Design Conditions

Code:	**ASME VIII-1**	
Year:	**2007**	
Addenda:	**2009**	
MAWP:	**30**	psi
MEAWP:	**15**	psi
Max. Temp.:	**150**	°F
MDMT:	**-20**	°F
MDMT Press.:	**30**	psi
Corrosion Allowance:	**0**	in
Hydrotest:	**39**	psi
Impact Testing:	**None**	
Impact Exemption:	**UHA-51(d)**	
Radiography:	**None**	

UG-22 Loadings Considered

Internal Press.:	**Yes**
External Press.:	**Yes**
Vessel Weight:	**No**
Weight of Attachments:	**No**
Attachment of Internals:	**No**
Attachment of Externals:	**No**
Cyclic or Dynamic Reactions:	**No**
Wind Loading:	**No**
Seismic Loading:	**No**
Fluid Impact Shock Reactions:	**No**
Temperature Gradients:	**No**
Differential Thermal Expansion:	**No**
Abnormal Pressures:	**No**
Hydrotest Loads:	**No**

ASME Section VIII-1 Calculations

Cust: **Pressure Vessel Engineering Ltd.**
File: **PVEcalc-3473-1.0**
Desc: **External Pressure Calculations**
Dwg: **None**
Date: **May 10, 2010**

Author: Laurence Brundrett
Reviewer: Ben Vanderloo

Conclusion: This is a sample calculation set showing various material thicknesses required to meet external pressure loads.

Table of Contents

Revision(s)			
Rev	Description	Date	By
0	Release	10-May-10	

External Pressure Calculations <- Vessel

Design Pressure UG-22(a)

30.0 <- P, internal operating pressure at top of vessel (psig)
15.0 <- mPa, external operation pressure
Steam / Water <- Operating Fluid
0.000 <- h, fluid height (ft)
0.000 <- rho, fluid density (1.0 for water)

Design Pressure = P + 0.4331*rho*h = 30 + 0.4331 * 0 * 0 **mDp =** **30.0**

Hydro Test (UG-99(b))

pressure measured at top of vessel, rounded up

Test Press = P * 1.3 * MR = 30 * 1.3 * 1 **mTp =** ***39***

Material Properties (ASME IID)

150 <- mTemp, design temp ºF Test at ambient temp

Material	Where Used	Ambient Strength	Design Strength	Strength Ratio	Max ºF	Ext Graph
SA-240 304 - Plate (S30400)	Head and Shell	**20000**	**18350**	**1.090**	**1500**	**HA-1**
SA-36 * - Bar (K02600)	Vacuum Rings	**16600**	**16600**	**1.000**	**900**	**CS-2**
SA-106 B* - Smls. pipe (K03006)	Half Pipe Jacket	**17100**	**17100**	**1.000**	**1000**	**CS-2**
			Min Ratio (MR) =	***1.000***		

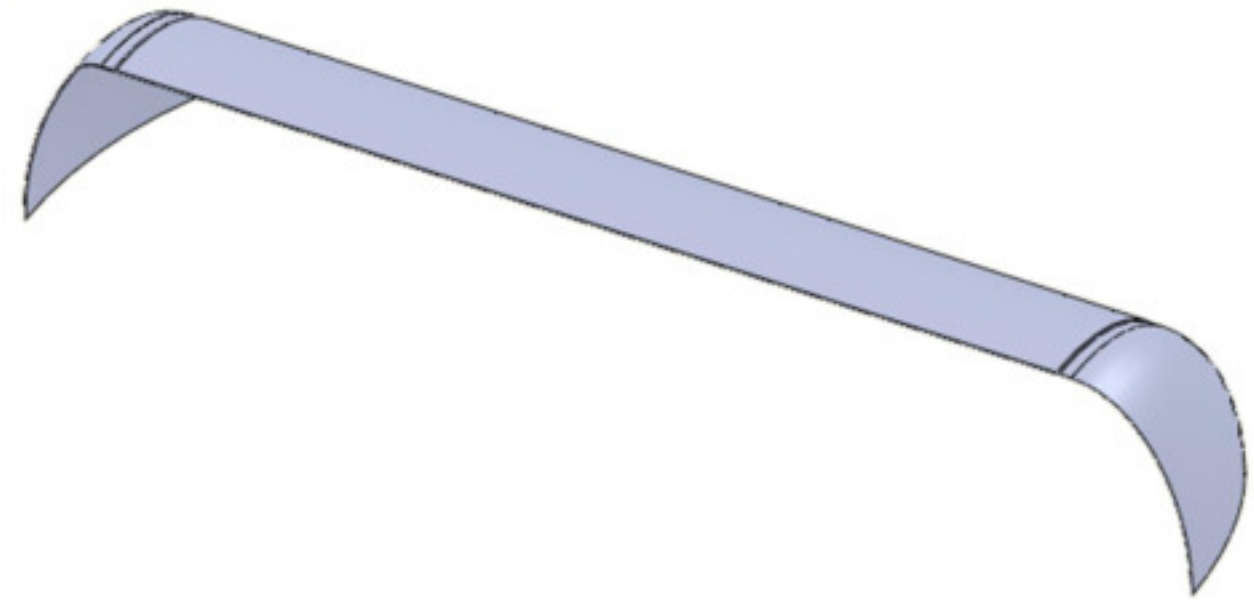
2 - Designing for External Pressure

Summary:

See web write up section 2 - Designing for External Pressure.

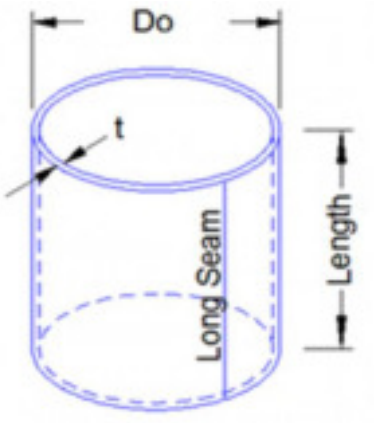
Comments:

This simple vessel is designed to code rules for external pressure, here the results are verified using Finite Element Analysis (FEA). The FEA results show that the code calculations are bit more conservative than the normally specified 3x factor of safety.



VIII-1-Pipe and Shell ver Modified

Straight Shell **Description**



Options:

Interior	**ip?** - Calculate interior pressure
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:

48.000	**Do** [in] - outside diameter
0.225	**t** [in] - nominal wall thickness
0.063	**tminUG16b** [in] - minimum wall per UG-16(b)
119.259	**Le** [in] - effective length
0.000	**Corr** [in] - corrosion allowance

Material and Conditions:

SA-240 304 **Material**

18,350	**S** [psi] - allowable stress level
0.70	**El** - longitudinal efficiency (circ. stress)
0.70	**Ec** - circ. connecting efficiency (longitudinal stress)
0.000%	**UTP** [%] - undertolerance allowance
0.000	**UTI** [in] - undertolerance allowance
30.00	**P** [psi] - interior pressure
15.0	**Pa** [psi] - exterior pressure

Exterior Pressure Inputs:

HA1	**chart** - Select external pressure chart
150	**extTemp** - Temperature for external pressure

Variables:

Td =	0.000	0 =	**0.000**
UT [in] =	t*UTP+UTI	0.225*0+0 =	**0.000**
nt [in] =	t-Corr-UT-Td	0.225-0-0-0 =	**0.225**
Ri [in] =	Do/2-nt	48/2-0.225 =	**23.775**
LDo =	Le/Do	119.259/48 =	**2.485**

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

ta [in] =	P*Ri/(S*El-0.6*P)	30*23.775/(18350*0.7-0.6*30) =	**0.056**
tb [in] =	P*Ri/(2*S*Ec+0.4*P)	30*23.775/(2*18350*0.7+0.4*30) =	**0.028**
tmin [in] =	MAX(ta,tb,tminUG16b)	MAX(0.056,0.028,0.063) =	**0.063**
tr1 [in] =	P*Ri/(S*1-0.6*P)	30*23.775/(18350*1-0.6*30) =	**0.039**
Checkt =	tmin <= nt	0.063 <= 0.225 =	**Acceptable**

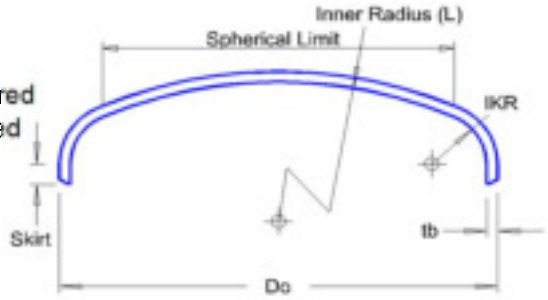
Exterior Pressure: VIII-1 UG-28(c)

DoT =	Do/nt	48/0.225 =	**213.333**
DoTe =	Do/tre	48/0.225 =	**213.713**
Aa =	10^PVELookup("TableLdo", "Int2DLin", DoT, LDo)		**0.0001743**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**2,410**
PaMax [psi] =	4*Ba/(3*DoT)	4*2410/(3*213.333) =	**15**
CheckPa =	PaMax >= Pa	15 >= 15 =	**Acceptable**
tre [in] =	(3*Do*Pa)/(4*Bb)	(3*48*15)/(4*2404) =	**0.225**
treCorr [in] =	tre+Corr+UT+Td	0.225+0+0+0 =	**0.225**
Bb =	PVELookup("BbChart","BbLookup",chart,extTemp,Do,Pa,LDo)		**2,404**

VIII-1-F&D Head ver Modified

Left Head - Flanged and Dished **Description**

Dimensions:



Interior	**ip?** - Calculate interior pressure
Exterior	**ep?** - Calculate exterior pressure
No	**relief?** - Stress Relief Calculations Required
No App 1-4	**App** 1-4? - App 1-4(f) Calculation Required
48.000	**Do** [in] - outside diameter of head
48.000	**L** [in] - inside crown radius (note 1)
2.880	**IKR** [in] - inside knuckle radius (note 2)
0.142	**tb** [in] - thickness before forming
0.142	**tf** [in] - thickness after forming (note 3)
0.063	**tminUG16b** [in] - min. t. per UG-16(b)
0.000	**Corr** [in] - corrosion allowance
1.500	**Skirt** [in] - straight skirt length

Material and Conditions:

SA-240 304	**Material**
18,350	**S** [psi] - allowable stress
0.85	**E** - head longitudinal efficiency
30.0	**P** [psi] - interior pressure
15.0	**Pa** [psi] - Exterior pressure

Exterior Pressure Inputs:

HA1	**chart** - Select external pressure chart
150	**extTemp** [°F] - Temperature for external pressure

Calculated Properties:

note 1:Suggested radius L per UG-32(j)	**48.00**	Depth of head (id), in =	**8.053**
note 2:Suggested radius IKR per UG-32(j)	**2.880**	Approx. head volume including skirt, cuft =	**6.64**

Variables:

t [in] =	tf-Corr	thickness with corrosion allowance removed	0.142-0 = **0.142**
D [in] =	Do-2*t	ID with corrosion allowance removed	48-2*0.142 = **47.716**
L/r =	L/IKR		48/2.88 = **16.667**
M =	0.25*(3+sqrt(L/IKR))		0.25*(3+SQRT(48/2.88)) = **1.771**
Ro [in] =	L+tb		48+0.142 = **48.142**

Interior Pressure - Required Thickness: App. 1-4(a), App. 1-4(d)

App1-4(f) =	tf/L	0.142/48 = **0.003**
App1-4(f)Calc =	if(AND(0.0005=<App1-4(f),App1-4(f)<0.002),"Calculation Required","Calculation not required")	
		App. 1-4(f) Calculation Not Required
Tmin [in] =	(P*L*M)/(2*S*E-0.2*P) required minimum thickness	
		(30*48*1.771)/(2*18350*0.85-0.2*30) = **0.082**
Checkt =	t >= Max(Tmin,tminUG16b)	0.142 >= MAX(0.082,0.063) = **Acceptable**

Exterior Pressure - Required Thickness: UG-33(d), UG-28(d)

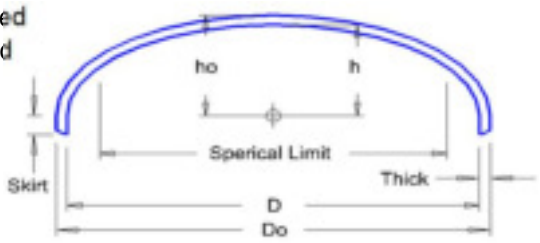
Aa =	0.125/(Ro/t)	0.125/(48.142/0.142) = **0.0004**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)	**5,097**
PaMax [psi] =	Ba/(Ro/t)	5097/(48.142/0.142) = **15.0**
CheckPaMax =	PaMax >= Pa	15 >= 15 = **Acceptable**
Bb =	PVELookup("BbChart","BbEHLookup",chart,extTemp,Ro,Pa)	**5,091**
TMinE [in] =	(Pa*Ro)/Bb	(15*48.142)/5091 = **0.142**
TMinEC [in] =	TMinE + Corr	0.142 + 0 = **0.142**

VIII-1-Elliptical Head ver 5.02

Semi Elliptical Right Head **Description**

Dimensions:

Interior	**ip?** - Calculate interior pressure
Exterior	**ep?** - Calculate exterior pressure
No	**relief?** - Stress Relief Calculations Required
No App 1-4	**App** 1-4? - App 1-4(f) Calculation Required
48.000	**Do** [in] - outside diameter of head
11.937	**h** [in] - inside crown height (note 1)
0.127	**tb** [in] - thickness before forming
0.127	**tf** [in] - thickness after forming (note 2)
0.063	**tminUG16b** [in] - min. t. per UG-16(b)
0.000	**Corr** [in] - corrosion allowance
1.500	**Skirt** [in] - straight skirt length



Material and Conditions:

SA-240 304	**Material**
18,350	**S** [psi] - allowable stress
0.85	**E** - head longitudinal efficiency
30.0	**P** [psi] - interior pressure
15.0	**Pa** [psi] - Exterior pressure

Exterior Pressure Inputs:

HA1	**chart** - Select external pressure chart
150	**extTemp** [°F] - Temperature for external pressure

Calculated Properties:

note 1: Suggested h	**11.9365**	Approx. head weight based on steel, lbs =	**100.93**
note 2: Suggested tf	**0.0645**	Approx. head volume including skirt, cuft =	**9.80**

Variables:

t [in] =	tf-Corr	thickness with corrosion allowance removed	0.127-0 =	**0.127**
D [in] =	Do-2*t	ID with corrosion allowance removed	48-2*0.127 =	**47.746**
ho [in] =	h+t		11.937+0.127 =	**12.064**
D/2h =	D/(2*h)		47.746/(2*11.937) =	**2.000**
Do/2ho =	Do/(2*ho)		48/(2*12.064) =	**1.989**
K =	1.000	Interpolated value from table 1-4.1	=	**1.000**
Kone =	0.900	Interpolated value from table UG-37	=	**0.900**
Kzero =	0.895	Interpolated value from table UG-33.1	=	**0.895**
Ro [in]=	Kzero*Do		0.895*48 =	**42.973**

Interior Pressure - Required Thickness: App. 1-4(c), UG-37(a)(1)

App1-4(f) =	tf/(Kone*D)	0.127/(0.9*47.746) =	**0.0030**
App1-4(f)Calc =	if(AND(0.0005=<App1-4(f),App1-4(f)<0.002),"Calculation Required","Calculation not required")		
			App. 1-4(f) Calculation Not Required
Tmin [in] =	(P*D*K)/(2*S*E-0.2*P)		
		(30*47.746*1)/(2*18350*0.85-0.2*30) =	**0.046**
Checkt =	t >= Max(Tmin,tminUG16b)	0.127 >= MAX(0.046,0.063) =	**Acceptable**

Exterior Pressure - Required Thickness: UG-33(d), UG-28(d)

Aa =	0.125/(Ro/t)	0.125/(42.973/0.127) =	**0.0004**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**5,107**
PaMax [psi] =	Ba/(Ro/t)	5107/(42.973/0.127) =	**15.1**
CheckPaMax =	PaMax >= Pa	15.1 >= 15 =	**Acceptable**
Bb =	PVELookup("BbChart","BbEHLookup",chart,extTemp,Ro,Pa)		**5,091**
TMinE [in] =	(Pa*Ro)/Bb	(15*42.973)/5091 =	**0.127**
TMinEC [in] =	TMinE + Corr	0.127 + 0 =	**0.127**

