0148$ in
 Required thickness for lateral stability $t_{gl} = d/16$ $t_{gl} = 0.375$ in

TEMA RGP-G-7.12 Vertical vessel supports

Bolt circle $db = 34.0$ in Number of lugs $N = 2$

External overturning moment at the supports, $M = -$

Maximum tension (uplift) force = $4 \cdot M / db \cdot N - W / N = -$

If $W > 4 \cdot M / db$ no uplift occurs

7100 lbf > -

Maximum compression force = $4 \cdot M / db \cdot N + W / N = 3550$ lbf

RGP-G-7.122 Base Plate

Load/lug compression $LLc = 3550$ lbf

Load/lug tension $LLt = -$

Height of lug $Ht = 7.0$ in

Gusset thickness $tg = 0.375$ in

Dist. between gussets $l = 3.25$ in

Bearing width $bw = 6.0$ in

Base plate thickness $tb = 0.375$ in

Bottom plate width $GB = 6.0$ in

$\omega = LLc / (l + 2 \cdot tg) = 887.51$

Bending Moment $M_b = \omega \cdot (l + tg)^2 / 8$

$M_b = 1458$ lbf*in

Moment in tension $M_t = LLt \cdot (l + tg) / 4$

$M_t = -$

$M^* = \text{Max}(M_b, M_t)$

$M^* = 1458$ lbf*in

Bending stress = $6 \cdot (M^*) / (bw \cdot tb^2)$

$S_b = 10367$ psi

OK if $S_b < 90\%$ Yield stress of base plate material

10367 psi < 29250 psi

Wind loads - ANSI/SEI/ASCE 7-02

Vessel outside diameter OD = 24 in

Vessel effective length EL = 115.5 in

Vessel effective diameter EOD = 36 in

Effective wind area $A_f = EOD \cdot EL = 28.87$ ft²

Velocity pressure exposure $K_z = 0.85$

Topographic factor $K_{zt} = 1$

Directionality factor $K_d = 1$

Importance factor $I = 1$

Wind speed, m/h $V = 100$

Velocity pressure, q_z , lbf/ft² = $0.00256 \cdot K_z \cdot K_{zt} \cdot I \cdot V^2 = 21.8$

Gust response factor $G = 0.85$

Force coefficient $C_f = 1$

Wind force $F = q_z \cdot G \cdot C_f \cdot A_f = 534.1$ lbf

Moment arm $L = 4.81$ ft

Overturning moment, OM, ft-lbf $OM = F \cdot L = 2570$

Earthquake Loads - ANSI/SEI/ASCE 7-02

Equipment occupancy category - wind/seismic design = II

Equipment seismic site class = B

Equipment seismic use group = I

Response modification factor $R = 3$

Seismic importance factor $I = 1$

Mapped maximum spectral response acceleration at short periods $S_s = 0.75$

Mapped maximum spectral response acceleration at 1-sec period $S_1 = 0.2$

Site coefficient F_a - Table 9.4.1.2.4a $F_a = 1$

Site coefficient F_v - Table 9.4.1.2.4b $F_v = 1$

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Maximum spectral response acceleration short periods	$S_{ms} = F_a * S_s = 0.75$
Maximum spectral response acceleration at 1-sec per.	$S_{m1} = F_v * S_1 = 0.2$
Spectral response acceleration at short periods	$S_{ds} = (2/3) * S_{ms} = 0.5$
Spectral response acceleration at 1-sec period	$S_{d1} = (2/3) * S_{m1} = 0.13$
Seismic response coefficient, $C_s = S_{ds} / (R/I)$	$C_s = 0.17$
$C_{sMin} = 0.5 * S_1 / (R/I)$	$C_{sMin} = 0.03$
Seismic zone coefficient, C_v	$C_v = 0.24$
Weight of vessel, full	$W = 5323 \text{ lbf}$
Total shear at the base, $V = C_s * W$	$V = 887.2 \text{ lbf}$
Maximum lateral force, $F = V$	$F = 887.2 \text{ lbf}$
Overturning moment, OM, ft-lbf	$OM = 0.5 * F * L = 2135$

Wind and Seismic Loads - Effect on Lugs

Distance center of vessel to supports	$l = 1.474 \text{ ft}$
Distance center of gravity to supports	$L = 1.5 \text{ ft}$
Distance between bolt holes (diametrical)	$B = 2.6667 \text{ ft}$
Projected area of vessel	$A_f = EOD * EL$ $A_f = 28.87 \text{ ft}^2$
Wind force	$F = A_f * C_f * G * q_z$ $F = 534.1 \text{ lbf}$
Wind load	$Q_w = F * l / B$ $Q_w = 295.2 \text{ lbf}$
Horizontal seismic force	$F_h = C_s * W$ $F_h = 887.2 \text{ lbf}$
Vertical seismic force	$F_v = C_v * W$ $F_v = 1277.6 \text{ lbf}$
Seismic load	$Q_s = F_v + F_h * L / B$ $Q_s = 1776.7 \text{ lbf}$
Controlling load, $Q = Q_{max}(Q_w, Q_s)$	$Q = 1776.7 \text{ lbf}$