

Sample Job #14
Vertical Vessel with Bolted Cover
Pressure Vessel Calculations

July 2, 2009

ABC-123-456

Cameron Moore
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Revision(s)			
Rev	Description	Date	By
0	Release	6/19/09	CM
1			
2			

XYZ-Vessel Corp.	Customer
Vertical Vessel with Bolted Cover	Vessel
ABC-123-456	Part Number
Sample 14	Drawing & Rev
PVE-3267	Job & Rev
Cameron Moore	Calculations by
Laurence Brundrett P. Eng.	Reviewed by

36	Outside Diameter [inch]
48	straight Shell (not including straight flange on heads)
35	Volume [cuft]
Water	Fluid (value from Material Properties)
2450	Weight Empty [lbs.]
4671	Weight Full
4671	Weight Under Test

Maximum Internal pressure, psi 125	Maximum External Pressure, psi 0	At Temperature, °F 200	Maximum Allowed Working Pressure
Maximum Temperature, °F 200	Minimum Temperature, °F -20	At Pressure, psi 125	Maximum Design Metal Temperature
Test Pressure, psi 163	At a Minimum Temperature of: °F 55°F	For a Minimum Duration of: 1/2 hr	Hydrostatic Test

SA-516 70	Primary Material of Construction
20,000	Allowable Stress
0.09375	Minimum Allowed Thickness Per UG-16(b)
No	Material Normalized
No	Material Impact Tested
UG-20(f)	Not Required Per
None	Radiography Required
0.0625	Corrosion Allowance

ASME VIII-1	Code	
2007	Edition	
2008	Addenda	
IID	Materials	
		Code Cases Required

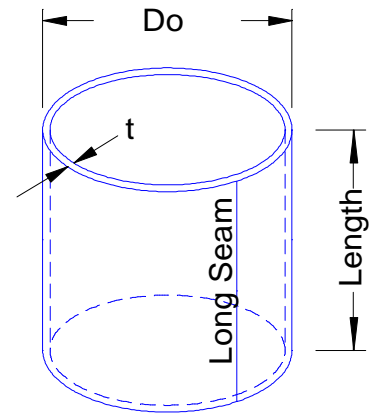
UG-22 Loadings Considered

Yes	(a) Internal pressure
	(a) External pressure
	(b) Vessel weight full, empty and at hydro test
	(c) Weight of attached equipment and piping
	(d)(1) Attachment of internals
Yes	(d)(2) Attachment of vessel supports
	(d) Cyclic or dynamic reactions
	(f) Wind
	(f) Snow
Yes	(f) Seismic
	(g) Fluid impact shock reactions
	(h) Temperature gradients
	(h) Differential thermal expansion
	(i) Abnormal pressures like deflagration
	(j) Hydrotest Loads

Shell Description

Options:

Interior	ip? - Calculate interior pressure
No Exterior	ep? - Calculate exterior pressure
Rolled Plate	pr? - Pipe or rolled plate
Non-Threaded	pt? - Type of pipe
No	relief? - Stress Relief Calculations Required



Dimensions:

36.000	Do [in] - outside diameter
0.2500	t [in] - nominal wall thickness
0.094	tminUG16b [in] - minimum wall per UG-16(b)
41.810	L [in] - length for volume and weight
0.063	Corr [in] - corrosion allowance

Material and Conditions:

SA-516 70	Material
20,000	S [psi] - allowable stress level
0.70	EI - longitudinal efficiency (circ. stress)
0.70	Ec - circ. connecting efficiency (longitudinal stress)
0.000%	UTP [%] - undertolerance allowance
0.000	UTI [in] - undertolerance allowance
126.95	P [psi] - interior pressure

Stress Classification:

NOTE: Both validity checks need to be "Acceptable" in order to use this sheet
If not, refer to sheet "Thick Cylindrical Shell"

ckValidity1 = $t_{min} < 0.5 \cdot (Do/2)$ $0.162 < 0.5 \cdot (36/2) =$ **Acceptable**
 ckValidity2 = $P < 0.385 \cdot S \cdot EI$ $126.95 < 0.385 \cdot 20000 \cdot 0.7 =$ **Acceptable**

Variables:

$Td = 0.000$ $0 =$ **0.000**
 $UT_{[in]} = t \cdot UTP + UTI$ $0.25 \cdot 0 + 0 =$ **0.000**
 $nt_{[in]} = t - Corr - UT - Td$ $0.25 - 0.063 - 0 - 0 =$ **0.188**
 $Ri_{[in]} = Do/2 - nt$ $36/2 - 0.188 =$ **17.813**
 $Volume_{[cuft]} = ((Do/2 - t)^2) \cdot \pi \cdot L / 1728$ $((36/2 - 0.25)^2) \cdot 3.1416 \cdot 41.81 / 1728 =$ **23.949**
 $Weight_{[lb]} = (Do - t) \cdot \pi \cdot L \cdot t \cdot 40.84 / 144$ $(36 - 0.25) \cdot 3.1416 \cdot 41.81 \cdot 0.25 \cdot 40.84 / 144 =$ **332.94**

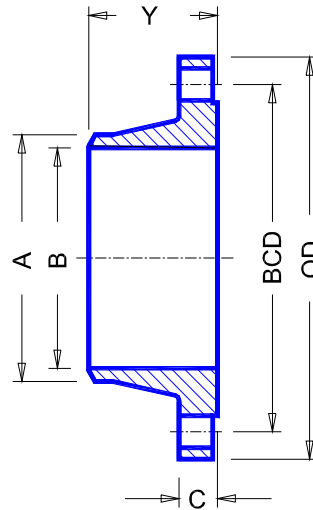
Interior Pressure: VIII-1 UG-27(c)(1,2)

$ta_{[in]} = P \cdot Ri / (S \cdot EI - 0.6 \cdot P)$ $126.95 \cdot 17.813 / (20000 \cdot 0.7 - 0.6 \cdot 126.95) =$ **0.162**
 $tb_{[in]} = P \cdot Ri / (2 \cdot S \cdot Ec + 0.4 \cdot P)$ $126.95 \cdot 17.813 / (2 \cdot 20000 \cdot 0.7 + 0.4 \cdot 126.95) =$ **0.081**
 $tmin_{[in]} = MAX(ta, tb, tminUG16b)$ $MAX(0.162, 0.081, 0.094) =$ **0.162**
 $tr1_{[in]} = P \cdot Ri / (S \cdot 1 - 0.6 \cdot P)$ $126.95 \cdot 17.813 / (20000 \cdot 1 - 0.6 \cdot 126.95) =$ **0.113**
 $Checkt = tmin \leq nt$ $0.162 \leq 0.188 =$ **Acceptable**
 $PMaxA_{[psi]} = (S \cdot EI \cdot nt) / (Ri + 0.6 \cdot nt)$ $(20000 \cdot 0.7 \cdot 0.188) / (17.813 + 0.6 \cdot 0.188) =$ **146**
 $PMaxB_{[psi]} = (2 \cdot S \cdot Ec \cdot nt) / (Ri - 0.4 \cdot nt)$ $(2 \cdot 20000 \cdot 0.7 \cdot 0.188) / (17.813 - 0.4 \cdot 0.188) =$ **296**
 $PMax_{[psi]} = Min(PMaxA, PMaxB)$ $MIN(146, 296) =$ **146**
 $CheckP = PMax \geq P$ $146 \geq 126.95 =$ **Acceptable**

19
20
21 **Vertical Vessel with Bolted Cover** <- Vessel
22 **36" 150# RFWN Flange** <- Description

23 **Select Flange**

24 **SA** <- Category
25 **Forged** <- Material Type
26 **SA 105** <- Material
27 **150** <- Pressure Class
28 **36.00** <- Nominal Size
29
30
31
32 Nominal - **C-Si**
33 Table - **2-1.1**
34 Max Temp °F - **1000**
35 Pod, pipe OD - **36.000**
36
37
38



39
40 **Operating Conditions**

41 **200** <- T, temperature °F
42 **126.9** <- P, pressure, psig
43 **0.063** <- Corr, corrosion allowance
44