Loads

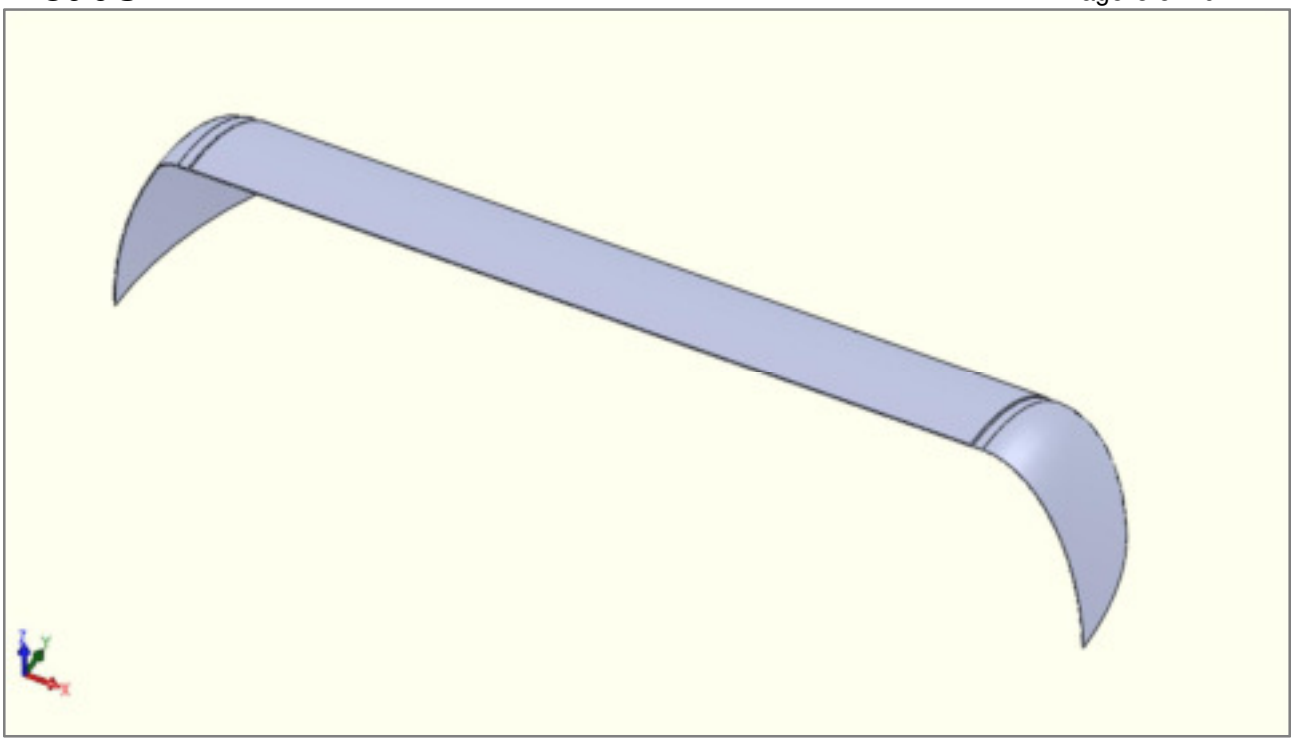


Fig-A 96" long vessel x 48" diameter - F&D head on left (0.142" thick)
96" straight shell (0.225" thick)
2:1 SE head on right (0.127" thick)

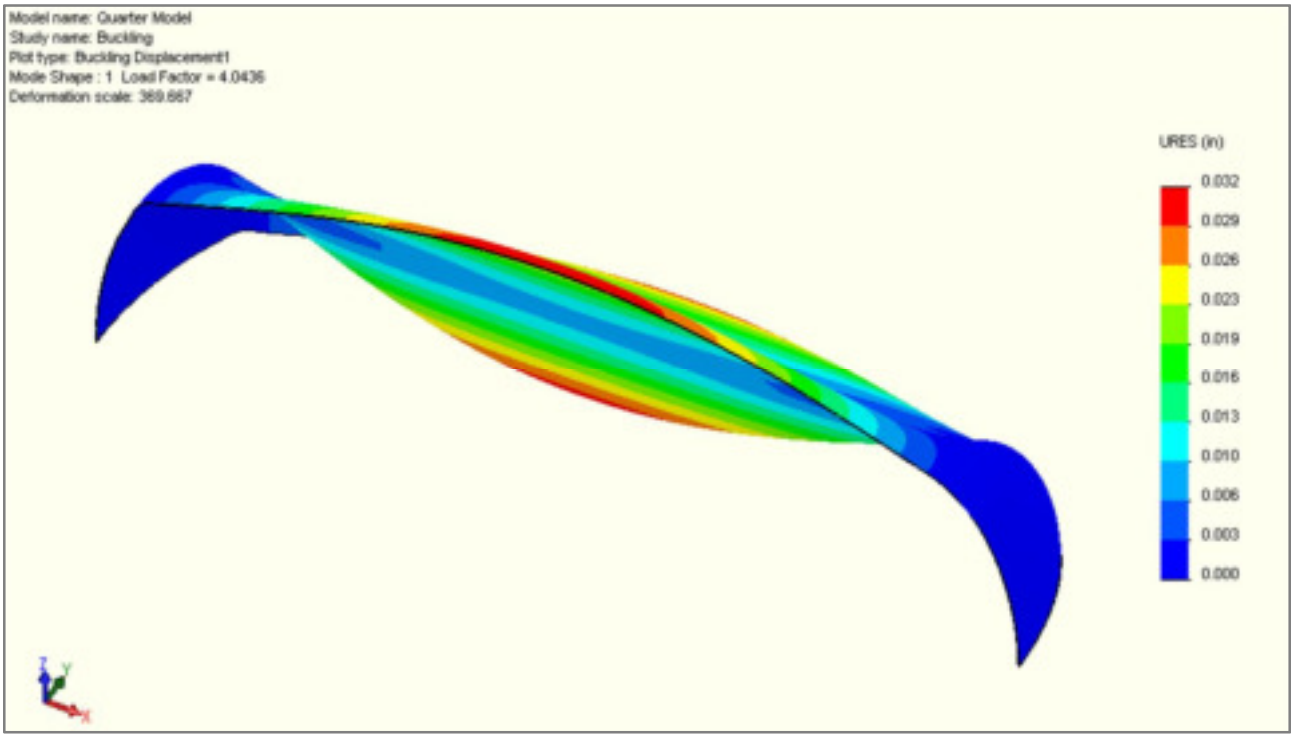


Fig-B 15 psi external load is applied
Reported factor of safety from buckling = 4.04 (>3x required by code)

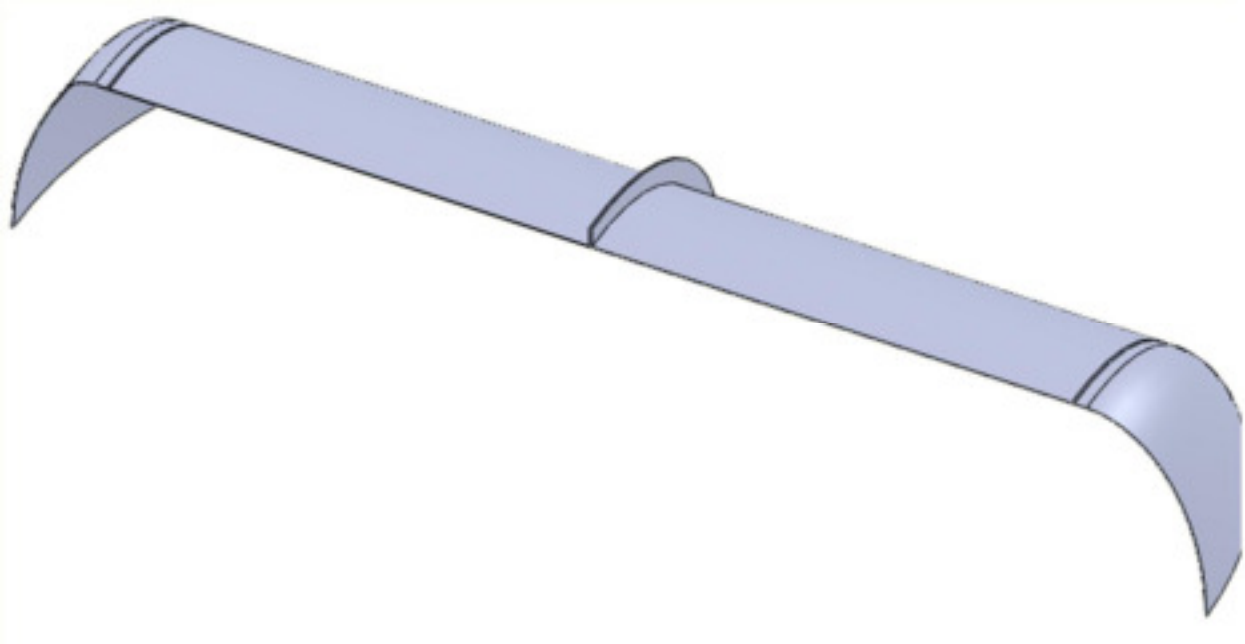
3 - Vacuum Rings

Summary:

See web write up section 3 - Vacuum Rings.

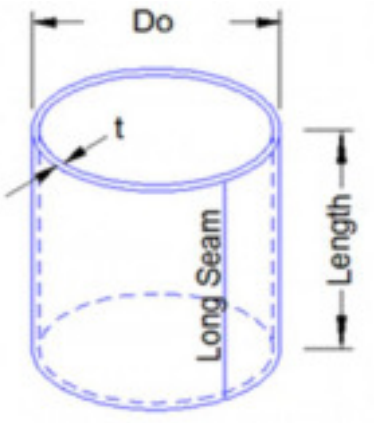
Comments:

The vessel shell has been reinforced by a vacuum ring to reduce the effective length of the shell. The shell thickness has been reduced to the optimum condition. FEA analysis shows that the vessel now has a very conservative 8x buckling factor of safety



VIII-1-Pipe and Shell ver Modified

Straight shell with vacuum ring **Description**



Options:

Interior	**ip?** - Calculate interior pressure
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:

48.000	**Do** [in] - outside diameter
0.169	**t** [in] - nominal wall thickness
0.063	**tminUG16b** [in] - minimum wall per UG-16(b)
59.629	**Le** [in] - effective length
0.000	**Corr** [in] - corrosion allowance

Material and Conditions:

SA-240 304 **Material**

18,350	**S** [psi] - allowable stress level
0.70	**El** - longitudinal efficiency (circ. stress)
0.70	**Ec** - circ. connecting efficiency (longitudinal stress)
0.000%	**UTP** [%] - undertolerance allowance
0.000	**UTI** [in] - undertolerance allowance
30.00	**P** [psi] - interior pressure
15.0	**Pa** [psi] - exterior pressure

Exterior Pressure Inputs:

HA1	**chart** - Select external pressure chart
150	**extTemp** - Temperature for external pressure

Variables:

Td =	0.000	0 =	**0.000**
UT [in] =	t*UTP+UTI	0.169*0+0 =	**0.000**
nt [in] =	t-Corr-UT-Td	0.169-0-0-0 =	**0.169**
Ri [in] =	Do/2-nt	48/2-0.169 =	**23.831**
LDo =	Le/Do	59.629/48 =	**1.242**

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

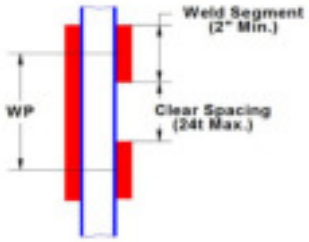
ta [in] =	P*Ri/(S*El-0.6*P)	30*23.831/(18350*0.7-0.6*30) =	**0.056**
tb [in] =	P*Ri/(2*S*Ec+0.4*P)	30*23.831/(2*18350*0.7+0.4*30) =	**0.028**
tmin [in] =	MAX(ta,tb,tminUG16b)	MAX(0.056,0.028,0.063) =	**0.063**
tr1 [in] =	P*Ri/(S*1-0.6*P)	30*23.831/(18350*1-0.6*30) =	**0.039**
Checkt =	tmin <= nt	0.063 <= 0.169 =	**Acceptable**

Exterior Pressure: VIII-1 UG-28(c)

DoT =	Do/nt	48/0.169 =	**284.024**
DoTe =	Do/tre	48/0.168 =	**285.003**
Aa =	10^PVELookup("TableLdo", "Int2DLin", DoT, LDo)		**0.0002332**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**3,224**
PaMax [psi] =	4*Ba/(3*DoT)	4*3224/(3*284.024) =	**15**
CheckPa =	PaMax >= Pa	15 >= 15 =	**Acceptable**
tre [in] =	(3*Do*Pa)/(4*Bb)	(3*48*15)/(4*3206) =	**0.168**
treCorr [in] =	tre+Corr+UT+Td	0.168+0+0+0 =	**0.168**
Bb =	PVELookup("BbChart","BbLookup",chart,extTemp,Do,Pa,LDo)		**3,206**

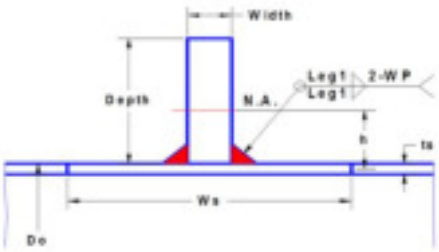
VIII-1-Vacuum Ring Calculator ver 4.02

Vacuum Ring **Description**



Vessel Inputs:

SA-240 304	**Material**	
16,600	**Ssa** [psi] - Allowable stress of shell	
48.000	**Do** [in] - Outside diameter of shell	
0.169	**ts** [in] - Corroded shell thickness	
0.169	**t** [in] - Required shell thickness for ext. pressure	
59.63	**Ls** [in] - Supported length	
15.00	**Pa** [psi] - External pressure	
HA1r	**chart** - Select external pressure chart	
150	**extTemp** [°F] - Temperature for external pressure	



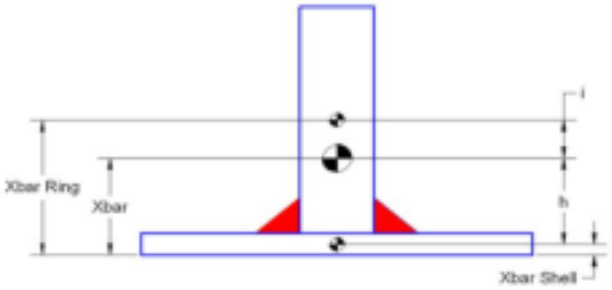
Vacuum Ring Inputs:

SA-36	**Material**	
16,600	**Sba** [psi] - Allowable stress of bar	
36,000	**Sby** [psi] - Bar yield stress	
30,000,000	**Eb** [psi] - Bar modulus of elacticity	
0.250	**Wid** [in] - Ring bar width	
2.500	**Dep** [in] - Ring bar depth	
0.250	**Leg1** [in] - Weld leg	
2.000	**WP** [in] - Weld pitch	
6.000	**WS** [in] - Weld segment	

Maximum Support Beam Depth: (Norsk Standard n004r1 B.5.81)

MaxDep [in] =	0.4*Wid*Sqrt(Eb/Sby)		0.4*0.25*SQRT(30000000/36000) =	**2.887**
effDep [in] =	Min(Dep,MaxDep)	Effective beam depth	MIN(2.5,2.887) =	**2.500**

Section Properties:



Wsm [in] =	1.10*SQRT(Do*ts)	Allowable shell width	1.10*SQRT(48*0.169) =	**3.133**
As [in^2] =	Wid*effDep	Ring cross section area	0.25*2.5 =	**0.625**
Ash [in^2] =	ts*Wsm	Shell cross section area	0.169*3.133 =	**0.529**
At [in^2] =	As+Ash	Combined cross section area	0.625+0.529 =	**1.154**
XbarAs [in^3] =	(ts/2)*ts*Wsm		(0.169/2)*0.169*3.133 =	**0.045**
XbarAsh [in^3] =	(effDep/2+ts)*effDep*Wid		(2.5/2+0.169)*2.5*0.25 =	**0.887**
Xbar [in] =	(XbarAsh +XbarAs)/At	Centroid location	(0.887 +0.045)/1.154 =	**0.807**
h [in] =	Xbar-ts/2	Distance from combined centroid to shell centroid	0.807-0.169/2 =	**0.722**
i [in] =	(ts+effDep)-effDep/2-Xbar	Distance from combined centroid to ring centroid	(0.169+2.5)-2.5/2-0.807 =	**0.612**
IxxR [in^4] =	(1/12)*Wid*effDep^3	Ring moment of interia	(1/12)*0.25*2.5^3 =	**0.3255**
IxxSh [in^4] =	(1/12)*Wsm*ts^3	Shell moment of interia	(1/12)*3.133*0.169^3 =	**0.0013**
IxxComb [in^4] =	(Ixxsh + Ash*h^2)+(Ixxs + As*i^2)	Combined moment of inertia	(Ixxs0.722 + 0.529*0.722^2)+(Ixxs + 0.625*0.612^2) =	**0.837**

Required Moment of Inertia: UG-29

B =	0.75*((Pa*Do)/(t+As/Ls))	0.75*((15*48)/(0.169+0.625/59.63)) =	**3009**	
A =	PVELookup("ExtChart","ExtLookup",chart,extTemp,B)		**0.000218**	
IRR [in^4] =	(Do^2*Ls*(t+As/Ls)*A)/14 Require moment of interia for ring	(48^2*59.63*(0.169+0.625/59.63)*0.000218)/14 =	**0.384**	
IRComb [in^4] =	(Do^2*Ls*(t+As/Ls)*A)/10.9 Require moment of interia for ring and shell combined	(48^2*59.63*(0.169+0.625/59.63)*0.000218)/10.9 =	**0.493**	
CheckI =	IF(OR(IxxR>=IRR,IxxComb>=IRComb),"Acceptable","Error") UG-29(a)		**Acceptable**	

Attachment Weld Strength: UG-30(e),(f) App L-5:

CheckWeld =	Leg1 >= min(0.25,ts,Wid)	0.25 >= MIN(0.25,0.169,0.25) =	**Acceptable**	
CSM [in] =	24*ts Clear space maximum	24*0.169 =	**4**	
CS [in] =	WP-WS Clear Spacing	2-6 =	**-4.000**	
CheckCS=	WP-WS<=CSM	2-6<=4 =	**Acceptable**	
E =	1+WS/(WS+CS) Spacing effiency	1+6/(6+-4) =	**4.000**	
S [psi] =	min(Ssa,Sba)	MIN(16600,16600) =	**16600**	
Wsa [psi] =	0.55*S Allowable weld stress	0.55*16600 =	**9130**	
Wla [lb/in] =	E*Leg1*Wsa Allowable weld load	4*0.25*9130 =	**9130**	
PL [lb/in] =	Pa*Ls Radial pressure load	15*59.63 =	**894**	
V [lbi] =	0.01*Pa*Ls*Do Shear load	0.01*15*59.63*48 =	**429**	
Q [in^3] =	Wsm*ts*h	3.133*0.169*0.722 =	**0.383**	
VQI [lb/in] =	V*Q/IxxComb Shear Flow	429*0.383/0.837 =	**196**	
CWL [lb/in] =	SQRT(PL^2+VQI^2) Combined load	SQRT(894^2+196^2) =	**916**	
CheckCWL =	CWL <= Wla	916 <= 9130 =	**Acceptable**	

Loads

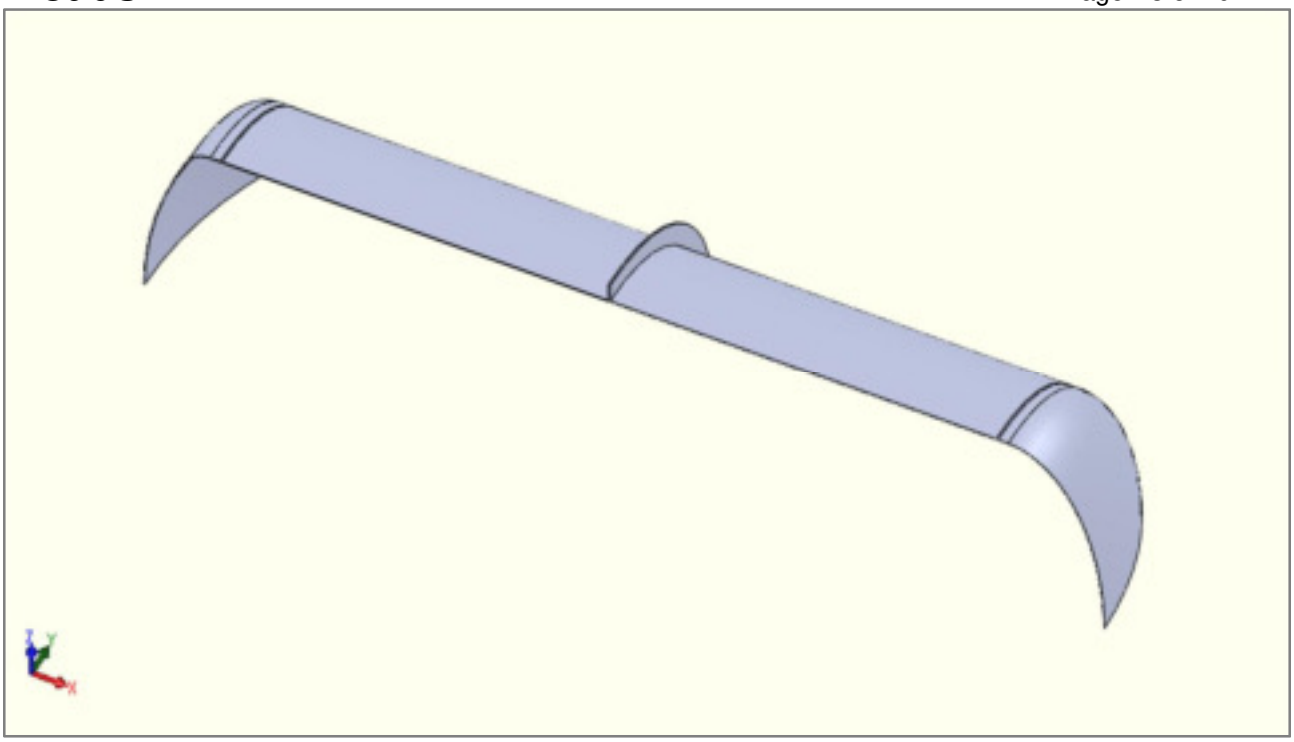


Fig-A 96" straight shell (0.169" thick)
Reinforcement is 0.25" x 2.5" bar rolled the hard way

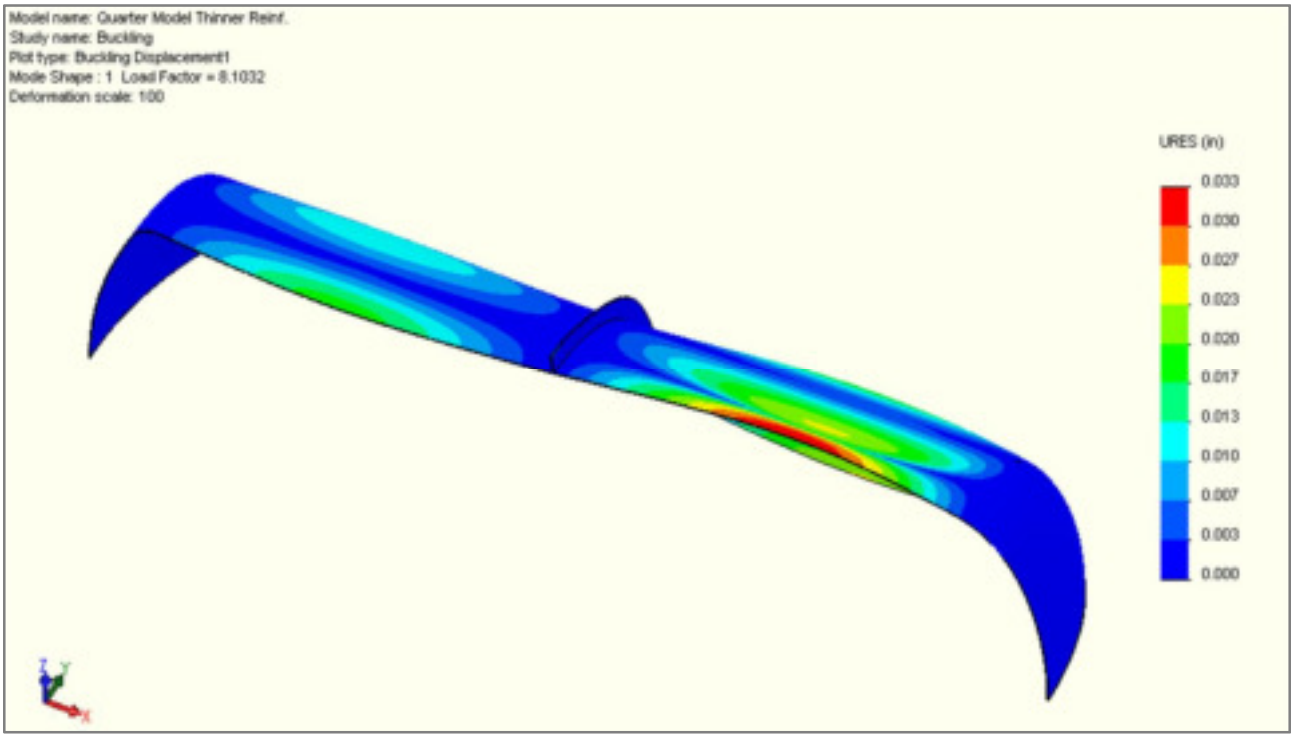


Fig-B 15 psi external load is applied
The reinforcement has successfully separated the action on the two sides
Reported factor of safety from buckling = 8.10 (>3x required by code)

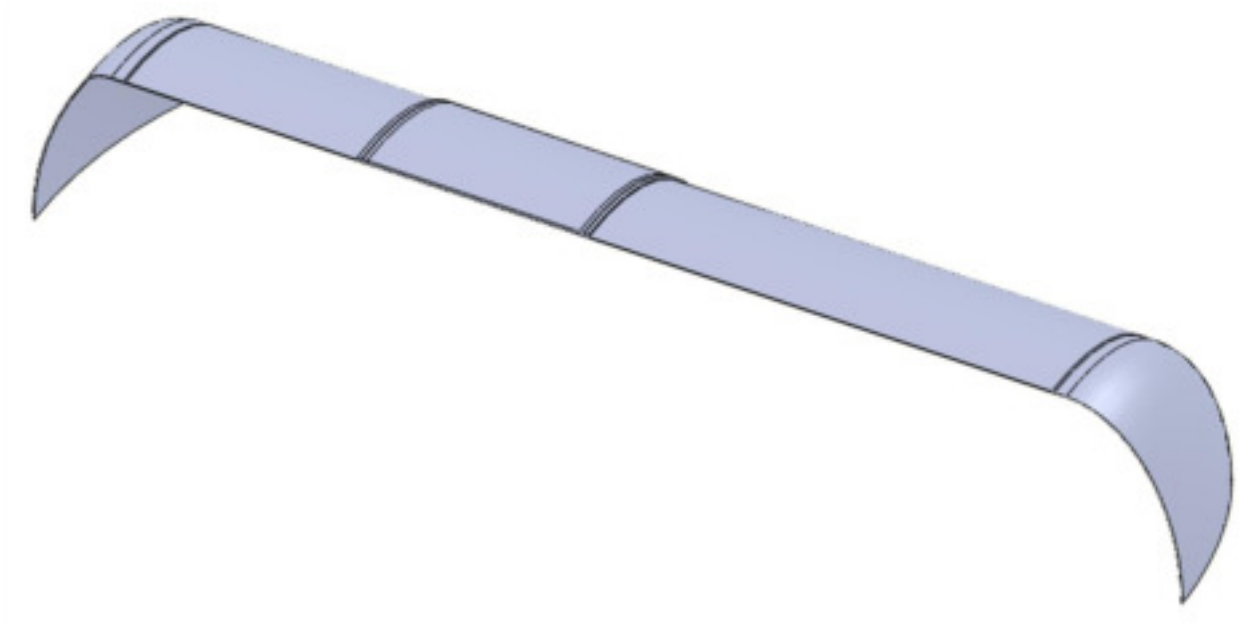
4a - External Pressure form Simple Jackets

Summary:

See web write up section 4 - External Pressure from Simple Jacket.

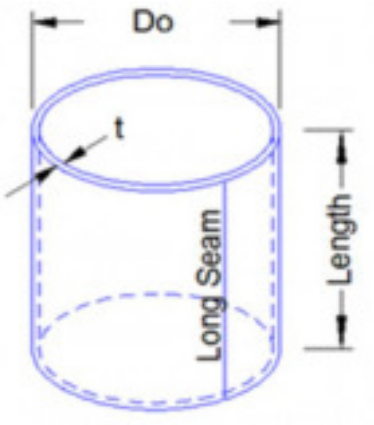
Contents:

The vessel shell has been jacketed with two rings an a shell to reduce the effective length of the shell. The shell thickness has been reduced to the optimum condition. The model contains jacket pressure only. FEA analysis shows that the vessel now has a 4.30x buckling factor of safety



VIII-1-Pipe and Shell ver Modified

Straight shell with simple jacket **Description**



Options:

Interior	**ip?** - Calculate interior pressure
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:

48.000	**Do** [in] - outside diameter
0.161	**t** [in] - nominal wall thickness
0.063	**tminUG16b** [in] - minimum wall per UG-16(b)
24.000	**Le** [in] - effective length
0.000	**Corr** [in] - corrosion allowance

Material and Conditions:

SA-240 304 **Material**

18,350	**S** [psi] - allowable stress level
0.70	**El** - longitudinal efficiency (circ. stress)
0.70	**Ec** - circ. connecting efficiency (longitudinal stress)
0.000%	**UTP** [%] - undertolerance allowance
0.000	**UTI** [in] - undertolerance allowance
30.00	**P** [psi] - interior pressure
30.0	**Pa** [psi] - exterior pressure

Exterior Pressure Inputs:

HA1	**chart** - Select external pressure chart
150	**extTemp** - Temperature for external pressure

Variables:

Td =	0.000	0 =	**0.000**
UT [in] =	t*UTP+UTI	0.161*0+0 =	**0.000**
nt [in] =	t-Corr-UT-Td	0.161-0-0-0 =	**0.161**
Ri [in] =	Do/2-nt	48/2-0.161 =	**23.839**
LDo =	Le/Do	24/48 =	**0.500**

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

ta [in] =	P*Ri/(S*El-0.6*P)	30*23.839/(18350*0.7-0.6*30) =	**0.056**
tb [in] =	P*Ri/(2*S*Ec+0.4*P)	30*23.839/(2*18350*0.7+0.4*30) =	**0.028**
tmin [in] =	MAX(ta,tb,tminUG16b)	MAX(0.056,0.028,0.063) =	**0.063**
tr1 [in] =	P*Ri/(S*1-0.6*P)	30*23.839/(18350*1-0.6*30) =	**0.039**
Checkt =	tmin <= nt	0.063 <= 0.161 =	**Acceptable**

Exterior Pressure: VIII-1 UG-28(c)

DoT =	Do/nt	48/0.161 =	**298.137**
DoTe =	Do/tre	48/0.16 =	**299.670**
Aa =	10^PVELookup("TableLdo", "Int2DLin", DoT, LDo)		**0.0005546**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**6,766**
PaMax [psi] =	4*Ba/(3*DoT)	4*6766/(3*298.137) =	**30**
CheckPa =	PaMax >= Pa	30 >= 30 =	**Acceptable**
tre [in] =	(3*Do*Pa)/(4*Bb)	(3*48*30)/(4*6743) =	**0.160**
treCorr [in] =	tre+Corr+UT+Td	0.16+0+0+0 =	**0.160**
Bb =	PVELookup("BbChart","BbLookup",chart,extTemp,Do,Pa,LDo)		**6,743**