Max press @ 100°F [p1] **285** **Acceptable**
Max press @ 200°F [p2] **260**

45 **Flange Welds: VIII UW-15 (c)**

46 **20000** <- Sp, allowable stress, pipe
47 **20000** <- Sf, allowable stress, flange
48 **35.500** <- B, flange bore
49 **1.00** <- E, weld efficiency
50
51
52

53 **Weld Strength:**

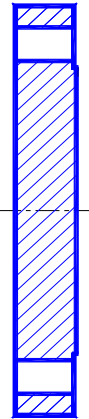
54
55 Min Sa = MIN(Sp,Sf) = MIN(20000,20000)
56 Max Weld Stress = Sa * E = 20000 * 1
57 Weld Load = $POD^2 \cdot \pi \cdot P / 4$ = $36^2 \cdot \pi \cdot 126.949 / 4$
58 Weld Area = $\pi \cdot (A^2 - (B + 2 \cdot Corr)^2) / 4$ = $\pi \cdot (36^2 - (35.5 + 2 \cdot 0.063)^2) / 4$
59 Weld Stress = Load/Area = 129218.292 / 21.095
60
61
62
63

Min Sa = **20,000**
Max Weld Stress = **20,000**
Load = **129,218**
Area = **21.095**
Stress = **6,125** **Acceptable**

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21 **Vertical Vessel with Bolted Cover** <- Vessel
22 **36" 150# Blind Flange** <- Description

23
24 **Select Flange**

25 **SA** <- Category
26 **Forged** <- Material Type
27 **SA 105** <- Material
28 **150** <- Pressure Class
29 **36.00** <- Nominal Size
32 Nominal - **C-Si**
33 Table - **2-1.1**
34 Max Temp °F - **1000**
35 Pod, pipe OD - **36.000**



38
39
40 **Operating Conditions**

41 **200** <- T, temperature °F
42 **126.9** <- P, pressure, psig

Acceptable

Max press @ 100°F [p1] **285**
Max press @ 200°F [p2] **260**

44
81 _____
82 _____
83 _____

Vertical Vessel with Bolted Cover <- Vessel

N1 - 18" Sch 40 Pipe <- Description

Shell:

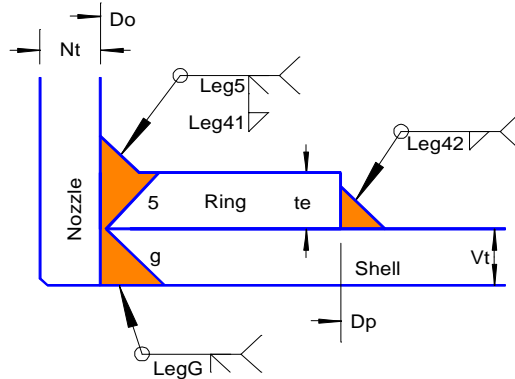
- SA-516 70 <- Shell Material
- 20,000 <- Sv, shell allowable stress level, PSI
- 1.00 <- E1, efficiency of shell at nozzle
- 35.50 <- Ds, Shell ID
- 0.250 <- Vt, shell wall thick, uncorroded, UT removed
- 0.113 <- tr, required shell wall thickness int. press.(E=1)
- 0.0625 <- sca, shell corrosion allowance
- 0.094 <- tmin16b, Min allowed wall per UG-16(b)

Nozzle:

- SA-106B <- Nozzle Material
- 17,100 <- Sn, allowable stress level (Sn)
- 1.00 <- E, nozzle efficiency
- 126.95 <- P, internal design pressure
- 18.000 <- Do, outside diameter
- 0.562 <- Nt, wall thick, uncorroded
- 12.5% <- UTP, undertolerance (%)
- 0.0625 <- nca, nozzle corrosion allowance
- 14.500 <- L, exterior Projection

Reinforcing:

- SA-516 70 <- Reinforcing plate material
- 20,000 <- Sp, allowable stress level
- 22.000 <- Dp, outside diameter
- 0.250 <- te, reinforcement thick
- 0.250 <- Leg41, size of weld fillet
- 0.250 <- Leg42, size of weld fillet
- 0.250 <- LegG, depth of groove
- 0.250 <- Leg5, depth of groove



UW-16.1(q) - modified

Variables:

UT = Nt*UTp	= 0.562 * 0.125	Undertolerance	UT = 0.070
Rn = Do/2 - (Nt-nca) + UT	= 18/2 - (0.562-0.063) + 0.07	Effective Radius	Rn = 8.571
Dp = Min(2*d,DpEntered)	= Min(2*17.001,22)	Effective Reinforcing	Dp = 22.000
t = Vt-sca	= 0.25 - 0.063	Effective Shell Thickness	t = 0.188
ti = Nt-2*nca	= 0.562 - 2 * 0.063	Nom Thick of Int. Proj.	ti = 0.437
te = teEntered		Effective Reinf. Thick.	te = 0.250
tn = Nt-nca	= 0.562-0.063	Avail. Nozzle Thick. No UT	tn = 0.500
d = Do-2*tn	= 18 - 2*0.5	Opening Dia.	d = 17.001
fr1 = MIN(Sn/Sv,1)	= MIN(17100/20000, 1)		fr1 = 0.855
fr2 = MIN(Sn/Sv,1)	= MIN(17100/20000, 1)		fr2 = 0.855
fr3 = MIN(Sn/Sv,Sp/Sv,1)	= MIN(17100/20000, 20000/20000,1)		fr3 = 0.855
fr4 = MIN(Sp/Sv,1)	= MIN(20000/20000,1)		fr4 = 1.000
Ro = Do/2	= 18/2		Ro = 9.000
tcLeg41 = Min(0.25,0.7*Min(0.75,tn,te))	= Min(0.25,0.7*Min(0.75,0.5,0.25))		tc41 = 0.175
F = 1.000			F = 1.000

Pipe Required Wall Thickness - trn from internal, trnE from external pressure

trn = (P*Rn)/(Sn*E - 0.6*P) <= tn-UT	= (126.9*8.571)/(17100*1 - 0.6*126.9)	trn = 0.064	Acceptable
trnR = (P*Rn)/(Sn*1 - 0.6*P)	= (126.9*8.571)/(17100*1 - 0.6*126.9)	trnR = 0.064	

Geometry Constraints:

0.7*Leg41 >= tc41	0.7*0.25 >= 0.175	0.175 >= 0.175	Acceptable
0.7*Leg42 >= 0.5*Min(0.75,te,t)	0.7*0.25 >= 0.5*Min(0.75,0.25,0.188)	0.175 >= 0.094	Acceptable
Leg5 >= 0.7*Min(0.75,te,tn)	0.25 >= 0.7*Min(0.75,0.25,0.5)	0.250 >= 0.175	Acceptable
LegG >= 0.7*Min(0.75,t,tn)	0.25 >= 0.7*Min(0.75,0.188,0.5)	0.250 >= 0.131	Acceptable

181 **Appendix 1-7 Necessary Check**

182 when $D_s > 60$, if $(2 \cdot R_n \leq D_s / 3)$, if $(2 \cdot R_n \leq 40)$, "App. 1-7 calculations not required", "App. 1-7 calculations required"), "App. 1-7 calculations required")
 183 when $D_s \leq 60$, if $(2 \cdot R_n < D_s / 2)$, if $(2 \cdot R_n < 20)$, "App. 1-7 calculations not required", "App. 1-7 calculations required"), "App. 1-7 calculations required")