Loads

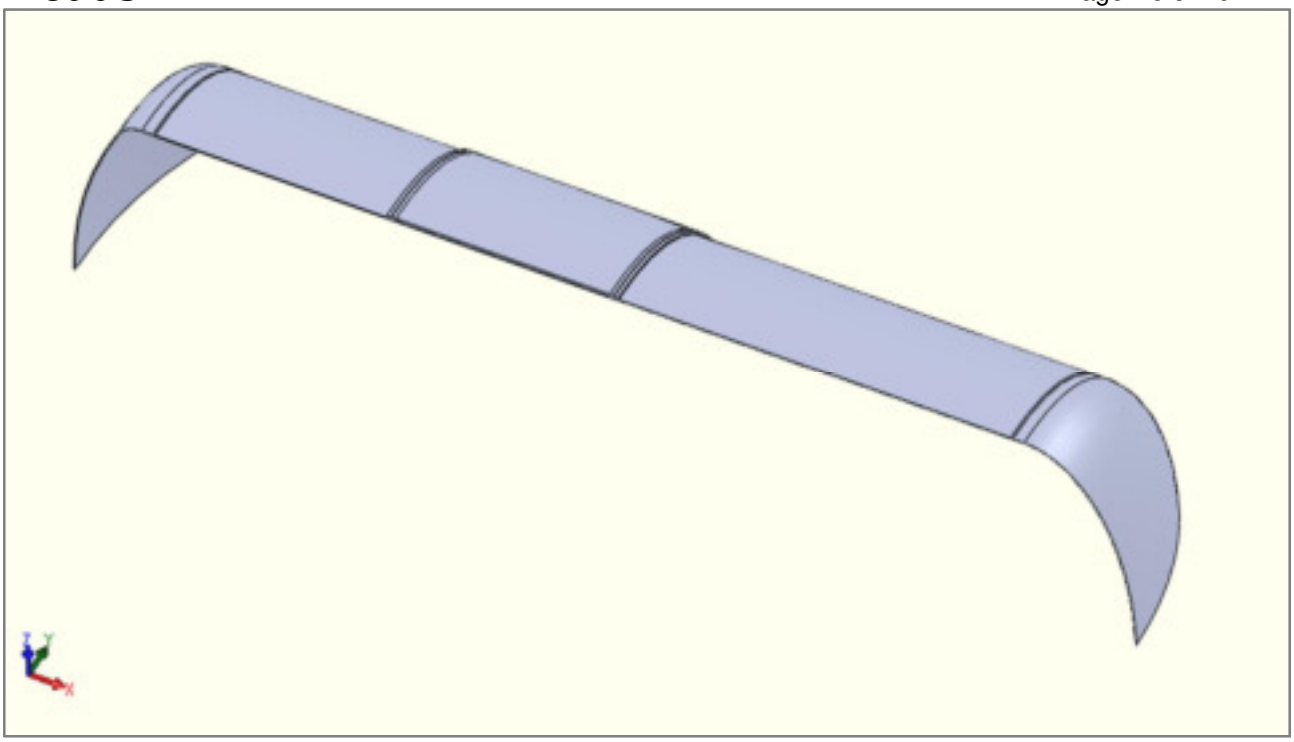


Fig-A 96" straight shell (0.161" thick)
The reinforcement is 1" x 0.25" bar

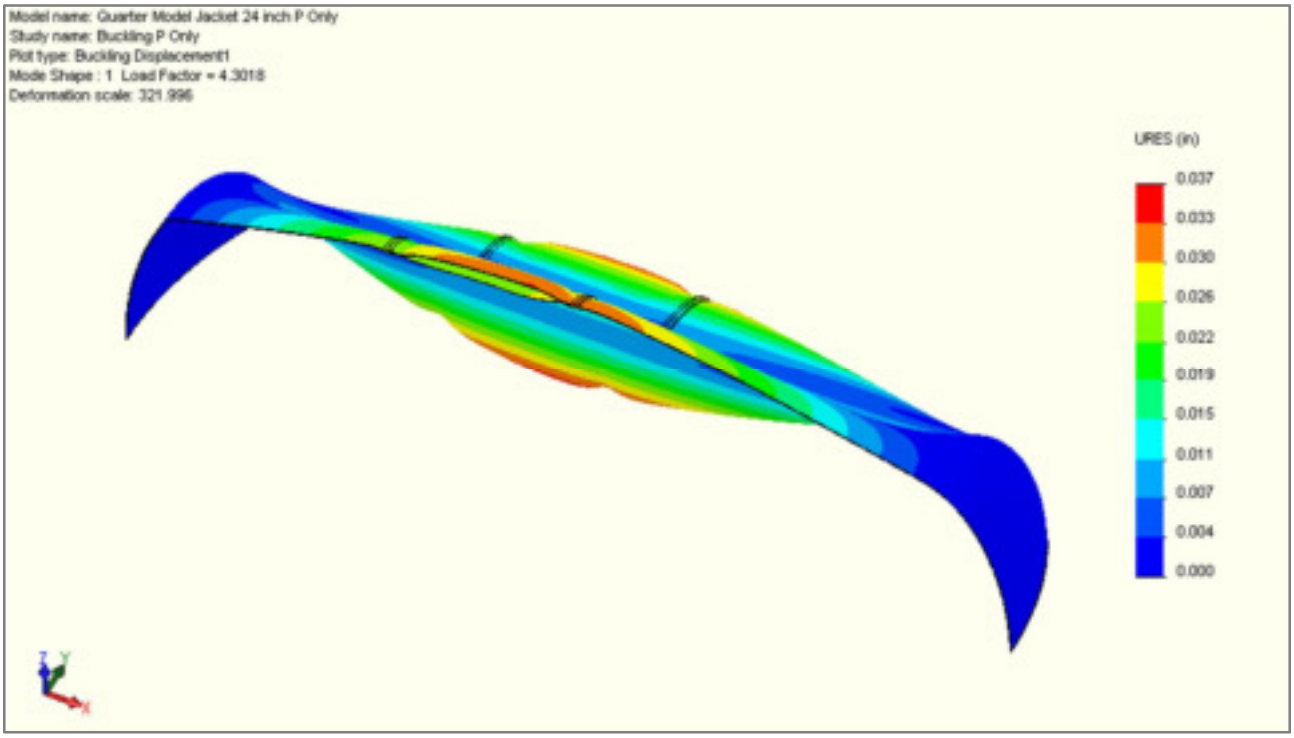


Fig-B 30 psi external load is applied under the jacket only
The reinforcement did not separate the action to under the jacket but
the factor of safety from buckling = 4.30 (>3x required by code) so the design passes.

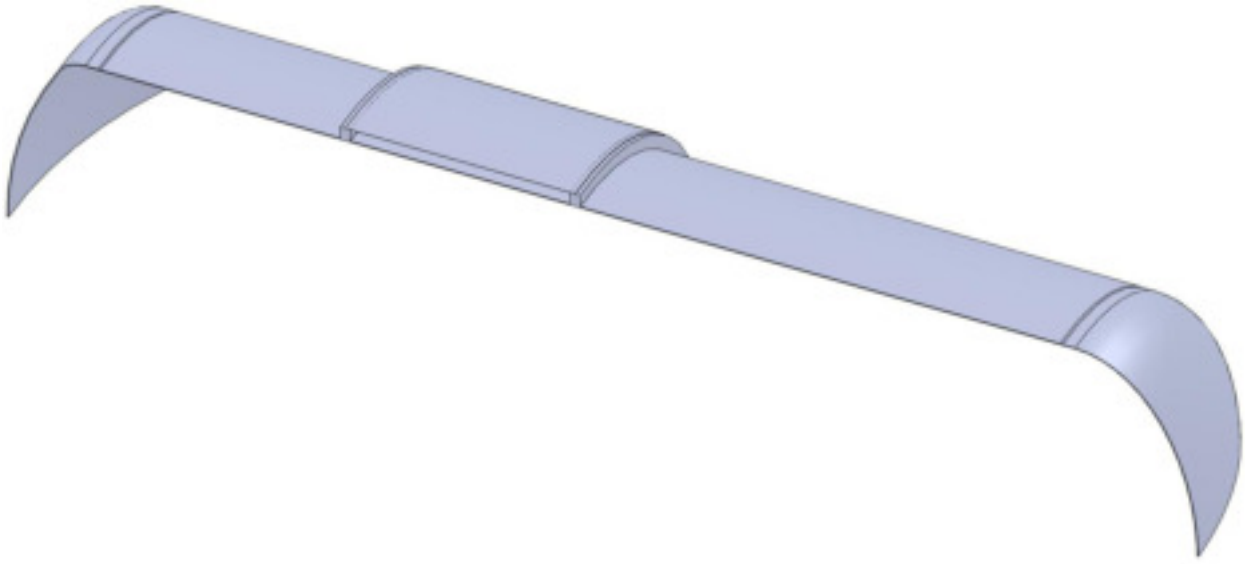
4b - External Pressure form Simple Jackets

Summary:

See web write up section 4 - External Pressure from Simple Jacket.

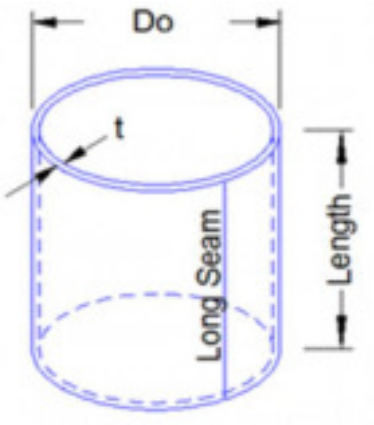
Contents:

The vessel shell has been jacketed with two UG-29 rings an a shell to reduce the effective length of the shell. The shell thickness has been reduced to the optimum condition. The model contains jacket pressure only. FEA analysis shows that the vessel now has a 5.8x buckling factor of safety



VIII-1-Pipe and Shell ver Modified

Straight shell with UG-29 closure and jacket **Description**



Options:

Interior	**ip?** - Calculate interior pressure
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:

48.000	**Do** [in] - outside diameter
0.161	**t** [in] - nominal wall thickness
0.063	**tminUG16b** [in] - minimum wall per UG-16(b)
24.000	**Le** [in] - effective length
0.000	**Corr** [in] - corrosion allowance

Material and Conditions:

SA-240 304 **Material**

18,350	**S** [psi] - allowable stress level
0.70	**El** - longitudinal efficiency (circ. stress)
0.70	**Ec** - circ. connecting efficiency (longitudinal stress)
0.000%	**UTP** [%] - undertolerance allowance
0.000	**UTI** [in] - undertolerance allowance
30.00	**P** [psi] - interior pressure
30.0	**Pa** [psi] - exterior pressure

Exterior Pressure Inputs:

HA1	**chart** - Select external pressure chart
150	**extTemp** - Temperature for external pressure

Variables:

Td =	0.000	0 =	**0.000**
UT [in] =	t*UTP+UTI	0.161*0+0 =	**0.000**
nt [in] =	t-Corr-UT-Td	0.161-0-0-0 =	**0.161**
Ri [in] =	Do/2-nt	48/2-0.161 =	**23.839**
LDo =	Le/Do	24/48 =	**0.500**

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

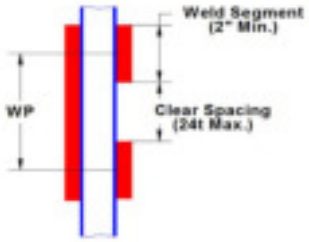
ta [in] =	P*Ri/(S*El-0.6*P)	30*23.839/(18350*0.7-0.6*30) =	**0.056**
tb [in] =	P*Ri/(2*S*Ec+0.4*P)	30*23.839/(2*18350*0.7+0.4*30) =	**0.028**
tmin [in] =	MAX(ta,tb,tminUG16b)	MAX(0.056,0.028,0.063) =	**0.063**
tr1 [in] =	P*Ri/(S*1-0.6*P)	30*23.839/(18350*1-0.6*30) =	**0.039**
Checkt =	tmin <= nt	0.063 <= 0.161 =	**Acceptable**

Exterior Pressure: VIII-1 UG-28(c)

DoT =	Do/nt	48/0.161 =	**298.137**
DoTe =	Do/tre	48/0.16 =	**299.670**
Aa =	10^PVELookup("TableLdo", "Int2DLin", DoT, LDo)		**0.0005546**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**6,766**
PaMax [psi] =	4*Ba/(3*DoT)	4*6766/(3*298.137) =	**30**
CheckPa =	PaMax >= Pa	30 >= 30 =	**Acceptable**
tre [in] =	(3*Do*Pa)/(4*Bb)	(3*48*30)/(4*6743) =	**0.160**
treCorr [in] =	tre+Corr+UT+Td	0.16+0+0+0 =	**0.160**
Bb =	PVELookup("BbChart","BbLookup",chart,extTemp,Do,Pa,LDo)		**6,743**

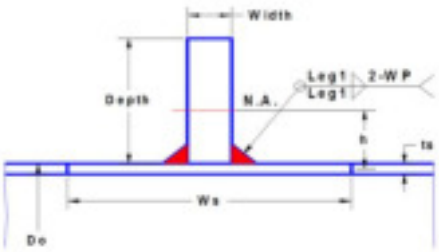
VIII-1-Vacuum Ring Calculator ver 4.02

Vacuum Ring **Description**



Vessel Inputs:

SA-240 304	**Material**
16,600	**Ssa** [psi] - Allowable stress of shell
48.000	**Do** [in] - Outside diameter of shell
0.161	**ts** [in] - Corroded shell thickness
0.161	**t** [in] - Required shell thickness for ext. pressure
12.00	**Ls** [in] - Supported length
30.00	**Pa** [psi] - External pressure
HA1r	**chart** - Select external pressure chart
150	**extTemp** [°F] - Temperature for external pressure



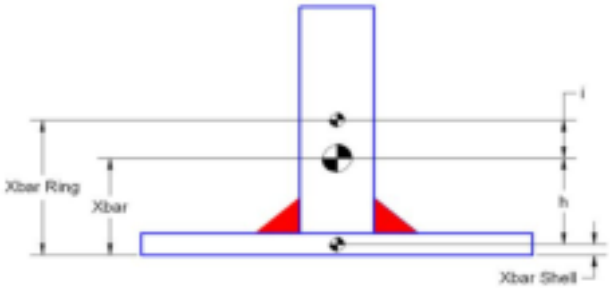
Vacuum Ring Inputs:

SA-36	**Material**
16,600	**Sba** [psi] - Allowable stress of bar
36,000	**Sby** [psi] - Bar yield stress
30,000,000	**Eb** [psi] - Bar modulus of elacticity
1.000	**Wid** [in] - Ring bar width
1.500	**Dep** [in] - Ring bar depth
0.250	**Leg1** [in] - Weld leg
2.000	**WP** [in] - Weld pitch
6.000	**WS** [in] - Weld segment

Maximum Support Beam Depth: (Norsk Standard n004r1 B.5.81)

MaxDep [in] =	0.4*Wid*Sqrt(Eb/Sby)	0.4*1*SQRT(30000000/36000) =	**11.547**
effDep [in] =	Min(Dep,MaxDep) Effective beam depth	MIN(1.5,11.547) =	**1.500**

Section Properties:



Wsm [in] =	1.10*SQRT(Do*ts) Allowable shell width	1.10*SQRT(48*0.161) =	**3.058**
As [in^2] =	Wid*effDep Ring cross section area	1*1.5 =	**1.500**
Ash [in^2] =	ts*Wsm Shell cross section area	0.161*3.058 =	**0.492**
At [in^2] =	As+Ash Combined cross section area	1.5+0.492 =	**1.992**
XbarAs [in^3] =	(ts/2)*ts*Wsm	(0.161/2)*0.161*3.058 =	**0.040**
XbarAsh [in^3] =	(effDep/2+ts)*effDep*Wid	(1.5/2+0.161)*1.5*1 =	**1.367**
Xbar [in] =	(XbarAsh +XbarAs)/At Centroid location	(1.367 +0.04)/1.992 =	**0.706**
h [in] =	Xbar-ts/2 Distance from combined centroid to shell centroid	0.706-0.161/2 =	**0.625**
i [in] =	(ts+effDep)-effDep/2-Xbar Distance from combined centroid to ring centroid	(0.161+1.5)-1.5/2-0.706 =	**0.205**
IxxR [in^4] =	(1/12)*Wid*effDep^3 Ring moment of interia	(1/12)*1*1.5^3 =	**0.2813**
IxxSh [in^4] =	(1/12)*Wsm*ts^3 Shell moment of interia	(1/12)*3.058*0.161^3 =	**0.0011**
IxxComb [in^4] =	(Ixxsh + Ash*h^2)+(Ixxs + As*i^2) Combined moment of inertia	(Ixxs0.625 + 0.492*0.625^2)+(Ixxs + 1.5*0.205^2) =	**0.538**

Required Moment of Inertia: UG-29

B =	0.75*((Pa*Do)/(t+As/Ls))	0.75*((30*48)/(0.161+1.5/12)) =	**3776**
A =	PVELookup("ExtChart","ExtLookup",chart,extTemp,B)		**0.000273**
IRR [in^4] =	(Do^2*Ls*(t+As/Ls)*A)/14 Require moment of interia for ring		
		(48^2*12*(0.161+1.5/12)*0.000273)/14 =	**0.154**
IRComb [in^4] =	(Do^2*Ls*(t+As/Ls)*A)/10.9 Require moment of interia for ring and shell combined		
		(48^2*12*(0.161+1.5/12)*0.000273)/10.9 =	**0.198**
CheckI =	IF(OR(IxxR>=IRR,IxxComb>=IRComb),"Acceptable","Error") UG-29(a)		**Acceptable**

Attachment Weld Strength: UG-30(e),(f) App L-5:

CheckWeld =	Leg1 >= min(0.25,ts,Wid)	0.25 >= MIN(0.25,0.161,1) =	**Acceptable**
CSM [in] =	24*ts Clear space maximum	24*0.161 =	**4**
CS [in] =	WP-WS Clear Spacing	2-6 =	**-4.000**
CheckCS=	WP-WS<=CSM	2-6<=4 =	**Acceptable**
E =	1+WS/(WS+CS) Spacing effiency	1+6/(6+-4) =	**4.000**
S [psi] =	min(Ssa,Sba)	MIN(16600,16600) =	**16600**
Wsa [psi] =	0.55*S Allowable weld stress	0.55*16600 =	**9130**
Wla [lb/in] =	E*Leg1*Wsa Allowable weld load	4*0.25*9130 =	**9130**
PL [lb/in] =	Pa*Ls Radial pressure load	30*12 =	**360**
V [lbi] =	0.01*Pa*Ls*Do Shear load	0.01*30*12*48 =	**173**
Q [in^3] =	Wsm*ts*h	3.058*0.161*0.625 =	**0.308**
VQI [lb/in] =	V*Q/IxxComb Shear Flow	173*0.308/0.538 =	**99**
CWL [lb/in] =	SQRT(PL^2+VQI^2) Combined load	SQRT(360^2+99^2) =	**373**
CheckCWL =	CWL <= Wla	373 <= 9130 =	**Acceptable**

Loads

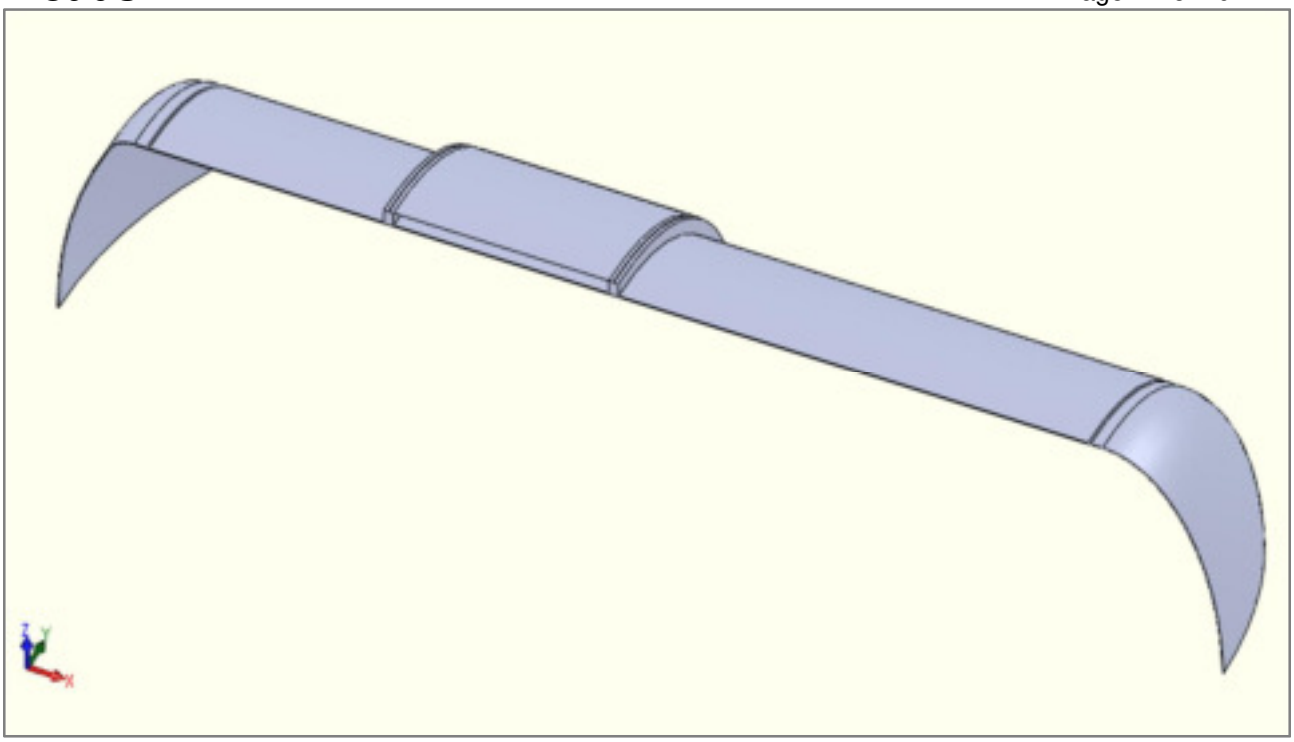


Fig-A 96" straight shell (0.161" thick)
The reinforcement is 1.5" x 1" bar

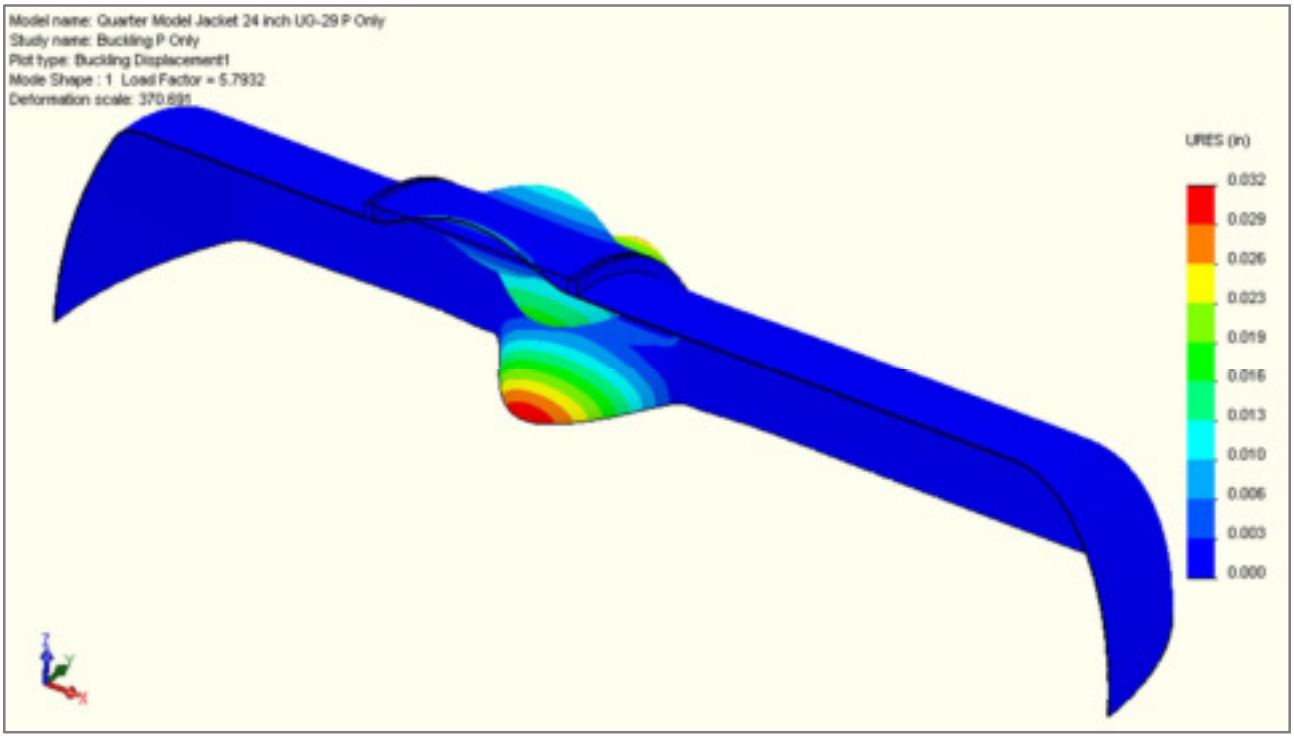


Fig-B 30 psi external load is applied under the jacket only
The reinforcement did not separate the action to under the jacket but
the factor of safety from buckling = 5.8 (>3x required by code) so the design passes.

5 - Half Pipe Jackets ver 5.0

Summary:

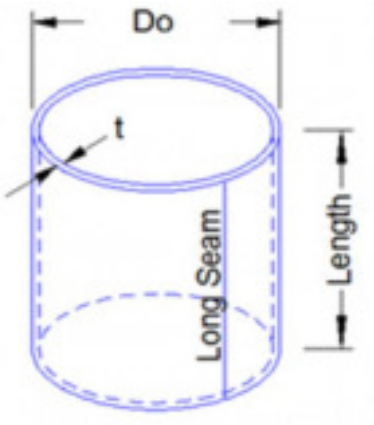
See web write up section 5 - Half Pipe Jackets

Contents:

The vessel shell has been jacketed with a half pipe to reduce the effective length of the external pressure on the shell. The shell thickness has been reduced to 3/16" thick, the minimum allowed by the Appendix EE charts. No FEA is completed for this section.

VIII-1-Pipe and Shell ver Modified

Straight Shell under a 3" half pipe jacket **Description**



Options:

Interior	**ip?** - Calculate interior pressure
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:

48.000	**Do** [in] - outside diameter
0.095	**t** [in] - nominal wall thickness
0.063	**tminUG16b** [in] - minimum wall per UG-16(b)
3.500	**Le** [in] - effective length
0.000	**Corr** [in] - corrosion allowance

Material and Conditions:

SA-240 304 **Material**

18,350	**S** [psi] - allowable stress level
0.70	**El** - longitudinal efficiency (circ. stress)
0.70	**Ec** - circ. connecting efficiency (longitudinal stress)
0.000%	**UTP** [%] - undertolerance allowance
0.000	**UTI** [in] - undertolerance allowance
30.00	**P** [psi] - interior pressure
30.0	**Pa** [psi] - exterior pressure

Exterior Pressure Inputs:

HA1	**chart** - Select external pressure chart
150	**extTemp** - Temperature for external pressure

Variables:

Td =	0.000	0 =	**0.000**
UT [in] =	t*UTP+UTI	0.095*0+0 =	**0.000**
nt [in] =	t-Corr-UT-Td	0.095-0-0-0 =	**0.095**
Ri [in] =	Do/2-nt	48/2-0.095 =	**23.905**
LDo =	Le/Do	3.5/48 =	**0.073**

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

ta [in] =	P*Ri/(S*El-0.6*P)	30*23.905/(18350*0.7-0.6*30) =	**0.056**
tb [in] =	P*Ri/(2*S*Ec+0.4*P)	30*23.905/(2*18350*0.7+0.4*30) =	**0.028**
tmin [in] =	MAX(ta,tb,tminUG16b)	MAX(0.056,0.028,0.063) =	**0.063**
tr1 [in] =	P*Ri/(S*1-0.6*P)	30*23.905/(18350*1-0.6*30) =	**0.039**
Checkt =	tmin <= nt	0.063 <= 0.095 =	**Acceptable**

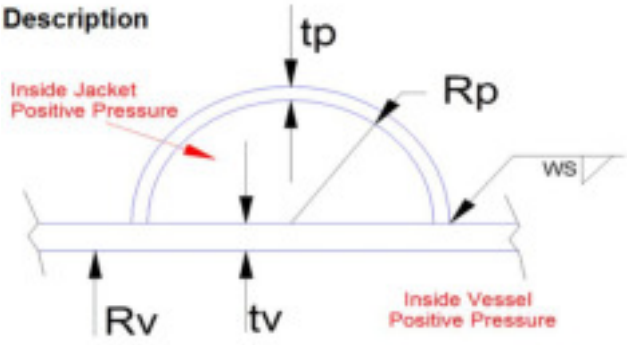
Exterior Pressure: VIII-1 UG-28(c)

DoT =	Do/nt	48/0.095 =	**503.145**
DoTe =	Do/tre	48/0.095 =	**504.691**
Aa =	10^PVELookup("TableLdo", "Int2DLin", DoT, LDo)		**0.0023854**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**11,367**
PaMax [psi] =	4*Ba/(3*DoT)	4*11367/(3*503.145) =	**30**
CheckPa =	PaMax >= Pa	30 >= 30 =	**Acceptable**
tre [in] =	(3*Do*Pa)/(4*Bb)	(3*48*30)/(4*11356) =	**0.095**
treCorr [in] =	tre+Corr+UT+Td	0.095+0+0+0 =	**0.095**
Bb =	PVELookup("BbChart","BbLookup",chart,extTemp,Do,Pa,LDo)		**11,356**

VIII-1-Half Pipe Jacket ver 4.02

ASME Code Section VIII Div I - Appendix EE

Half Pipe Jacket **Description**



SA-240 304	**Material** - Vessel Material	
18,350	**Sv** [psi] - allowed stress	
0.700	**E** - long seam efficiency	
0	**P** [psi] - vessel pressure	
48.000	**OD** [in] - vessel outside diameter	
0.188	**tv** [in] - thickness of vessel	
SA-106 B	**Jacket** Material	
17,100	**Sp** [psi] - allowed stress	
30	**POne** [psi] - jacket pressure	
3.500	**POD** [in] - pipe outside diameter	*note: use full penetration weld for cyclic service*
0.216	**tp** [in] - jacket wall thickness	
0.189	**tpUT** [in] - jacket wall thickness, UT removed	
0.313	**ws** [in] - weld size	
105.0	**K** - value looked up from chart	

Rv [in] =	OD/2-tv	48/2-0.188 =	**23.812**
treq [in] =	P*Rv/(Sv*E-0.6*P)	0*23.812/(18350*0.7-0.6*0) =	**0.000**
CheckTreq =	treq <= tv	0 <= 0.188 =	**Acceptable**
Svp [psi] =	P*Rv/(2*tv)	0*23.812/(2*0.188) =	**0**
F [psi] =	Min(1.5*Sv, 1.5*Sv-Svp)	MIN(1.5*18350, 1.5*18350-0) =	**27,525**
Pp [psi] =	F/K	27525/105 =	**262**
CheckPp =	POne <= Pp	30 <= 262 =	**Acceptable**
Rp [in] =	POD/2-tpUT	3.5/2-0.189 =	**1.561**
treqP [in] =	POne*Rp/(Sp*0.85-0.6*POne)	30*1.561/(17100*0.85-0.6*30) =	**0.003**
CheckTreqP =	treqP <= tpUT	0.003 <= 0.189 =	**Acceptable**
wsMin [in] =	1.414*min(tv,tp)	1.414*MIN(0.188,0.216) =	**0.266**
CheckWsMin =	wsMin <= ws	0.266 <= 0.313 =	**Acceptable**

6 - Stayed Surfaces for External Pressure ver 5.0

Summary:

See web write up section 6 - Stayed Surfaces for External Pressure

Contents:

The vessel shell has been jacketed with a stayed surface to reduce the required thickness. The shell thickness has been reduced to the optimum condition. Pressure is only consider in the jacket. No FEA is completed for this section.