184 **App. 1-7 calculations not required**

208 **Area Replacement:** Fig UG-37.1

		Pressure From:	Internal	External
209	$A = 1.0 \cdot d \cdot tr \cdot F + 2 \cdot tn \cdot tr \cdot F \cdot (1 - fr_1)$	A Required (internal) =	1.937	
210	$= 1.0 \cdot 17.001 \cdot 0.113 \cdot 1 + 2 \cdot 0.5 \cdot 0.113 \cdot 1 \cdot (1 - 0.855)$			
213	$A_e = 0.5 \cdot (d \cdot tr \cdot E^1 + 2 \cdot tn \cdot tr \cdot E^1 \cdot (1 - fr_1))$	A Required (external) =	0.000	
216	$= 0.5 \cdot (17.001 \cdot 0 \cdot 1 + 2 \cdot 0.5 \cdot 0 \cdot 1 \cdot (1 - 0.855))$			
217	$A_1 = \max(d, 2 \cdot (t + tn)) \cdot (E_1 \cdot t - F \cdot tr) - 2 \cdot tn \cdot (E_1 \cdot t - F \cdot tr) \cdot (1 - fr_1)$	A1 =	1.256	
220	$= \max(17.001, 2 \cdot (0.188 + 0.5)) \cdot (1 \cdot 0.188 - 1 \cdot 0.113) - 2 \cdot 0.5 \cdot (1 \cdot 0.188 - 1 \cdot 0.113) \cdot (1 - 0.855)$	A1e =		3.161
221	$A_{1e} = \max(d, 2 \cdot (t + tn)) \cdot (E_1 \cdot t - F \cdot tr \cdot E) - 2 \cdot tn \cdot (E_1 \cdot t - F \cdot tr \cdot E) \cdot (1 - fr_1)$			
224	$= \max(17.001, 2 \cdot (0.188 + 0.5)) \cdot (1 \cdot 0.188 - 1 \cdot 0) - 2 \cdot 0.5 \cdot (1 \cdot 0.188 - 1 \cdot 0) \cdot (1 - 0.855)$	A2 =	0.349	
225	$A_2 = \min((tn - tr \cdot R) \cdot fr_2 \cdot \min(5 \cdot t, 2 \cdot L), (tn - tr \cdot R) \cdot (\min(2.5 \cdot tn + te, L) \cdot fr_2^2))$			
230	$= \min((0.5 - 0.064) \cdot 0.855 \cdot \min(5 \cdot 0.188, 2 \cdot 14.5), (0.5 - 0.064) \cdot (\min(2.5 \cdot 0.5 + 0.25 \cdot 2 \cdot 14.5) \cdot 0.855^2))$			
237	$A_5 = (D_p - d - 2tn) \cdot te \cdot fr_4$	A5 =	1.000	1.000
242	$A_{41} = \text{Leg41}^2 \cdot fr_3$	A41 =	0.053	0.053
245	$A_{42} = \text{Leg42}^2 \cdot fr_4$	A42 =	0.063	0.063
250		Actual Area =	2.721	4.276
251		Actual-Required =	0.783	4.276

Acceptable

257 **Internal Weld Load:** (UG-41)

258	$W_{maxI} = (A - A_1 + 2 \cdot T_n \cdot F_r \cdot (E_1 \cdot t - F \cdot tr)) \cdot S_v, \min 0$	$= (1.937 - 1.256 + 2 \cdot 0.5 \cdot 0.855 \cdot (1 \cdot 0.188 - 1 \cdot 0.113)) \cdot 20000$	$W_{maxI} =$	14,907
262	$W_{1-1} = \text{MIN}((A_2 + A_5 + A_{41} + A_{42}) \cdot S_v, W_{maxI})$	$= \text{MIN}((0.349 + 1 + 0.053 + 0.063) \cdot 20000, 14907)$	$W_{1-1} =$	14,907
263	$W_{2-2} = \text{Min}((A_2 + A_3 + A_4 + A_{43} + 2 \cdot T_n \cdot t \cdot fr_{one}) \cdot S_v, W_{maxI})$	$= \text{Min}((0.349 + 0 + 0.053 + 0 + 2 \cdot 0.5 \cdot 0.188 \cdot 0.855) \cdot 20000, 14907)$	$W_{2-2} =$	11,255
267	$W_{3-3} = \text{Min}((A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 \cdot T_n \cdot t \cdot fr_1) \cdot S_v, W_{maxI})$	$= \text{Min}((0.349 + 0 + 1 + 0.053 + 0.063 + 0 + 2 \cdot 0.5 \cdot 0.188 \cdot 0.855) \cdot 20000, 14907)$	$W_{3-3} =$	14,907

273 **External Weld Load:** (UG-41)

274	$W_{maxE} = (A_e - A_{1e} + 2 \cdot T_n \cdot F_r \cdot (E_1 \cdot t - F \cdot tr)) \cdot S_v, \min 0$	$= (0 - 3.161 + 2 \cdot 0.5 \cdot 0.855 \cdot (1 \cdot 0.188 - 1 \cdot 0.113)) \cdot 20000$	$W_{maxE} =$	0
278	$W_{1-1} = \text{MIN}((A_{2e} + A_5 + A_{41} + A_{42}) \cdot S_v, W_{maxE})$	$= \text{MIN}((0 + 1 + 0.053 + 0.063) \cdot 20000, 0)$	$W_{1-1e} =$	0
280	$W_{2-2} = \text{Min}((A_{2e} + A_3 + A_4 + A_{43} + 2 \cdot T_n \cdot t \cdot fr_{one}) \cdot S_v, W_{maxE})$	$= \text{Min}((0 + 0 + 0.053 + 0 + 2 \cdot 0.5 \cdot 0.188 \cdot 0.855) \cdot 20000, 0)$	$W_{2-2e} =$	0
284	$W_{3-3} = \text{Min}((A_{2e} + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 \cdot T_n \cdot t \cdot fr_1) \cdot S_v, W_{maxE})$	$= \text{Min}((0 + 0 + 1 + 0.053 + 0.063 + 0 + 2 \cdot 0.5 \cdot 0.188 \cdot 0.855) \cdot 20000, 0)$	$W_{3-3e} =$	0

295 **Component Strength** (UG-45(c), UW-15(c))

296	$A_2 \text{ shear} = \text{PI}() / 2 \cdot (Do - tn) \cdot tn \cdot Sn \cdot 0.7$	$= \text{PI}() / 2 \cdot (18 - 0.5) \cdot 0.5 \cdot 17100 \cdot 0.7$	$A_2s =$	164,361
297	$g \text{ tension} = \text{PI}() / 2 \cdot Do \cdot \text{LegG} \cdot \text{Min}(S_v, S_n) \cdot 0.74$	$= \text{PI}() / 2 \cdot 18 \cdot 0.25 \cdot \text{Min}(20000, 17100) \cdot 0.74$	$gt =$	89,446
298	$A_{41} \text{ shear} = \text{PI}() / 2 \cdot Do \cdot \text{Leg41} \cdot \text{Min}(S_n, S_p) \cdot 0.49$	$= \text{PI}() / 2 \cdot 18 \cdot 0.25 \cdot \text{Min}(17100, 20000) \cdot 0.49$	$A_{41s} =$	59,228
302	$A_{42} \text{ shear} = \text{PI}() / 2 \cdot DP \cdot \text{Leg42} \cdot \text{Min}(S_v, S_p) \cdot 0.49$	$= \text{PI}() / 2 \cdot 22 \cdot 0.25 \cdot \text{Min}(20000, 20000) \cdot 0.49$	$A_{42s} =$	84,666
307	$\text{Leg 5 tens} = \text{PI}() / 2 \cdot Do \cdot \text{Leg5} \cdot \text{Min}(S_n, S_p) \cdot 0.74$	$= \text{PI}() / 2 \cdot 18 \cdot 0.25 \cdot \text{Min}(17100, 20000) \cdot 0.74$	$\text{Leg5t} =$	89,446

310 **Failure mode along strength path** (Greater than Weld Load, see App L-7)

313	$S_{1-1} = A_{42s} + A_{2s} \geq W_{1-1}$	$= 84666 + 164361 \geq 14907$	Acceptable	$S_{1-1} =$	249,027
319	$S_{2-2} = A_{41s} + gt + \text{Leg5t} + A_{43s} \geq W_{2-2}$	$= 59228 + 89446 + 89446 + 0 \geq 11255$	Acceptable	$S_{2-2} =$	238,119
325	$S_{3-3} = gt + A_{42s} + A_{43s} \geq W_{3-3}$	$= 89446 + 84666 + 0 \geq 14907$	Acceptable	$S_{3-3} =$	174,112
332	Tstd = Standard pipe wall thickness from chart			Tstd =	0.375
333	$Swre = tr \cdot Pa / P$	$= 0.113 \cdot 0 / 126.949$	Req. Exterior pressure	Swre =	0.000
334	$Nact = Nt \cdot (1 - UTp)$	$= 0.562 \cdot (1 - 0.125)$	Actual Wall Thick.	Nact =	0.492
335	$Tt = 0.8 / Nth$	$= 0.8 / 0$	Ug-31(c)(2) threads	Tt =	0.000