External Pressure Calculations <- Vessel
Stayed surface <- Desc

Dimensions:

0.164 <- Plate Thickness (t)
48.000 <- Diameter (Ds)

0.000 <- Hole Dia (d)
6.000 <- Horizontal Spacing (h)
6.000 <- Vertical Spacing (v)

0.500 <- Support Pin Diameter (pd)
10.000 <- Maximum pin length (L)
6.000 <- Horizontal Pin Spacing (hs)
6.000 <- Vertical Pin Spacing (vs)

0.250 <- Strainer To Shell Weld Size (x)

Material Properties:

SA-240 304 <- Strainer Plate and Beam Material
18,350 <- Allowable Stress (S)
SA-240 304 <- Support Pin Material
18,350 <- Allowable Pin Stress (Sp)
30.0 <- Differential Pressure (P)

Minimum Pitch Distances and Efficiency (UG53.2)

Diagonal =	SQRT(v^2+h^2/4)	= SQRT(6^2+6^2/4)	Diagonal = ***6.708***
Min Pitch =	Min(Diagonal,h)	= Min(6.708,6)	MinP = ***6.000***
Efficiency =	(MinP - d)/MinP	= (6 - 0)/6	Eff = ***1.000***
Sw =	S*eff	= 18350*1	Sw = ***18,350***

Support Spacing (UG-47a, UW-19)

Diagonal =	SQRT(vs^2+hs^2/4)	= SQRT(6^2+6^2/4)	Diagonal = ***6.708***
Min Pitch =	Min(Diagonal,h)	= Min(6.708,6)	MinPP = ***6.000***
C =	2.2	*UG-47 (a)*	
UW-19 Max Spacing =	IF(t<=0.75,"Unlimited",20)		UW-19 Max Spacing = ***Unlimited***
$Max_{Spacing}$ =	t / SQRT(P/(Sw*C))	= 0.164 / SQRT(30/(18350*2.2))	$Max_{Spacing}$ = ***6.016***

Acceptable

Pin Dia (UG-47f - welded pins only)

Min Pin Dia =	MinPP/15	= 6/15	Min Pin Dia = ***0.400***

Acceptable

Pin Load (lbs per pin)

Pin Load =	P*hs*vs	= 30*6*6	PinLoad = ***1,080***
Pin Stress =	PinLoad/(pi*Pd^2/4)	= 1080/(pi()*0.5^2/4)	Pin Stress = ***5,500***

Acceptable

7 - More than One Source of External Pressure ver 5.0

Summary:

See web write up section 7 - More than One Source of External Pressure

Contents:

The vessel shell has been jacketed both half pipes and stayed surfaces. The shell thickness has been reduced to the optimum condition. Both vacuum and jacket pressures are consider. No FEA is completed for this section.

External Pressure Calculations <- Vessel
Dimpled Jacket <- Desc

Dimensions:

0.172 <- Plate Thickness (t)
48.000 <- Diameter (Ds)

0.000 <- Hole Dia (d)
6.000 <- Horizontal Spacing (h)
6.000 <- Vertical Spacing (v)

0.500 <- Support Pin Diameter (pd)
10.000 <- Maximum pin length (L)
6.000 <- Horizontal Pin Spacing (hs)
6.000 <- Vertical Pin Spacing (vs)

0.250 <- Strainer To Shell Weld Size (x)

Material Properties:

SA-240 304 <- Strainer Plate and Beam Material
18,350 <- Allowable Stress (S)
SA-240 304 <- Support Pin Material
18,350 <- Allowable Pin Stress (Sp)
45.0 <- Differential Pressure (P)

Minimum Pitch Distances and Efficiency (UG53.2)

Diagonal =	SQRT(v^2+h^2/4)	= SQRT(6^2+6^2/4)	Diagonal = ***6.708***
Min Pitch =	Min(Diagonal,h)	= Min(6.708,6)	MinP = ***6.000***
Efficiency =	(MinP - d)/MinP	= (6 - 0)/6	Eff = ***1.000***
Sw =	S*eff	= 18350*1	Sw = ***18,350***

Support Spacing (17-5(1))

Diagonal =	SQRT(vs^2+hs^2/4)	= SQRT(6^2+6^2/4)	Diagonal = ***6.708***
Min Pitch =	Min(Diagonal,h)	= Min(6.708,6)	MinPP = ***6.000***
UW-19 Max Spacing =	IF(t<=0.75,"Unlimited",20)		UW-19 Max Spacing = ***Unlimited***
$Max_{Spacing}$ =	t / SQRT(P/(Sw*3))	= 0.172 / SQRT(45/(18350*2.2))	$Max_{Spacing}$ = ***6.000***

Acceptable

Pin Dia (UG-47f - welded pins only)

Min Pin Dia =	MinPP/15	= 6/15	Min Pin Dia = ***0.400***

Acceptable

Pin Load (lbs per pin)

Pin Load =	P*hs*vs	= 45*6*6	PinLoad = ***1,620***
Pin Stress =	PinLoad/(pi*Pd^2/4)	= 1620/(pi()*0.5^2/4)	Pin Stress = ***8,251***

Acceptable

External Pressure Calculations <- Vessel
Stayed surface <- Desc

Dimensions:

0.200 <- Plate Thickness (t)
48.000 <- Diameter (Ds)

0.000 <- Hole Dia (d)
6.000 <- Horizontal Spacing (h)
6.000 <- Vertical Spacing (v)

0.500 <- Support Pin Diameter (pd)
10.000 <- Maximum pin length (L)
6.000 <- Horizontal Pin Spacing (hs)
6.000 <- Vertical Pin Spacing (vs)

0.250 <- Strainer To Shell Weld Size (x)

Material Properties:

SA-240 304 <- Strainer Plate and Beam Material
18,350 <- Allowable Stress (S)
SA-240 304 <- Support Pin Material
18,350 <- Allowable Pin Stress (Sp)
45.0 <- Differential Pressure (P)

Minimum Pitch Distances and Efficiency (UG53.2)

Diagonal =	SQRT(v^2+h^2/4)	= SQRT(6^2+6^2/4)	Diagonal = ***6.708***
Min Pitch =	Min(Diagonal,h)	= Min(6.708,6)	MinP = ***6.000***
Efficiency =	(MinP - d)/MinP	= (6 - 0)/6	Eff = ***1.000***
Sw =	S*eff	= 18350*1	Sw = ***18,350***

Support Spacing (UG-47a, UW-19)

Diagonal =	SQRT(vs^2+hs^2/4)	= SQRT(6^2+6^2/4)	Diagonal = ***6.708***
Min Pitch =	Min(Diagonal,h)	= Min(6.708,6)	MinPP = ***6.000***
C =	2.2	*UG-47 (a)*	
UW-19 Max Spacing =	IF(t<=0.75,"Unlimited",20)		UW-19 Max Spacing = ***Unlimited***
$Max_{Spacing}$ =	t / SQRT(P/(Sw*C))	= 0.2 / SQRT(45/(18350*2.2))	$Max_{Spacing}$ = ***6.000***

Acceptable

Pin Dia (UG-47f - welded pins only)

Min Pin Dia =	MinPP/15	= 6/15	Min Pin Dia = ***0.400***

Acceptable

Pin Load (lbs per pin)

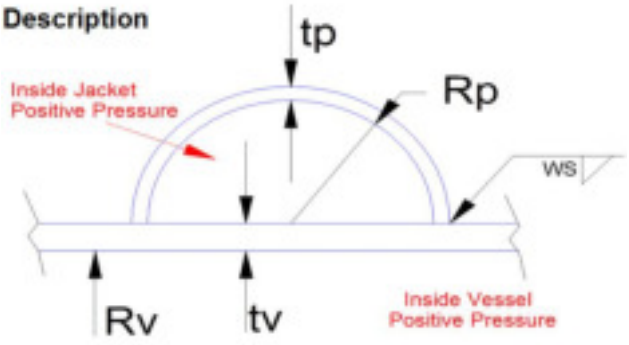
Pin Load =	P*hs*vs	= 45*6*6	PinLoad = ***1,620***
Pin Stress =	PinLoad/(pi*Pd^2/4)	= 1620/(pi()*0.5^2/4)	Pin Stress = ***8,251***

Acceptable

VIII-1-Half Pipe Jacket ver 4.02

ASME Code Section VIII Div I - Appendix EE

	Half Pipe Jacket	**Description**
SA-240 304	**Material** - Vessel Material	
18,350	**Sv** [psi] - allowed stress	
0.700	**E** - long seam efficiency	
45	**P** [psi] - vessel pressure	
48.000	**OD** [in] - vessel outside diameter	
0.188	**tv** [in] - thickness of vessel	
SA-106 B	**Jacket** Material	
17,100	**Sp** [psi] - allowed stress	
45	**POne** [psi] - jacket pressure	
3.500	**POD** [in] - pipe outside diameter	
0.216	**tp** [in] - jacket wall thickness	
0.189	**tpUT** [in] - jacket wall thickness, UT removed	
0.313	**ws** [in] - weld size	
105.0	**K** - value looked up from chart	



note: use full penetration weld for cyclic service

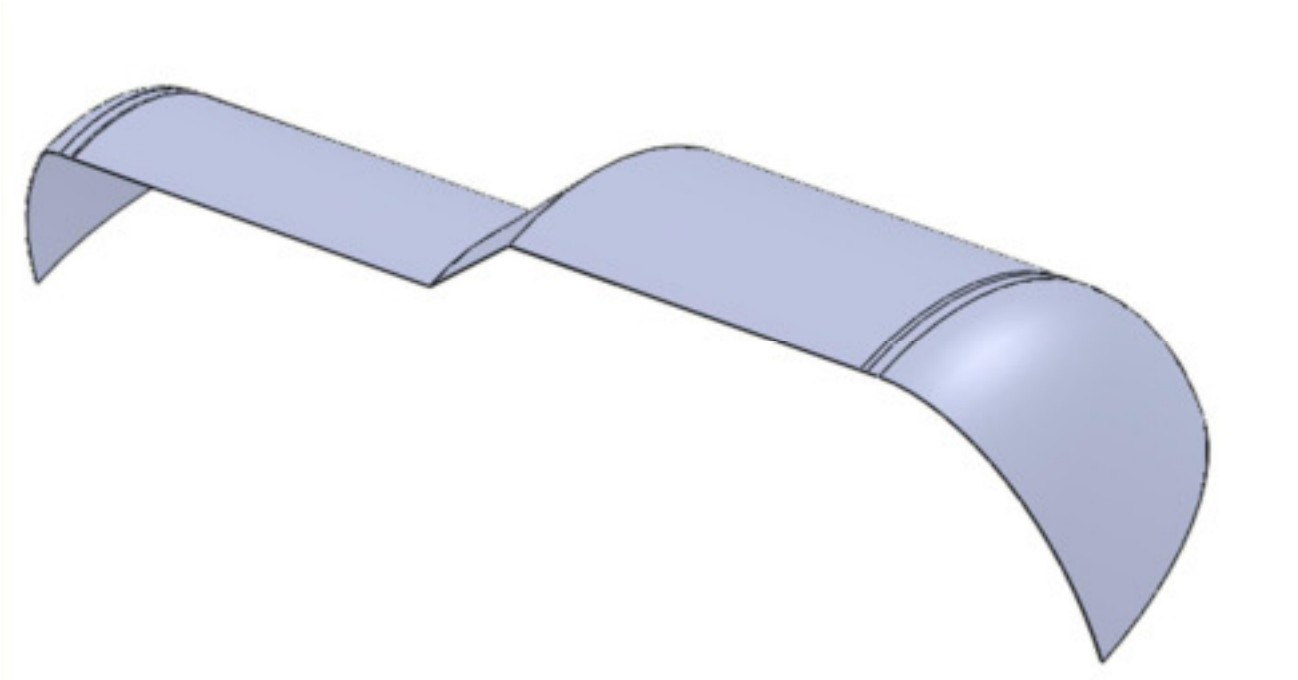
Rv [in] =	OD/2-tv	48/2-0.188 =	**23.812**
treq [in] =	P*Rv/(Sv*E-0.6*P)	45*23.812/(18350*0.7-0.6*45) =	**0.084**
CheckTreq =	treq <= tv	0.084 <= 0.188 =	**Acceptable**
Svp [psi] =	P*Rv/(2*tv)	45*23.812/(2*0.188) =	**2,850**
F [psi] =	Min(1.5*Sv, 1.5*Sv-Svp)	MIN(1.5*18350, 1.5*18350-2850) =	**24,675**
Pp [psi] =	F/K	24675/105 =	**235**
CheckPp =	POne <= Pp	45 <= 235 =	**Acceptable**
Rp [in] =	POD/2-tpUT	3.5/2-0.189 =	**1.561**
treqP [in] =	POne*Rp/(Sp*0.85-0.6*POne)	45*1.561/(17100*0.85-0.6*45) =	**0.005**
CheckTreqP =	treqP <= tpUT	0.005 <= 0.189 =	**Acceptable**
wsMin [in] =	1.414*min(tv,tp)	1.414*MIN(0.188,0.216) =	**0.266**
CheckWsMin =	wsMin <= ws	0.266 <= 0.313 =	**Acceptable**

Summary:

See web write up section "Designing for External Pressure"

Contents:

The vessel shell has a cone added which is calculated as a line of support. The shell thickness has been set to the most optimum thickness. FEA analysis shows that the vessel now has a 5.8x buckling factor of safety.

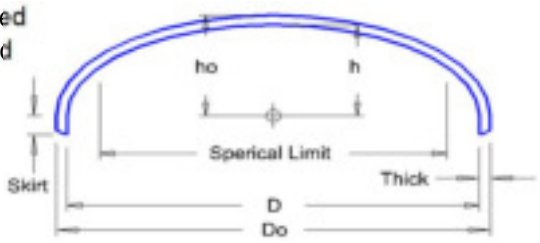


VIII-1-Elliptical Head ver 5.02

Left Head - 72" dia SE **Description**

Dimensions:

Interior	**ip?** - Calculate interior pressure
Exterior	**ep?** - Calculate exterior pressure
No	**relief?** - Stress Relief Calculations Required
No App 1-4	**App** 1-4? - App 1-4(f) Calculation Required
72.000	**Do** [in] - outside diameter of head
17.905	**h** [in] - inside crown height (note 1)
0.190	**tb** [in] - thickness before forming
0.190	**tf** [in] - thickness after forming (note 2)
0.063	**tminUG16b** [in] - min. t. per UG-16(b)
0.000	**Corr** [in] - corrosion allowance
1.500	**Skirt** [in] - straight skirt length



Material and Conditions:

SA-240 304	**Material**
18,350	**S** [psi] - allowable stress
0.85	**E** - head longitudinal efficiency
30.0	**P** [psi] - interior pressure
15.0	**Pa** [psi] - Exterior pressure

Exterior Pressure Inputs:

HA1	**chart** - Select external pressure chart
150	**extTemp** [°F] - Temperature for external pressure

Calculated Properties:

note 1: Suggested h	**17.9050**	Approx. head weight based on steel, lbs =	**328.47**
note 2: Suggested tf	**0.1275**	Approx. head volume including skirt, cuft =	**31.33**

Variables:

t [in] =	tf-Corr	thickness with corrosion allowance removed	0.19-0 =	**0.190**
D [in] =	Do-2*t	ID with corrosion allowance removed	72-2*0.19 =	**71.620**
ho [in] =	h+t		17.905+0.19 =	**18.095**
D/2h =	D/(2*h)		71.62/(2*17.905) =	**2.000**
Do/2ho =	Do/(2*ho)		72/(2*18.095) =	**1.989**
K =	1.000	Interpolated value from table 1-4.1	=	**1.000**
Kone =	0.900	Interpolated value from table UG-37	=	**0.900**
Kzero =	0.895	Interpolated value from table UG-33.1	=	**0.895**
Ro [in]=	Kzero*Do		0.895*72 =	**64.460**

Interior Pressure - Required Thickness: App. 1-4(c), UG-37(a)(1)

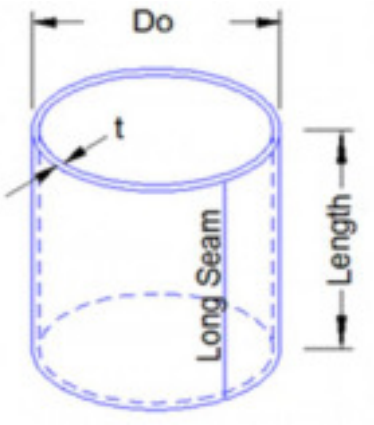
App1-4(f) =	tf/(Kone*D)	0.19/(0.9*71.62) =	**0.0029**
App1-4(f)Calc =	if(AND(0.0005=<App1-4(f),App1-4(f)<0.002),"Calculation Required","Calculation not required")		
			App. 1-4(f) Calculation Not Required
Tmin [in] =	(P*D*K)/(2*S*E-0.2*P)		
		(30*71.62*1)/(2*18350*0.85-0.2*30) =	**0.069**
Checkt =	t >= Max(Tmin,tminUG16b)	0.19 >= MAX(0.069,0.063) =	**Acceptable**

Exterior Pressure - Required Thickness: UG-33(d), UG-28(d)

Aa =	0.125/(Ro/t)	0.125/(64.46/0.19) =	**0.0004**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**5,094**
PaMax [psi] =	Ba/(Ro/t)	5094/(64.46/0.19) =	**15.0**
CheckPaMax =	PaMax >= Pa	15 >= 15 =	**Acceptable**
Bb =	PVELookup("BbChart","BbEHLookup",chart,extTemp,Ro,Pa)		**5,091**
TMinE [in] =	(Pa*Ro)/Bb	(15*64.46)/5091 =	**0.190**
TMinEC [in] =	TMinE + Corr	0.19 + 0 =	**0.190**

VIII-1-Pipe and Shell ver Modified

Straight Shell - 72" dia x 42" long **Description**



Options:

Interior	**ip?** - Calculate interior pressure
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:

72.000	**Do** [in] - outside diameter
0.200	**t** [in] - nominal wall thickness
0.063	**tminUG16b** [in] - minimum wall per UG-16(b)
49.500	**Le** [in] - effective length
0.000	**Corr** [in] - corrosion allowance

Material and Conditions:

SA-240 304 **Material**

18,350	**S** [psi] - allowable stress level
0.70	**El** - longitudinal efficiency (circ. stress)
0.70	**Ec** - circ. connecting efficiency (longitudinal stress)
0.000%	**UTP** [%] - undertolerance allowance
0.000	**UTI** [in] - undertolerance allowance
30.00	**P** [psi] - interior pressure
15.0	**Pa** [psi] - exterior pressure

Exterior Pressure Inputs:

HA1	**chart** - Select external pressure chart
150	**extTemp** - Temperature for external pressure

Variables:

Td =	0.000	0 =	**0.000**
UT [in] =	t*UTP+UTI	0.2*0+0 =	**0.000**
nt [in] =	t-Corr-UT-Td	0.2-0-0-0 =	**0.200**
Ri [in] =	Do/2-nt	72/2-0.2 =	**35.800**
LDo =	Le/Do	49.5/72 =	**0.688**

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

ta [in] =	P*Ri/(S*El-0.6*P)	30*35.8/(18350*0.7-0.6*30) =	**0.084**
tb [in] =	P*Ri/(2*S*Ec+0.4*P)	30*35.8/(2*18350*0.7+0.4*30) =	**0.042**
tmin [in] =	MAX(ta,tb,tminUG16b)	MAX(0.084,0.042,0.063) =	**0.084**
tr1 [in] =	P*Ri/(S*1-0.6*P)	30*35.8/(18350*1-0.6*30) =	**0.059**
Checkt =	tmin <= nt	0.084 <= 0.2 =	**Acceptable**

Exterior Pressure: VIII-1 UG-28(c)

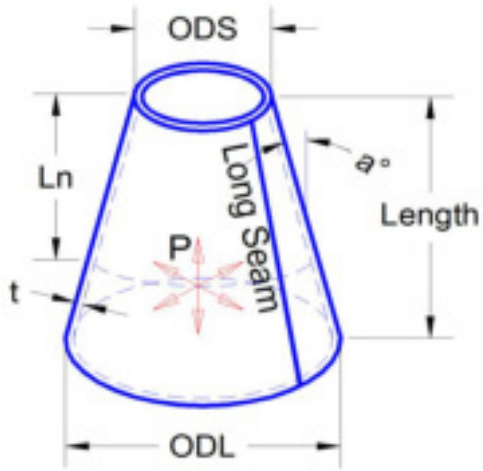
DoT =	Do/nt	72/0.2 =	**360.000**
DoTe =	Do/tre	72/0.2 =	**360.393**
Aa =	10^PVELookup("TableLdo", "Int2DLin", DoT, LDo)		**0.0002938**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**4,061**
PaMax [psi] =	4*Ba/(3*DoT)	4*4061/(3*360) =	**15**
CheckPa =	PaMax >= Pa	15 >= 15 =	**Acceptable**
tre [in] =	(3*Do*Pa)/(4*Bb)	(3*72*15)/(4*4054) =	**0.200**
treCorr [in] =	tre+Corr+UT+Td	0.2+0+0+0 =	**0.200**
Bb =	PVELookup("BbChart","BbLookup",chart,extTemp,Do,Pa,LDo)		**4,054**

VIII-1-Cone ver 3.00

Cone Design **Description**

Dimension Inputs:

Internal	**Int**
External	**Ext**
72.000	**DL** [in] - outside diameter large end
48.000	**DS** [in] - outside diameter small end
0.126	**t** [in] - thickness of cone
12.046	**L** [in] - length of cone
0.000	**ca** [in] - corrosion allowance



Material Properties:

SA-240 304 **Material**

18,350	**S** [psi] - allowable stress
0.70	**E** - long seam weld efficiency
HA1	**Chart** - external pressure chart

Design Conditions:

30.0	**P** [psi] - design pressure
15.0	**Pa** [psi] - design external pressure
300.0	**Temp** [°F] - temperature for external pressure

Calculated Properties:

V [cuft] =	((DL-2*t)^2+(DL-2*t)*(DS-2*t)+(DS-2*t)^2)*π*L/12^4 volume		
	((72-2*0.126)^2+(72-2*0.126)*(48-2*0.126)+(48-2*0.126)^2)*3*12.046/12^4 =		**19.808**
W [lb] =	SQRT((DL/2-DS/2)^2+L^2) * (PI()*(DL+DS-2*t)/2) *(40.84*t/144)		
	SQRT((72/2-48/2)^2+12.046^2) * (PI()*(72+48-2*0.126)/2) *(40.84*0.126/144) =		**114.291**
α [rad] =	ATAN((DL-DS)/(2*L))	ATAN((72-48)/(2*12.046)) =	**0.783**
αdeg [°] =	DEGREES(α)	DEGREES(0.783) =	**44.890**

Interior Pressure: App. 1-4(e)

nt [in] =	t-ca corroded thk	0.126-0 =	**0.126**
treq [in] =	P*DL/(2*COS(α)*(S*E+0.4*P)) min required thk		
		30*72/(2*COS(0.783)*(18350*0.7+0.4*30)) =	**0.119**
cktreq =	nt >= treq	0.126 >= 0.119 =	**Acceptable**
Pmax [psi] =	2*S*E*nt*COS(α)/(DL-0.8*nt*COS(α)) max pressure		
		2*18350*0.7*0.126*COS(0.783)/(72-0.8*0.126*COS(0.783)) =	**31.9**

Exterior Pressure: UG-33(f)

DLT =	DL/nt	72/0.126 =	**571.4**
LeDL =	MIN(50,L/DL)	MIN(50,12.046/72) =	**0.167**
Aa =	10^PVELookup("TableLdo", "Int2DLin", DLT, LeDL)		**0.00068**
Ba =	PVELookup("ExtChart","ExtLookup",Chart,Temp,Aa)		**6501**
PaMax [pis] =	4*Ba/(3*DL/nt) max ext pressure	4*6501/(3*72/0.126) =	**15.2**
ckPa =	Pa <= PaMax	15 <= 15.2 =	**Acceptable**
DLTe =	DL/tre	72/0.125 =	**575.5**
Bb =	PVELookup("BbChart","BbLookup",Chart,Temp,DL,Pa,L/DL)		**6474**
tre [in] =	(3*DL*Pa)/(4*Bb)	(3*72*15)/(4*6474) =	**0.125**
treCorr [in] =	tre+ca min required thk	0.125+0 =	**0.125**
cktre =	nt >= treCorr	0.126 >= 0.125 =	**Acceptable**

VIII-1-Cone Discontinuity ver 4.04

Pressure Vessel Design Handbook - Second Edition - Henry H Bednar. Pages 231 to 240 & ASME VIII-1 5(g)

Cone to Shell - External Pressure **Description**

Large Cylinder - Zone A:

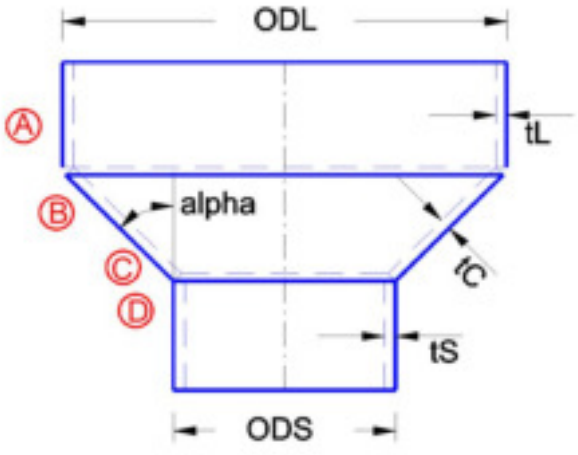
SA-240 304	**Material**
18,350	**Sl** [psi] - allowed stress
72.000	**ODL** [in] - outside diameter
0.200	**tLn** [in] - thickness

Cone - Zones B and C:

SA-240 304	**Material**
18,350	**Sc** [psi] - allowed stress
0.70	**Ec** - longitudinal efficiency
45.0	**AlphaDeg** - Angle in degrees
0.126	**tCn** [in] - thickness

Small Cylinder - Zone D:

SA-240 304	**Material**
18,350	**Ss** [psi] - allowed stress
0.70	**Es** - longitudinal efficiency
48.000	**ODS** [in] - outside diameter
0.154	**tSn** [in] - thickness



Operating Conditions:

15.0	**P** [psi] - design internal pressure
0.000	**Ca** [in] - corrosion allowance
0.0	**W** [lb] - External load
0.0	**M** [in-lb] - External moment

Geometry:

El = 1	El equals 1 - joint A to B is in compression VIII-1 App 1-5		1 = **1.000**
tL [in] = tLn - Ca			0.2 - 0 = **0.200**
tC [in] = tCn - Ca			0.126 - 0 = **0.126**
tS [in] = tSn - Ca			0.154 - 0 = **0.154**
RL [in] = (ODL-tL)/2		*Large End*	(72-0.2)/2 = **35.900**
Rs [in] = (ODS-tS)/2		*Small End*	(48-0.154)/2 = **23.923**
Alpha [rad] = AlphaDeg/180*π			45/180*3.142 = **0.785**

Constants - Large End:

nL = tC / tL	0.126 / 0.2 = **0.630**
kL = sqrt(cos(Alpha)/nL)	SQRT(COS(0.785)/0.63) = **1.059**
V1L = kL*(1+nL^2*(1+2*kL*nL))/(kL*nL^4+2*kL^2*nL^3+2*kL*nL^2+2*nL+kL)	
1.059*(1+0.63^2*(1+2*1.059*0.63))/(1.059*0.63^4+2*1.059^2*0.63^3+2*1.059*0.63^2+2*0.63+1.059) = **0.525**	
V2L = kL*nL*(1+V1L*(nL^2-1))/(4*(kL*nL^3+1))	
1.059*0.63*(1+0.525*(0.63^2-1))/(4*(1.059*0.63^3+1)) = **0.090**	

Constants - Small End:

nS = tC / tS	0.126 / 0.154 = **0.818**
kS = sqrt(cos(Alpha)/nS)	SQRT(COS(0.785)/0.818) = **0.930**
V1S = kS*(1+nS^2*(1+2*kS*nS))/(kS*nS^4+2*kS^2*nS^3+2*kS*nS^2+2*nS+kS)	
0.93*(1+0.818^2*(1+2*0.93*0.818))/(0.93*0.818^4+2*0.93^2*0.818^3+2*0.93*0.818^2+2*0.818+0.93) = **0.483**	
V2S = kS*nS*(1+V1S*(nS^2-1))/(4*(kS*nS^3+1))	
0.93*0.818*(1+0.483*(0.818^2-1))/(4*(0.93*0.818^3+1)) = **0.106**	

Discontinuity Influence Coefficients - Large End:

XL = 4.669*V2L*TAN(Alpha)	4.669*0.09*TAN(0.785) = **0.421**
YL = 1.285*(V1L - 2*V2L)*tan(Alpha)	1.285*(0.525 - 2*0.09)*TAN(0.785) = **0.443**
UL = XL/nL^2	0.421/0.63^2 = **1.061**

Discontinuity Influence Coefficients - Small End:

XS = 4.669*V2S*TAN(Alpha) 4.669*0.106*TAN(0.785) = **0.494**

YS = 1.285*(V1S - 2*V2S)*TAN(Alpha) 1.285*(0.483 - 2*0.106)*TAN(0.785) = **0.348**

US = XL/nL^2 0.421/0.63^2 = **1.061**

Equivalent Loads from W and M:

IL [lb/in] = (4*M/(π*4*RL^2) + (W / (π*2*RL))) (4*0/(3.142*4*35.9^2) + (0 / (3.142*2*35.9))) = **0.000**

PeL [psi] = P+(2*lL/RL) 15+(2*0/35.9) = **15.000**

lS [lb/in] = (4*M/(π*4*Rs^2)+(W/(π*2*Rs))) (4*0/(3.142*4*23.923^2)+(0/(3.142*2*23.923))) = **0.000**

PeS [psi] = P+(2*lS/Rs) 15+(2*0/23.923) = **15.000**

Maximum Allowed Stresses: ASME 1-5(g) & UG-23(e)

LLmax [psi] = 3*Sl*El 3*18350*1 = **55,050**

MLmax [psi] = 1.5*Sl*El 1.5*18350*1 = **27,525**

LBCmax [psi] = 3*Sc*El max long stress for zone B 3*18350*1 = **55,050**

LCCmax [psi] = 3*Sc*Es max long stress for zone C 3*18350*0.7 = **38,535**

MBCmax [psi] = 1.5*Sc*El max membrane stress for zone B 1.5*18350*1 = **27,525**

MCCmax [psi] = 1.5*Sc*Es max membrane stress for zone C 1.5*18350*0.7 = **19,268**

LSmax [psi] = 3*Ss*Es 3*18350*0.7 = **38,535**

MSmax [psi] = 1.5*Ss*Es 1.5*18350*0.7 = **19,268**

Combined Stresses - Large Cylinder - Zone A:

Long1 [psi] = (PeL*RL/tL)*(0.5 + XL*SQRT(RL/tL))
(15*35.9/0.2)*(0.5 + 0.421*SQRT(35.9/0.2)) = **16,530**

CkLong1 = ABS(Long1) <= LLmax ABS(16530) <= 55050 = **Acceptable**

Long2 [psi] = (PeL*RL/tL)*(0.5 - XL*SQRT(RL/tL))
(15*35.9/0.2)*(0.5 - 0.421*SQRT(35.9/0.2)) = **-13,838**

CkLong1 = ABS(Long2) <= LLmax ABS(-13838) <= 55050 = **Acceptable**

MemTan1 [psi] = (P*RL/tL)*(1-(PeL/P)*YL*SQRT(RL/tL))
(15*35.9/0.2)*(1-(15/15)*0.443*SQRT(35.9/0.2)) = **-13,282**

CkMemTan1 = ABS(MemTan1) <= MLmax ABS(-13282) <= 27525 = **Acceptable**

Combined Stresses - Large End of Cone - Zone B:

Long3 [psi] = (PeL*RL/tL)*(0.5/(nL*cos(Alpha)) + UL*SQRT(RL/tL))
(15*35.9/0.2)*(0.5/(0.63*COS(0.785)) + 1.061*SQRT(35.9/0.2)) = **41,279**

CkLong3 = ABS(Long3) <= LBCmax ABS(41279) <= 55050 = **Acceptable**

Long4 [psi] = (PeL*RL/tL)*(0.5/(nL*cos(Alpha)) - UL*SQRT(RL/tL))
(15*35.9/0.2)*(0.5/(0.63*COS(0.785)) - 1.061*SQRT(35.9/0.2)) = **-35,235**

CkLong4 = ABS(Long4) <= LBCmax ABS(-35235) <= 55050 = **Acceptable**

MemTan2 [psi] = (P*RL/tL)*(1/(nL*cos(Alpha))-(PeL/P)*YL*SQRT(RL/tL))
(15*35.9/0.2)*(1/(0.63*COS(0.785))-(15/15)*0.443*SQRT(35.9/0.2)) = **-9,930**