Acceptable

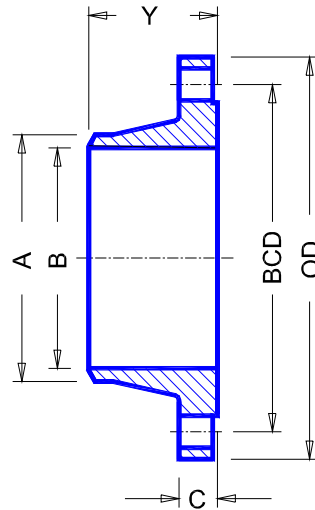
336 **UG-45**

337	$UG45 = \text{Max}(UG45a, UG45b) \leq Nact$	$= \text{Max}(0.126, 0.176) \leq 0.492$	$UG45 =$	0.176
338	$UG45a = trn + Nca + Tt$	$= 0.064 + 0.063 + 0$	$UG45a =$	0.126
339	$UG45b = \text{Min}(UG45b3, UG45b4)$	$= \text{Min}(0.176, 0.391)$	$UG45b =$	0.176
340	$UG45b1 = \text{Max}(tr + Sca, tmin16b + Sca)$	$= \text{Max}(0.113 + 0.063, 0.094 + 0.063)$	$UG45b1 =$	0.176
341	$UG45b2 = \text{Max}(Swre + Sca, tmin16b + Sca)$	$= \text{Max}(0 + 0.063, 0.094 + 0.063)$	$UG45b2 =$	
342	$UG45b3 = \text{Max}(UG45b1, UG45b2)$	$= \text{Max}(0.176,)$	$UG45b3 =$	0.176
343	$UG45b4 = Tstd \cdot 0.875 + Nca$	$= 0.375 \cdot 0.875 + 0.063$	$UG45b4 =$	0.391

19
20
21 **Vertical Vessel with Bolted Cover** <- Vessel
22 **18" 150# RFWN** <- Description

23 **Select Flange**

24 **SA** <- Category
25 **Forged** <- Material Type
26 **SA 105** <- Material
27 **150** <- Pressure Class
28 **18.00** <- Nominal Size
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32 Nominal - **C-Si**
33 Table - **2-1.1**
34 Max Temp °F - **1000**
35 Pod, pipe OD - **18.000**



36
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38
39 **Operating Conditions**

40 **200** <- T, temperature °F
41 **126.9** <- P, pressure, psig
42 **0.063** <- Corr, corrosion allowance
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44 **Flange Welds: VIII UW-15 (c)**

45 **17100** <- Sp, allowable stress, pipe
46 **20000** <- Sf, allowable stress, flange
47 **16.876** <- B, flange bore
48 **1.00** <- E, weld efficiency

49 **Weld Strength:**

50 Min Sa = MIN(Sp,Sf) = MIN(17100,20000)
51 Max Weld Stress = Sa * E = 17100 * 1
52 Weld Load = $POD^2 * \pi * P / 4$ = $18^2 * \pi * 126.949 / 4$
53 Weld Area = $\pi * (A^2 - (B + 2 * Corr)^2) / 4$ = $\pi * (18^2 - (16.876 + 2 * 0.063)^2) / 4$
54 Weld Stress = Load/Area = $32304.573 / 27.462$

55 Min Sa = **17,100**
56 Max Weld Stress = **17,100**
57 Load = **32,305**
58 Area = **27.462**
59 Stress = **1,176**
60 **Acceptable**

Vertical Vessel with Bolted Cover <- Vessel
N2 - 4" SCH 40 Pipe <- Description

Shell:

SA-516 70 <- Shell Material
20,000 <- Sv, shell allowable stress level, PSI
1.00 <- E1, efficiency of shell at nozzle
35.50 <- Ds, Shell ID
0.250 <- Vt, shell wall thick, uncorroded, UT removed
0.113 <- tr, required shell wall thickness int. press.(E=1)
0.0625 <- sca, shell corrosion allowance
0.094 <- tmin16b, Min allowed wall per UG-16(b)

Nozzle:

SA-106B <- Nozzle Material
17,100 <- Sn, allowable stress level (Sn)
1.00 <- E, nozzle efficiency
126.95 <- P, internal design pressure
4.500 <- Do, outside diameter
5.250 <- dh, id of hillside nozzle
0.237 <- Nt, wall thick, uncorroded
12.5% <- UTp, undertolerance (%)
0.0625 <- nca, nozzle corrosion allowance
11.000 <- L, exterior Projection

Reinforcing:

0.375 <- Leg41, size of weld fillet
1.000 <- F

Variables:

UT = Nt*UTp = 0.237 * 0.125
Rn = Do/2 - (Nt-nca) + UT = 4.5/2 - (0.237-0.063) + 0.03
t = Vt-sca = 0.25 - 0.063
tn = Nt-nca = 0.237-0.063
d = dh = 5.25
fr1 = MIN(Sn/Sv,1) = MIN(17100/20000, 1)
fr2 = MIN(Sn/Sv,1) = MIN(17100/20000, 1)
tcLeg41 = Min(0.25,0.7*Min(0.75,tn,t)) = Min(0.25,0.7*Min(0.75,0.175,0.188))
F = Min(Fenterered, 1)

Undertolerance UT = 0.030
Effective Radius Rn = 2.105
Effective Shell Thickness t = 0.188
Avail. Nozzle Thick. No UT tn = 0.175
Finished Opening Dia. d = 5.250
fr1 = 0.855
fr2 = 0.855
tc41 = 0.122
F = 1.000

Pipe Required Wall Thickness - trn from internal, trnE from external pressure

trn = (P*Rn)/(Sn*E - 0.6*P) <= tn-UT = (126.9*2.105)/(17100*1 - 0.6*126.9)
trnR = (P*Rn)/(Sn*1 - 0.6*P) = (126.9*2.105)/(17100*1 - 0.6*126.9)

E=1 trn = **0.016** Acceptable
trnR = **0.016**

Geometry Constraints:

0.7*Leg41 >= tc41 0.7*0.375 >= 0.122

0.263 >= 0.122 Acceptable

Appendix 1-7 Necessary Check

when Ds>60,if(2*Rn<=Ds/3,if(2*Rn<=40, "App. 1-7 calculations not required", "App. 1-7 calculations required"), "App. 1-7 calculations required")
when Ds<=60,if(2*Rn<Ds/2,if(2*Rn<20, "App. 1-7 calculations not required", "App. 1-7 calculations required"), "App. 1-7 calculations required")

App. 1-7 calculations not required

Area Replacement: Fig UG-37.1

A = 1.0*d*tr*F + 2*tn*tr*F*(1-fr1) = 1.0*5.25*0.113*1 + 2*0.175*0.113*1*(1-0.855)
Ae = 0.5*(d*trE1 + 2*tn*trE1*(1-fr1)) = 0.5*(5.25*0*1 + 2*0.175*0*1*(1-0.855))
A1 = max(d, 2*(t+tn)) * (E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1) = max(5.25, 2*(0.188+0.175)) * (1*0.188-1*0.113) - 2*0.175*(1*0.188-1*0.113)*(1-0.855)
A1e = max(d, 2*(t+tn)) * (E1*t-F*trE) - 2*tn*(E1*t-F*trE)*(1-fr1) = max(5.25, 2*(0.188+0.175)) * (1*0.188-1*0) - 2*0.175*(1*0.188-1*0)*(1-0.855)
A2 = min((tn-trnR)*fr2*Min(5*t,2*L), (tn-trnR)*fr2*Min(5*tn,2*L)) = min((0.175-0.016)*0.855*Min(5*0.188,2*11), (0.175-0.016)*0.855*Min(5*0.175,2*11))
A2e = min((tn-trnE)*fr2*Min(5*t,2*L), (tn-trnE)*fr2*Min(5*tn,2*L))
A41 = Leg41^2*fr2 = 0.375^2*0.855

Pressure From: Internal External
A Required (internal) = **0.599**

A Required (external) =	0.000
A1 =	0.387
A1e =	0.975
A2 =	0.118
A2e =	0.000
A41 =	0.120 0.120
Actual Area =	0.626 1.095
Actual-Required =	0.027 1.095

Acceptable

Tstd = Standard pipe wall thickness from chart
Swre = tr * Pa / P = 0.113 * 0 / 126.949
Nact = Nt * (1-UTp) = 0.237 * (1-0.125)
Tt = 0.8/Nth = 0.8/0

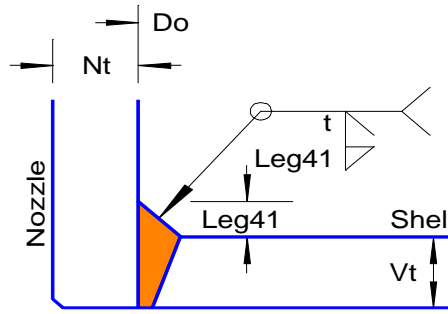
Req. Exterior pressure Tstd = 0.237
Actual Wall Thick. Swre = 0.000
Ug-31(c)(2) threads Nact = 0.207
Tt = 0.000

Acceptable

UG-45

UG45 = Max(UG45a, UG45b) <= Nact = Max(0.078, 0.176) <= 0.207
UG45a = trn + Nca + Tt = 0.016 + 0.063 + 0
UG45b = Min(UG45b3, UG45b4) = Min(0.176, 0.27)
UG45b1 = Max(tr + Sca, tmin16b + Sca) = Max(0.113 + 0.063, 0.094 + 0.063)
UG45b2 = Max(Swre + Sca, tmin16b + Sca) = Max(0 + 0.063, 0.094 + 0.063)
UG45b3 = Max(UG45b1, UG45b2) = Max(0.176,)
UG45b4 = Tstd*0.875 + Nca = 0.237*0.875 + 0.063

UG45 = **0.176**
UG45a = **0.078**
UG45b = **0.176**
UG45b1 = **0.176**
UG45b2 =
UG45b3 = **0.176**
UG45b4 = **0.270**

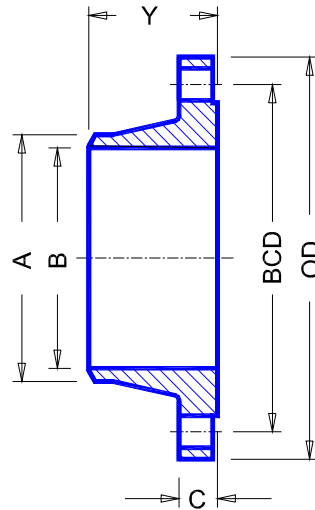


UW-16.1 (c)

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21 **Vertical Vessel with Bolted Cover** <- Vessel
22 **4" 150# RFWN** <- Description

23 **Select Flange**

24 **SA** <- Category
25 **Forged** <- Material Type
26 **SA 105** <- Material
27 **150** <- Pressure Class
28 **4.00** <- Nominal Size
29
30
31
32 Nominal - **C-Si**
33 Table - **2-1.1**
34 Max Temp °F - **1000**
35 Pod, pipe OD - **4.500**



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39 **Operating Conditions**

40 **200** <- T, temperature °F
41 **126.9** <- P, pressure, psig
42 **0.063** <- Corr, corrosion allowance
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44 **Flange Welds:** VIII UW-15 (c)

45 **17100** <- Sp, allowable stress, pipe
46 **20000** <- Sf, allowable stress, flange
47 **4.026** <- B, flange bore
48 **1.00** <- E, weld efficiency

49 **Weld Strength:**

50 Min Sa = MIN(Sp,Sf) = MIN(17100,20000)
51 Max Weld Stress = Sa * E = 17100 * 1
52 Weld Load = $POD^2 * \pi * P / 4$ = $4.5^2 * \pi * 126.949 / 4$
53 Weld Area = $\pi * (A^2 - (B + 2 * Corr)^2) / 4$ = $\pi * (4.5^2 - (4.026 + 2 * 0.063)^2) / 4$
54 Weld Stress = Load/Area = 2019.036/2.371

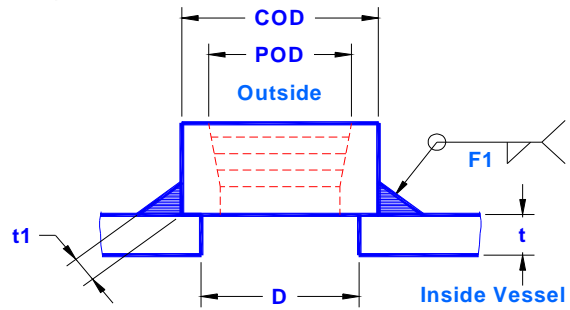
55 Min Sa = **17,100**
56 Max Weld Stress = **17,100**
57 Load = **2,019**
58 Area = **2.371**
59 Stress = **851**
60 **Acceptable**

Vertical Vessel with Bolted Cover <- Vessel

N3 - 1" 3000# NPT Coupling <- Description

Shell:

SA-516 70	<- Shell material
20,000	<- Sv, Allowable Stress Level (psi)
0.226	<- t, Shell Wall Thick (inch)
0.102	<- tMin, Min Required Wall at E=1 (inch)
0.063	<- Corr, Corrosion Allowance (inch)
1.000	<- D, Shell Opening Diameter (inch)
35.548	<- ID, Shell Inside Diameter (inch)
126.9	<- P, design Pressure (psi)



Coupling:

1 inch 3000#	<- Coupling
SA-105	<- Coupling Material
20,000	<- Sn, Allowable Stress Level (Sn)
0.3750	<- F1, Weld Size
0.094	<- tmin16b, Min allowed wall per UG-16(b)
0.063	<- Corrc, Coupling Corrosion Allowance (inch)
1.750	<- COD - Coupling OD
1.315	<- POD - Pipe OD
11.500	<- n, Threads Per Inch
0.250	<- pt, Corresponding sch160 Wall Thickness (inch)
0.133	<- tstd, Standard Pipe Wall Thickness (inch)
12.5%	<- UT, Under Tolerance (%)

Geometry Restrictions UW-16 (f)(3)(a)(1),(2),(3)

$t1 = 0.7 \cdot F1$	$= 0.7 \cdot 0.375$	$t1 = 0.263$
UW-16(f)(3)(a)(3) $t1 \text{ req} = \text{Max}(trn, ug45) \leq t1$	$= \text{Max}(0.004, 0.165) < 0.263$	Acceptable
UW-16(f)(3)(a) $POD \leq 3.5$	$= 1.315 \leq 3.5$	Acceptable
UW-16(f)(3)(a)(1) $t \leq 0.375$	$= 0.226 \leq 0.375$	Acceptable
UW-16(f)(3)(a)(2) $D \leq POD + 0.75$	$= 1 \leq 1.315 + 0.75$	Acceptable
UW-16(f)(3)(a)(2) $D \leq ID/2$	$= 1 \leq 35.548/2$	Acceptable

Required Coupling Wall Thickness UG-44(c), B16.11 - 2.1.1 and UG-31(c)(2)

$Ro = POD/2 - 0.8/n$	$= 1.315/2 - 0.8/11.5$	$Ro = 0.588$
$tp = (1-UT) \cdot pt - Corrc - 0.8/n$	$= (1-0.125) \cdot 0.25 - 0.063 - 0.8/11.5$	$tp = 0.087$
$\text{Min Thick} = P \cdot Ro / (Sn \cdot 1 + 0.4 \cdot P)$	$= 127 \cdot 0.588 / (20000 \cdot 1 + 0.4 \cdot 126.949)$	$trn = 0.004$
		Acceptable

Pressure Weld Stress UW-18(d) - Pressure Load only UW-16(f)(3)(a)(3)(b)