CkMemTan2 = ABS(MemTan2) <= MBCmax ABS(-9930) <= 27525 = **Acceptable**

Combined Stresses - Small End of Cone - Zone C:

Long5 [psi] = (PeS*Rs/tS)*(0.5/(nS*cos(Alpha)) + US*SQRT(Rs/tS))
(15*23.923/0.154)*(0.5/(0.818*COS(0.785)) + 1.061*SQRT(23.923/0.154)) = **32,814**

CkLong5 = ABS(Long5) <= LCCmax ABS(32814) <= 38535 = **Acceptable**

Long6 [psi] = (PeS*Rs/tS)*(0.5/(nS*cos(Alpha)) - US*SQRT(Rs/tS))
(15*23.923/0.154)*(0.5/(0.818*COS(0.785)) - 1.061*SQRT(23.923/0.154)) = **-28,787**

CkLong6 = ABS(Long6) <= LCCmax ABS(-28787) <= 38535 = **Acceptable**

MemTan3 [psi] = (P*Rs/tS)*(1/(nS*cos(Alpha))+(PeS/P)*YS*SQRT(Rs/tS))
(15*23.923/0.154)*(1/(0.818*COS(0.785))+(15/15)*0.348*SQRT(23.923/0.154)) = **14,147**

CkMemTan3 = ABS(MemTan3) <= MCCmax ABS(14147) <= 19268 = **Acceptable**

Combined Stresses - Small Cylinder - Zone D:

Long7 [psi] = (PeS*Rs/tS)*(0.5 + XS*SQRT(Rs/tS))
(15*23.923/0.154)*(0.5 + 0.494*SQRT(23.923/0.154)) = **15,523**

CkLong7 = ABS(Long7) <= LSmax ABS(15523) <= 38535 = **Acceptable**

Long8 [psi] = (PeS*Rs/tS)*(0.5 - XS*SQRT(Rs/tS))
(15*23.923/0.154)*(0.5 - 0.494*SQRT(23.923/0.154)) = **-13,193**

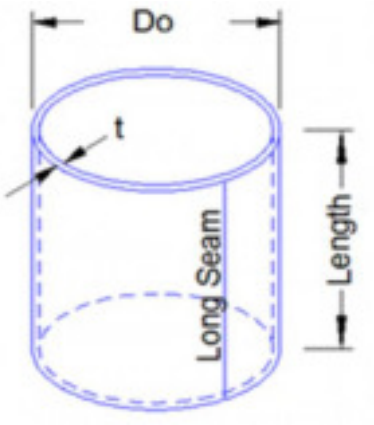
CkLong8 = ABS(Long8) <= LSmax ABS(-13193) <= 38535 = **Acceptable**

MemTan4 [psi] = (P*Rs/tS)*(1+(PeS/P)*YS*SQRT(Rs/tS))
(15*23.923/0.154)*(1+(15/15)*0.348*SQRT(23.923/0.154)) = **12,450**

CkMemTan4 = ABS(MemTan4) <= MSmax ABS(12450) <= 19268 = **Acceptable**

VIII-1-Pipe and Shell ver Modified

Straight Shell **Description**



Options:

Interior	**ip?** - Calculate interior pressure
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:

48.000	**Do** [in] - outside diameter
0.154	**t** [in] - nominal wall thickness
0.063	**tminUG16b** [in] - minimum wall per UG-16(b)
46.150	**Le** [in] - effective length
0.000	**Corr** [in] - corrosion allowance

Material and Conditions:

SA-240 304 **Material**

18,350	**S** [psi] - allowable stress level
0.70	**El** - longitudinal efficiency (circ. stress)
0.70	**Ec** - circ. connecting efficiency (longitudinal stress)
0.000%	**UTP** [%] - undertolerance allowance
0.000	**UTI** [in] - undertolerance allowance
30.00	**P** [psi] - interior pressure
15.0	**Pa** [psi] - exterior pressure

Exterior Pressure Inputs:

HA1	**chart** - Select external pressure chart
150	**extTemp** - Temperature for external pressure

Variables:

Td =	0.000	0 =	**0.000**
UT [in] =	t*UTP+UTI	0.154*0+0 =	**0.000**
nt [in] =	t-Corr-UT-Td	0.154-0-0-0 =	**0.154**
Ri [in] =	Do/2-nt	48/2-0.154 =	**23.846**
LDo =	Le/Do	46.15/48 =	**0.961**

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

ta [in] =	P*Ri/(S*El-0.6*P)	30*23.846/(18350*0.7-0.6*30) =	**0.056**
tb [in] =	P*Ri/(2*S*Ec+0.4*P)	30*23.846/(2*18350*0.7+0.4*30) =	**0.028**
tmin [in] =	MAX(ta,tb,tminUG16b)	MAX(0.056,0.028,0.063) =	**0.063**
tr1 [in] =	P*Ri/(S*1-0.6*P)	30*23.846/(18350*1-0.6*30) =	**0.039**
Checkt =	tmin <= nt	0.063 <= 0.154 =	**Acceptable**

Exterior Pressure: VIII-1 UG-28(c)

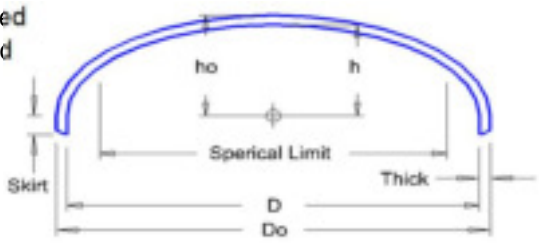
DoT =	Do/nt	48/0.154 =	**311.688**
DoTe =	Do/tre	48/0.154 =	**311.719**
Aa =	10^PVELookup("TableLdo", "Int2DLin", DoT, LDo)		**0.0002537**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**3,507**
PaMax [psi] =	4*Ba/(3*DoT)	4*3507/(3*311.688) =	**15**
CheckPa =	PaMax >= Pa	15 >= 15 =	**Acceptable**
tre [in] =	(3*Do*Pa)/(4*Bb)	(3*48*15)/(4*3507) =	**0.154**
treCorr [in] =	tre+Corr+UT+Td	0.154+0+0+0 =	**0.154**
Bb =	PVELookup("BbChart","BbLookup",chart,extTemp,Do,Pa,LDo)		**3,507**

VIII-1-Elliptical Head ver 5.02

Semi Elliptical Right Head **Description**

Dimensions:

Interior	**ip?** - Calculate interior pressure
Exterior	**ep?** - Calculate exterior pressure
No	**relief?** - Stress Relief Calculations Required
No App 1-4	**App** 1-4? - App 1-4(f) Calculation Required
48.000	**Do** [in] - outside diameter of head
11.937	**h** [in] - inside crown height (note 1)
0.127	**tb** [in] - thickness before forming
0.127	**tf** [in] - thickness after forming (note 2)
0.063	**tminUG16b** [in] - min. t. per UG-16(b)
0.000	**Corr** [in] - corrosion allowance
1.500	**Skirt** [in] - straight skirt length



Material and Conditions:

SA-240 304	**Material**
18,350	**S** [psi] - allowable stress
0.85	**E** - head longitudinal efficiency
30.0	**P** [psi] - interior pressure
15.0	**Pa** [psi] - Exterior pressure

Exterior Pressure Inputs:

HA1	**chart** - Select external pressure chart
150	**extTemp** [°F] - Temperature for external pressure

Calculated Properties:

note 1: Suggested h	**11.9365**	Approx. head weight based on steel, lbs =	**100.93**
note 2: Suggested tf	**0.0645**	Approx. head volume including skirt, cuft =	**9.80**

Variables:

t [in] =	tf-Corr	thickness with corrosion allowance removed	0.127-0 =	**0.127**
D [in] =	Do-2*t	ID with corrosion allowance removed	48-2*0.127 =	**47.746**
ho [in] =	h+t		11.937+0.127 =	**12.064**
D/2h =	D/(2*h)		47.746/(2*11.937) =	**2.000**
Do/2ho =	Do/(2*ho)		48/(2*12.064) =	**1.989**
K =	1.000	Interpolated value from table 1-4.1	=	**1.000**
Kone =	0.900	Interpolated value from table UG-37	=	**0.900**
Kzero =	0.895	Interpolated value from table UG-33.1	=	**0.895**
Ro [in]=	Kzero*Do		0.895*48 =	**42.973**

Interior Pressure - Required Thickness: App. 1-4(c), UG-37(a)(1)

App1-4(f) =	tf/(Kone*D)	0.127/(0.9*47.746) =	**0.0030**
App1-4(f)Calc =	if(AND(0.0005=<App1-4(f),App1-4(f)<0.002),"Calculation Required","Calculation not required")		
			App. 1-4(f) Calculation Not Required
Tmin [in] =	(P*D*K)/(2*S*E-0.2*P)		
		(30*47.746*1)/(2*18350*0.85-0.2*30) =	**0.046**
Checkt =	t >= Max(Tmin,tminUG16b)	0.127 >= MAX(0.046,0.063) =	**Acceptable**

Exterior Pressure - Required Thickness: UG-33(d), UG-28(d)

Aa =	0.125/(Ro/t)	0.125/(42.973/0.127) =	**0.0004**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**5,107**
PaMax [psi] =	Ba/(Ro/t)	5107/(42.973/0.127) =	**15.1**
CheckPaMax =	PaMax >= Pa	15.1 >= 15 =	**Acceptable**
Bb =	PVELookup("BbChart","BbEHLookup",chart,extTemp,Ro,Pa)		**5,091**
TMinE [in] =	(Pa*Ro)/Bb	(15*42.973)/5091 =	**0.127**
TMinEC [in] =	TMinE + Corr	0.127 + 0 =	**0.127**

Loads

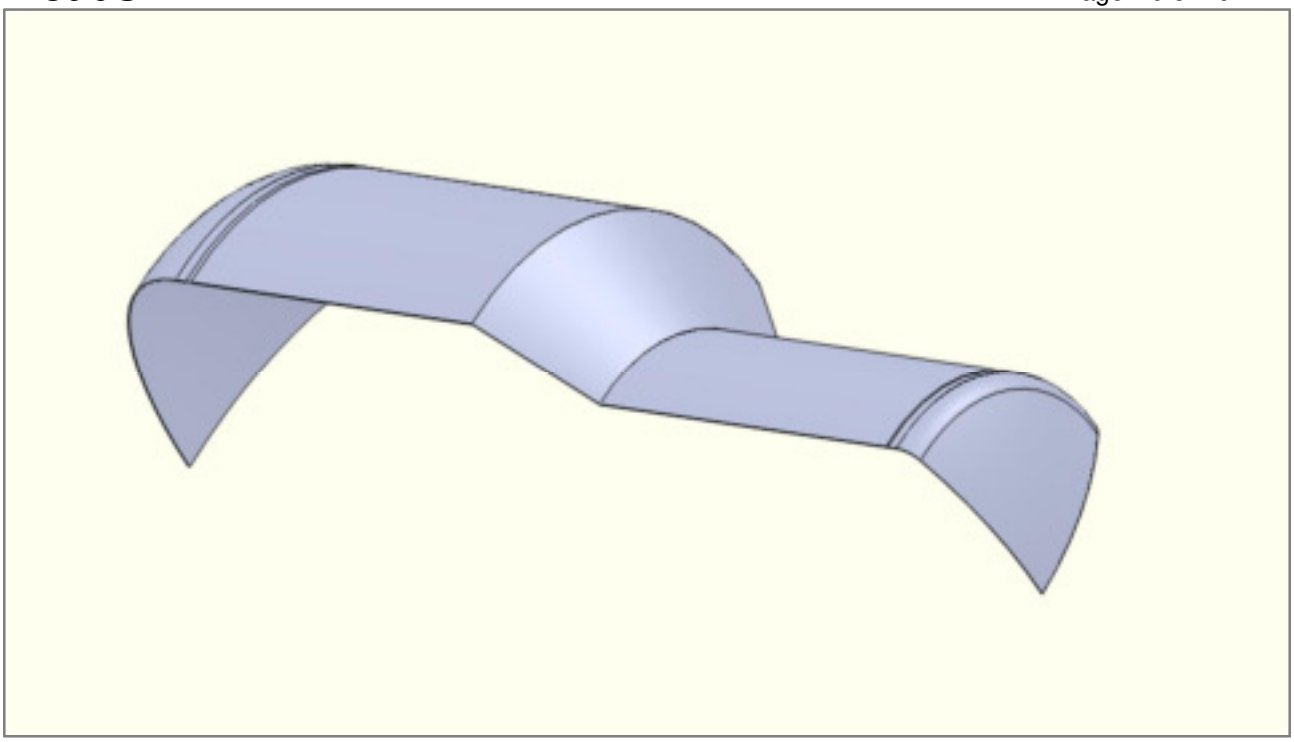


Fig-A - left head 72" dia x 0.190" SE, 72" shell x42" long x 0.193", transition x 0.126" at 45º, 48" shell x 44" long x 0.154" thick, right head x 0.127" thick (F&D)
Quarter model

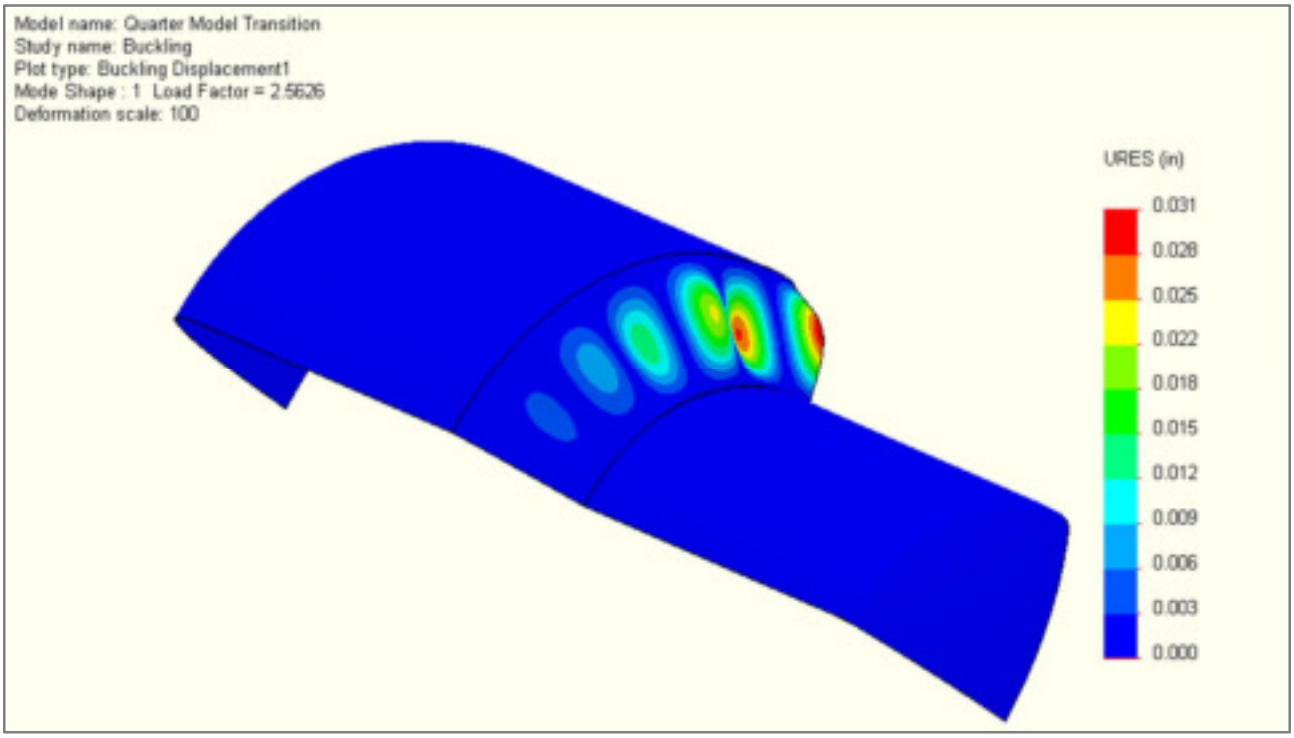


Fig-B 15 psi external load is applied. The cone provides 2 lines of support.
Reported factor of safety from buckling = 2.56 (close to the 3x required by code).
Experience indicates that this design is safe.