$\text{Load} = COD^2 \cdot (\pi/4) \cdot P$	$= 1.75^2 \cdot (\pi/4) \cdot 126.949$	$\text{Load} = 305$
$\text{Weld Area} = \pi \cdot ((COD+F1)^2 - COD^2) / 4$	$= \pi \cdot ((1.75+0.375)^2 - 1.75^2) / 4$	$\text{Weld Area} = 1.141$
$\text{Max Stress} = \text{Min}(Sn, Sv) \cdot 0.55$	$= \text{Min}(20000, 20000) \cdot 0.55$	$\text{Max Stress} = 11000$
$\text{Weld Stress} = \text{Load} / \text{Area}$	$= 305 / 1.141$	$\text{Weld Stress} = 268$
		Acceptable

UG-45

$Tstd = \text{Standard pipe wall thickness from chart}$	$Tstd = 0.133$
$Nact = Pt \cdot (1-UT)$	$Nact = 0.219$
$Tt = 0.8/n$	$Tt = 0.070$
$UG45 = \text{Max}(UG45a, UG45b) \leq Nact$	$UG45 = 0.165$
$= \text{Max}(0.136, 0.165) \leq 0.219$	Acceptable
$UG45a = trn + corrc + Tt$	$UG45a = 0.136$
$= 0.004 + 0.063 + 0.07$	
$UG45b = \text{Min}(UG45b1, UG45b4)$	$UG45b = 0.165$
$= \text{Min}(0.165, 0.179)$	
$UG45b1 = \text{Max}(tmin + CORRC, Tmin16b + CORRC)$	$UG45b1 = 0.165$
$= \text{Max}(0.102 + 0.063, 0.094 + 0.063)$	
$UG45b4 = Tstd \cdot 0.875 + corrc$	$UG45b4 = 0.179$
$= 0.133 \cdot 0.875 + 0.063$	

Actual Wall Thick.
Ug-31(c)(2) threads

www.pveng.com

Vertical Vessel with Bolted Cover <- Vessel

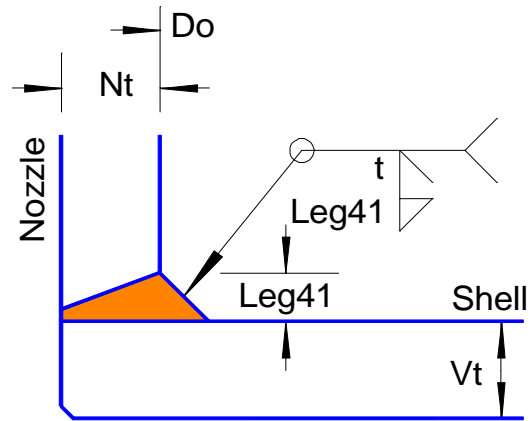
N4 - 2" 3000# NPT Coupling <- Description

Shell:

3.560 <- t, Shell Wall Thick (inch)
3.560 <- tMin, Min Required Wall at E=1 (inch)
2.000 <- D, Shell Opening Diameter (inch)
126.9 <- P, design Pressure (psi)

Coupling:

2 inch 3000# <- Coupling
SA-105 <- Coupling Material
20,000 <- Sn, Allowable Stress Level (Sn)
0.3750 <- F1, Weld Size
0.094 <- tmin16b, Min allowed wall per UG-16(b)
0.063 <- Corrc, Coupling Corrosion Allowance (inch)
3.000 <- COD - Coupling OD
2.375 <- POD - Pipe OD
11.500 <- n, Threads Per Inch
0.344 <- pt, Corresponding sch160 Wall Thickness (inch)
12.5% <- UT, Under Tolerance (%)



UW-16.1 (a)

Geometry Restrictions Fig. UW-16.1

twmin = pt	= 0.344	twmin = 0.344
t1 = 0.7*F1	= 0.7*0.375	t1 = 0.263
t1 >= 0.25	= 0.263 >= 0.25	Acceptable
POD <= 3.5	= 2.375 <= 3.5	Acceptable

Required Coupling Wall Thickness UG-44(c), B16.11 - 2.1.1 and UG-31(c)(2)

Ro = POD/2-0.8/n	= 2.375/2-0.8/11.5	Ro = 1.118
tp = (1-UT)*pt-Corrc-0.8/n	= (1-0.125)*0.344-0.063-0.8/11.5	tp = 0.169
Min Thick = P*Ro/(Sn*1+0.4*P)	= 127*1.118/(20000*1+0.4*126.949)	trn = 0.007
		Acceptable

UG-45

Tstd = Standard pipe wall thickness from chart		Tstd = 0.154
Nact = Pt * (1-UT)		Nact = 0.301
Tt = 0.8/n		Tt = 0.070
UG45 = Max(UG45a, UG45b) <= Nact		UG45 = 0.197
= Max(0.139, 0.197) <= 0.301		Acceptable
UG45a = trn + corrc + Tt		UG45a = 0.139
0.007 + 0.063 + 0.07		
UG45b = Min(UG45b1, UG45b4)		UG45b = 0.197
= Min(3.623, 0.197)		
UG45b1 = Max(tmin+ CORRC, Tmin16b + CORRC)		UG45b1 = 3.623
= Max(3.56 + 0.063, 0.094 + 0.063)		
UG45b4 = Tstd*0.875 + corrc	= 0.154*0.875 + 0.063	UG45b4 = 0.197

Actual Wall Thick.
 Ug-31(c)(2) threads

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Vertical Vessel with Bolted Cover <- Vessel

www.pveng.com **NBC-95**

Vessel Dimensions (Inch and Lbs):

75.940	<- H, height
46.200	<- L, center of gravity
21.750	<- ls, leg free length
36.000	<- Do, shell outside diameter
38.003	<- ds, leg pitch diameter
0.188	<- t, shell corroded thickness
0.250	<- ws - leg weld size
6.000	<- lw - length of leg to shell weld
6.000	<- lwf - length of weld on foot
4,671	<- W, Weight lbs
126.9	<- Pr, Pressure

Site Specific Seismic Information per NBC-95:

1.000	<- I, occupation importance factor
0.050	<- v, zonal velocity ratio
1.000	<- Za, acceleration-related seismic zone
0.000	<- Zv, velocity-related seismic zone
1.000	<- Foundation Factor (F)

Leg Supports: Per Machinery's Handbook

3x3x1/4 Angles	<- Structural Description
4	<- n, number of legs
1.240	<- lx, for one leg
1.240	<- ly, for one leg
0.930	<- fFactor, Least radius of Gyration
1.440	<- A, Leg Cross Sectional Area
4.243	<- 2cx, Beam Depth
2.298	<- 2cy, Beam Width
0.800	<- K1, Leg Anchor Factor

Material Properties:

16,600	<- maximum leg bending stress (Sb)
20,000	<- maximum shell stress (Sa)

Attachment Dimensions:

4.243	<- 2C1, Width of rectangular loading
10.000	<- 2C2, Length of rectangular loading

Static Deflection

E = 30,000,000
 bc = 12.0 leg boundary condition based on fixed or loose leg

$$y = \frac{(2 \cdot W \cdot ls^3)}{(bc \cdot n \cdot E \cdot (lx + ly))} = \frac{(2 \cdot 4671 \cdot 21.75^3)}{(12 \cdot 4 \cdot 30000000 \cdot (1.24 + 1.24))}$$
 y = 0.027

Period of Vibration

g = 386

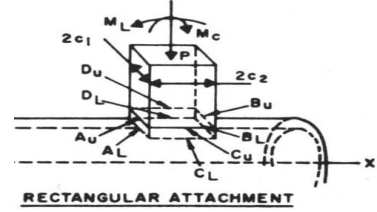
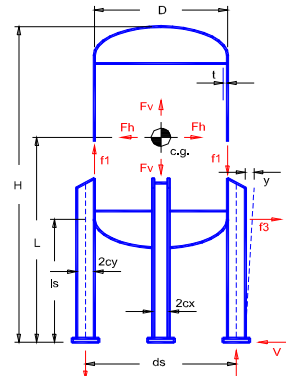
$$T = 2 \cdot \pi \cdot \sqrt{y/g} = 2 \cdot 3.14 \cdot \sqrt{0.03/386}$$
 T = 0.052

Base Shear

U = 0.6
 R = 4
 Seismic Response Factor (S) = 2.100

$$Ve = v \cdot S \cdot I \cdot F \cdot W = 0.05 \cdot 2.1 \cdot 1 \cdot 1 \cdot 4671 = 490$$

$$V = (Ve/R) \cdot U = (490.455/4) \cdot 0.6 = 74$$



RECTANGULAR ATTACHMENT

116 **Vertical Vessel with Bolted Cover Vessel On Beams**

117 **Horizontal Seismic Force at Top of Vessel**

118 $F_{tmax} = 0.25 * V = 0.25 * 74$
 119 $F_{tp} = 0.07 * T * V = 0.07 * 0.052 * 74$
 120 $F_t = \text{if } (T < 0.7, 0, \text{min}(0.07 * T * V, F_{tmax}))$

$F_{tmax} = 18$
 $F_{tp} = 0.27$
 $F_t = 0$

122 **Horizontal Seismic Force at cg**

123 $F_h = V - F_t = 74 - 0$

$F_h = 74$

125 **Vertical force at cg**

126 $F_v = W$

$F_v = 4,671$

128 **Overtuning Moment at Base**

129 $M_b = L * F_h + H * F_t = 46.2 * 74 + 75.94 * 0$

$M_b = 3,399$

131 **Overtuning Moment at Bottom Tangent Line**

132 $M_t = (L-ls) * F_h + (H-ls) * F_t = (46.2 - 21.75) * 74 + (75.94 - 21.75) * 0$

$M_t = 1,799$

134 **Maximum eccentric load**

135 $f_1 = F_v/n + 4 * M_{to}/(n * D_o) = 4671/4 + 4 * 1799/(4 * 36)$

$f_1 = 1,218$

137 **Axial Load**

138 $f_2 = F_v/n + 4 * M_b/(n * ds) = 4671/4 + 4 * 3399/(4 * 38.0032)$

$f_2 = 1,257$

140 **Leg Loads**

141 $f_{3x} = 0.5 * V * l_x / (l_x + l_y) = 0.5 * 74 * 1.24 / (1.24 + 1.24)$

$f_{3x} = 18$

142 $f_{3y} = 0.5 * V * l_y / (l_x + l_y) = 0.5 * 74 * 1.24 / (1.24 + 1.24)$

$f_{3y} = 18$

144 **Leg Bending Moments**

145 $e = (ds - D_o) / 2 = (38.0032 - 36) / 2$

$e = 1.0016$

146 $M_x = f_1 * e + f_{3x} * l_s = 1218 * 1.0016 + 18 * 21.75$

$M_x = 1,620$

147 $M_y = f_1 * e + f_{3y} * l_s = 1218 * 1.0016 + 18 * 21.75$

$M_y = 1,620$

149 **Leg Bending Stress**

150 $S_{bmax} = S_b * 1.25 = 16600 * 1.25$

$S_{bmax} = 20,750$

151 $f_x = M_x * c_x / l_x = 1620 * 2.1215 / 1.24$

Acceptable $f_x = 2,771$

152 $f_y = M_y * c_y / l_y = 1620 * 1.149 / 1.24$

Acceptable $f_y = 1,501$

154 **Leg axial stress**

155 $K_1 * l_s / f_{Factor} = 0.8 * 21.75 / 0.93$

$K_1 * l_s / f_{Factor} = 18.710$

156 $F_a \text{ max} = \text{AISC code lookup based on } K_1 * l_s / r$

$F_a \text{ max} = 25,675$

157 $f_a = f_2 / A = 1257 / 1.44$

Acceptable $f_a = 873$

159 **Maximum Euler Stress**

160 $F_e = 12 * \pi^2 * E / (23 * (K_1 * L / r)^2)$
 161 $= 12 * \pi^2 * 30000000 / (23 * 18.71^2)$

$F_e = 441,308$

163 **Combined Stress**

164 $F_{c1} = f_a / F_{amax} + 0.85 * f_x / ((1 - f_a / F_e) * S_{bmax})$
 165 $= 873 / 25675 + 0.85 * 2771 / ((1 - 873 / 441308) * 20750)$

Acceptable $F_{c1} = 0.15$

166 $F_{c2} = f_a / F_{amax} + 0.85 * f_y / ((1 - f_a / F_e) * S_{bmax})$
 167 $= 873 / 25675 + 0.85 * 1501 / ((1 - 873 / 441308) * 20750)$

Acceptable $F_{c2} = 0.10$

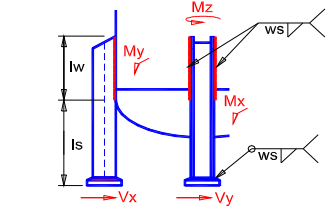
172 **Beam to Shell Attachment Stresses**

173 **Beam Dimensions**

176 $cx = 2cx/2$ $cx = 2.122$
 177 $cy = 2cy/2$ $cy = 1.149$

181 **C dimensions for weld stress**

182 weld area = $ws \cdot lw$ $wa = 1.500$
 183 $wcx = lw/2$ $wcx = 3.000$
 184 $wcz = cy + ws$ $wcz = 1.399$
 185 $wcy = \sqrt{wcx^2 + wcz^2}$



$= \sqrt{3^2 + 3.31^2}$ $wcy = 3.310$

187 **Shear Force Distribution**

188 $Vx = (V \cdot lx) / ((n/2) \cdot (lx + ly))$ $= (73.568 \cdot 1.24) / ((4/2) \cdot (1.24 + 1.24))$ $Vx = 18$
 189 $Vy = (V \cdot ly) / ((n/2) \cdot (lx + ly))$ $= (73.568 \cdot 1.24) / ((4/2) \cdot (1.24 + 1.24))$ $Vy = 18$
 190 $Vg = W/n$ $gravity$ $= 4671/4$ $Vg = 1,168$

192 **Weld Moments of Inertias**

193 $lwx = (ws \cdot lw^3 / 12) \cdot 2$ $= (0.25 \cdot 6^3 / 12) \cdot 2$ $lwx = 9.0$
 194 $lwy = (lw \cdot ws^3 / 12 + wa \cdot (cy + ws/2)^2) \cdot 2$ $lwy = 4.9$
 195 $= (6^3 \cdot 0.25^3 / 12 + 1.5 \cdot (1.149 + 0.25/2)^2) \cdot 2$
 196 $lwy = lwx + lwz$ $= 9 + 5$ $lwy = 13.9$

198 **Weld Moments**

199 $Mx = Vx \cdot (ls + lw/2) + Vg \cdot (ds - Do) / 2$ $Mx = 1,625$
 $= 18 \cdot (21.75 + 6/2) + 1167.75 \cdot (38.003 - 36) / 2$
 200 $My1 = Vy \cdot (ls + lw/2)$ $My1 = 455$
 201 $Mz = Vy \cdot (ds - Do) / 2$ $Mz = 18$

204 **Weld Stresses**

205 $Sx = Mx \cdot wcx / lwx$ $Bending$ $= 1620 \cdot 3 / 9$ $Sx = 540$
 206 $Sy = My1 \cdot wcy / lwy$ $Twisting$ $= 455 \cdot 3.31 / 13.9$ $Sy = 109$
 207 $Sz = Mz \cdot wcz / lwz$ $Torsion$ $= 18 \cdot 1.399 / 4.9$ $Sz = 5$
 208 $Sg = Vg / (wa \cdot 2)$ $Gravity$ $= 1168 / (1.5 \cdot 2)$ $Sg = 389$

210 **Stress Limits and Ratios**

211 $Slim = \min(Sb, Sa) \cdot 0.49$ $= \min(16600, 20000) \cdot 0.49$ $Slim = 8,134$
 212 $SxR = Sx / Slim$ $= 540 / 8134$ $SxR = 0.066$
 213 $SyR = Sy / Slim$ $= 109 / 8134$ $SyR = 0.013$
 214 $SzR = Sz / Slim$ $= 5 / 8134$ $SzR = 0.001$
 215 $SgR = Sg / Slim$ $= 389 / 8134$ $SgR = 0.048$
 216 **Acceptable** **total (<1) 0.128**

218 **Foot Plate Attachment Stresses**

219 $waf = ws \cdot lwf$ $weld\ area\ in\ foot = 0.25 \cdot 6$ $waf = 1.500$
 220 $Vv = V / n$ $= 74 / 4$ $Vv = 18$
 221 $Sv = Vv / waf$ $= 18 / 1.5$ $Sv = 12$
 222 $Sgf = Vg / waf$ $= 1167.75 / 1.5$ $Sgf = 779$
 223 $SvRf = Sv / Slim$ $= 12 / 8134$ $SvRf = 0.002$
 224 $SgRf = Sgf / Slim$ $= 778.5 / 8134$ $SgRf = 0.096$
 225 **Acceptable** **total (<1) 0.097**

WRC 107 - shell local stress at support

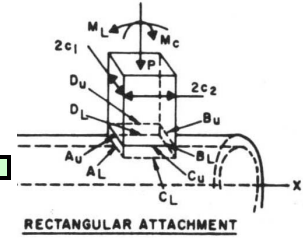
Loads (psi and lb)

18.4	<- P, Axial Load (=vx)
1,257.2	<- VL, Longitudinal load(=f2)
0.0	<- Vc, Circumferential load
1,619.7	<- ML, Moment (=My)
0.0	<- Mc, Moment
0.0	<- MT, Torisional

Parameters

MaxSPm = Sa	for Pm stresses	Pm - primary membrane stress
MaxSPmb = 1.5*Sa	for Pm + Pb stresses	Pb - primary bending stress
MaxSPmbQ = 1.5*Sa	for Pm + Pb + Q stresses	Q - secondary stress
Ri = (Do-2*T)/2		
Rm = (Do-T)/2		
r = Rm/T		= 17.906/0.188
Beta1 = 2C1/2/Rm		= 4.243/2/17.906
Beta2 = 2C2/2/Rm		= 10/2/17.906
SL = (Ri-0.4*T)*Pr/(2*T)		= (17.813-0.4*0.188)*126.949/(2*0.188)
Sc = (Ri+0.6*T)*Pr/T		= (17.813+0.6*0.188)*126.949/0.188
		Kb = 1

MaxSPm = 20,000
MaxSPmb = 30,000
MaxSPmbQ = 30,000
Ri = 17.813
Rm = 17.906
r = 95.50
Beta1 = 0.118
Beta2 = 0.279
SL = 6,005
Sc = 12,136
Kn = 1



Stress concentration factors

Shell Combined Stresses:

Lookup A	Curve	A Value	A Value	Equation	Cat	Au	AL	Bu	BL	Cu	CL	Du	DL
Pressure Stress	VIII-1 Code	4C	3C	SC	Pm	12136	12136	12136	12136	12136	12136	12136	12136
No/(P/Rm)	3C or 4C	10.38126	3.60020	$Kn^*A^*P/(Rm^*T)$	Pm	-57	-57	-57	-57	-20	-20	-20	-20
Mo/P	1C or 2C-1	0.06372	0.02611	$Kb^*A^*6^*P/T^2$	Pb	-82	82	-82	82	-200	200	-200	200
No/(Mc/(Rm^2*beta))	3A		3.67979	$Kn^*A^*Mc/(Rm^2*beta^*T)$	Pm					0	0	0	0
Mo/(Mc/(Rm^2*beta))	1A		0.06547	$Kb^*A^*6^*Mc/(Rm^2*beta^*T^2)$	Q					0	0	0	0
No/(ML/(Rm^2*beta))	3B		6.85732	$Kn^*A^*ML/(Rm^2*beta^*T)$	Pm	-880	-880	880	880				
Mo/(ML/(Rm^2*beta))	1B or 1B-1		0.00771	$Kb^*A^*6^*ML/(Rm^2*beta^*T^2)$	Q	-469	469	469	-469				
				Pm	So	11199	11199	12960	12960	12117	12117	12117	12117
				Pm+Pb	So	11117	11281	12878	13042	11917	12317	11917	12317
				Pm+Pb+Q	So	10648	11750	13347	12572	11917	12317	11917	12317
Pressure Stress	VIII-1 Code			SL	Pm	6005	6005	6005	6005	6005	6005	6005	6005
Nx/(P/Rm)	3C or 4C	10.38126	3.60020	$Kn^*A^*P/(Rm^*T)$	Pm	-20	-20	-20	-20	-57	-57	-57	-57
Mx/P	1C-1 or 2C	0.03202	0.03773	$Kb^*A^*6^*P/T^2$	Pb	-118	118	-118	118	-101	101	-101	101
Nx/(Mc/(Rm^2*beta))	4A		7.91563	$Kn^*A^*Mc/(Rm^2*beta^*T)$	Pm					0	0	0	0
Mx/(Mc/(Rm^2*beta))	2A		0.02452	$Kb^*A^*6^*Mc/(Rm^2*beta^*T^2)$	Q					0	0	0	0
Nx/(ML/(Rm^2*beta))	4B		3.30438	$Kn^*A^*ML/(Rm^2*beta^*T)$	Pm	-424	-424	424	424				
Mx/(ML/(Rm^2*beta))	2B or 2B-1		0.01385	$Kb^*A^*6^*ML/(Rm^2*beta^*T^2)$	Q	-972	972	972	-972				
				Pm	Sx	5561	5561	6409	6409	5948	5948	5948	5948
				Pm+Pb	Sx	5442	5679	6291	6528	5847	6048	5847	6048
				Pm+Pb+Q	Sx	4470	6651	7263	5556	5847	6048	5847	6048
Shear VL				$VL/(Pi^*sqrt(c1^*c2)^*T)$						-655	-655	655	655
Shear VC				$VC/(Pi^*sqrt(c1^*c2)^*T)$		0	0	0	0				
Total Shear				Sum of shears	Txo	0	0	0	0	-655	-655	655	655
S1m				$((Sx+So)/2)+SQRT(((Sx-So)/2)^2+Txo^2)$		11,199	11,199	12,960	12,960	12,185	12,185	12,185	12,185
S2m				$((Sx+So)/2)-SQRT(((Sx-So)/2)^2+Txo^2)$		5,561	5,561	6,409	6,409	5,879	5,879	5,879	5,879
S12				abs(S1m - S2m)		5,638	5,638	6,551	6,551	6,306	6,306	6,306	6,306
S23				abs(S2m-0)		5,561	5,561	6,409	6,409	5,879	5,879	5,879	5,879
S31				abs(0-S1m)		11,199	11,199	12,960	12,960	12,185	12,185	12,185	12,185
Smb<= MaxSPmb				max(S12,S23,S31)<=30000	Acceptable	11,199	11,199	12,960	12,960	12,185	12,185	12,185	12,185
S1m+b				$((Sx+So)/2)+SQRT(((Sx-So)/2)^2+Txo^2)$		11,117	11,281	12,878	13,042	11,987	12,384	11,987	12,384
S2m+b				$((Sx+So)/2)-SQRT(((Sx-So)/2)^2+Txo^2)$		5,442	5,679	6,291	6,528	5,777	5,981	5,777	5,981
S12				abs(S1m - S2m)		5,675	5,602	6,587	6,514	6,209	6,404	6,209	6,404
S23				abs(S2m-0)		5,442	5,679	6,291	6,528	5,777	5,981	5,777	5,981
S31				abs(0-S1m)		11,117	11,281	12,878	13,042	11,987	12,384	11,987	12,384
Smb<= MaxSPmb				max(S12,S23,S31)<=30000	Acceptable	11,117	11,281	12,878	13,042	11,987	12,384	11,987	12,384
S1m+b+Q				$((Sx+So)/2)+SQRT(((Sx-So)/2)^2+Txo^2)$		10,648	11,750	13,347	12,572	11,987	12,384	11,987	12,384
S2m+b+Q				$((Sx+So)/2)-SQRT(((Sx-So)/2)^2+Txo^2)$		4,470	6,651	7,263	5,556	5,777	5,981	5,777	5,981
S12				abs(S1m - S2m)		6,177	5,099	6,085	7,017	6,209	6,404	6,209	6,404
S23				abs(S2m-0)		4,470	6,651	7,263	5,556	5,777	5,981	5,777	5,981
S31				abs(0-S1m)		10,648	11,750	13,347	12,572	11,987	12,384	11,987	12,384
Smb<= MaxSPmbQ				max(S12,S23,S31)<=60000	Acceptable	10,648	11,750	13,347	12,572	11,987	12,384	11,987	12,384