PVEng

Pressure Vessel Engineering Ltd.

ASME Calculations - CRN Assistance - Vessel Design - Finite Element Analysis

Design Conditions

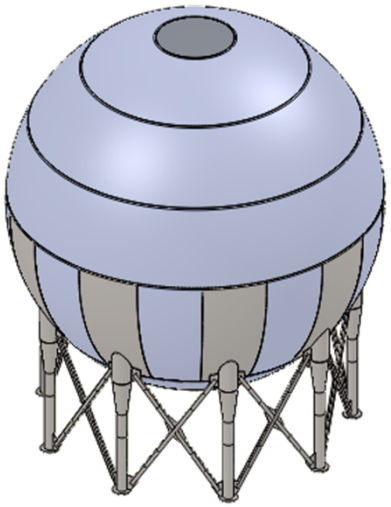
Code:	**ASME VIII-1**	
Year:	**2007**	
Addenda:	**2009**	
MAWP:	**157**	psi
MEAWP:	**15**	psi
Max. Temp.:	**150**	°F
MDMT:	**-20**	°F
MDMT Press.:	**157**	psi
Min. Thk. (UG-16b):	**0.09375**	in
Corrosion Allowance:	**0.03**	in
Hydrotest:	**205**	psi
Impact Testing:	**Yes**	
Impact Exemption:	**Impact Required**	
Radiography:	**100%**	

UG-22 Loadings Considered

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

ASME Section VIII-1 Calculations

Cust: **Pressure Vessel Engineering Ltd.**
Desc: **Propane/Butane Sphere**
Dwg: **PVEdwg 4225-0-0**



PVEcalc-4225-0-1

Author: Laurence Brundrett
Reviewer: Brian Munn

The Propane/Butane Sphere PVEdwg 4225-0-0 has been calculated to Section VIII-1 using IID allowed stress and is found to be acceptable.

Refer to the companion Finite Element Analysis report for more information

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Revision(s)			
Rev	Description	Date	By
0	Release	4/15/10	BEM
1	Updated	5/3/10	BEM
2			

Material Properties ver 2.01

Propane/Butane Sphere <- Vessel

Design Pressure UG-22(a)

157.0 <- P, internal operating pressure at top of vessel (psig)
15.0 <- mPa, external operation pressure
Hydrocarbons <- Operating Fluid
60.000 <- h, fluid height (ft)
0.580 <- rho, fluid density (1.0 for water)

Material Select

Design Pressure = P + 0.4331*rho*h = 157 + 0.4331 * 0.58 * 60 **mDp =** 172.1

Hydro Test (UG-99(b))

pressure measured at top of vessel, rounded up

Test Press = P * 1.3 * MR = 157 * 1.3 * 1 **mTp =** *205*

Material Properties (ASME IID)

150 <- mTemp, design temp ºF

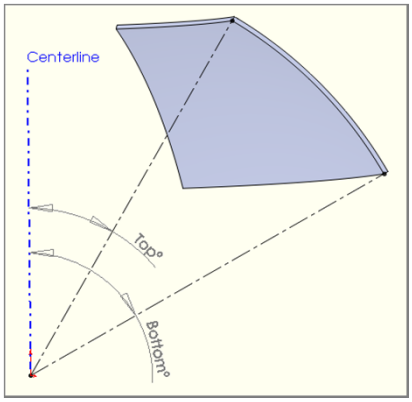
Test at ambient temp

Material	Where Used	Ambient Strength	Design Strength	Strength Ratio	Max ºF	Ext Graph
SA-299 - Plate (K02803) [> 1]	Plate	**21400**	**21400**	**1.000**	**1000**	**CS-2**
SA-350 LF2* - Forgings (K03011) [1]	Forgings	**20000**	**20000**	**1.000**	**1000**	**CS-2**
SA-106 B* - Smls. pipe (K03006)		**17100**	**17100**	**1.000**	**1000**	**CS-2**
SA-105 * - Forgings (K03504)	Forgings	**20000**	**20000**	**1.000**	**1000**	**CS-2**

Min Ratio (MR) = ***1.000***

VIII-1-Segmented Sphere ver 5.01

Top Cap Segment Description



Dimensions:

720.000	**Di** [in] - inside diameter of head
1.480	**t** [in] - thickness after forming
0.030	**Corr** [in] - corrosion allowance
0.000	**Top** [°] - angle from CL to top
12.000	**Bottom** [°] - angle from CL to bottom

Material and Conditions:

SA-299	**Material**
21,400	**S** [psi] - allowable stress
1.00	**E** - head efficiency
157.0	**Pt** [psi] - interior pressure at top
0.58	**sg** [] - specific gravity of fluid (relative to water = 1.0)
15.0	**Pa** [psi] - Exterior pressure

Exterior Pressure Inputs:

CS2	**chart** - Select external pressure chart
150	**extTemp** [°F] - Temperature for external pressure

Variables:

L [in] =	Di/2+Corr	inside radius with corrosion allowance removed	720/2+0.03 = **360.030**
Ro [in] =	Di/2 + t		720/2 + 1.48 = **361.480**
h [in] =	(Di/2)*(1-cos(Radians(Bottom)))		(720/2)*(1-COS(RADIANS(12))) = **7.867**
P [psi] =	Pt + 0.4331*sg*h/12	pressure at bottom of segment	
			157 + 0.4331*0.58*7.867/12 = **157.165**

Interior Pressure - Required Thickness : UG-32(f)

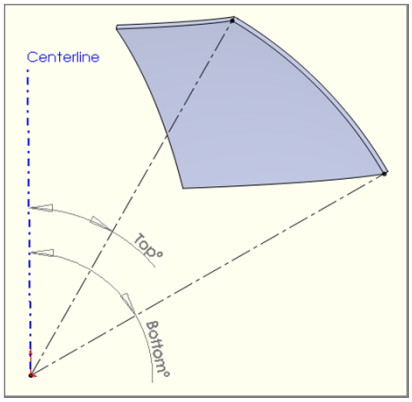
Tmin [in] =	(P*L)/(2*S*E-0.2*P)+Corr	required thickness at bottom of segment including corrosion allowance	
			(157.165*360.03)/(2*21400*1-0.2*157.165)+0.03 = **1.353**
Pmax [psi] =	(2*S*E*(t-Corr))/(L+0.2*(t-Corr))	maximum allowed pressure at bottom of corroded segment	
			(2*21400*1*(1.48-0.03))/(360.03+0.2*(1.48-0.03)) = **172.2**
CheckTmin =	t >= Tmin		1.48 >= 1.353 = **Acceptable**
CheckPMax =	Pmax >= P		172.2 >= 157.165 = **Acceptable**

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

Aa =	0.125/(Ro/(t-Corr))		0.125/(361.48/(1.48-0.03)) = **0.0005**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**7,270**
PaMax [psi] =	Ba/(Ro/(t-Corr))	Maximum allowed external pressure for segment in corroded state	
			7270/(361.48/(1.48-0.03)) = **29.2**
Bb =	PVELookup("BbChart","BbEHLookup",chart,extTemp,Ro,Pa)		**5,214**
TMinEC [in] =	(Pa*Ro)/Bb + Corr	required thickness for segment including corrosion allowance	
			(15*361.48)/5214 + 0.03 = **1.070**
CheckPaMax =	PaMax >= Pa		29.2 >= 15 = **Acceptable**
CheckTminEC =	TMinEC <= t		1.07 <= 1.48 = **Acceptable**

VIII-1-Segmented Sphere ver 5.01

Segment Z1 **Segment** Description



Dimensions:

720.000	**Di** [in] - inside diameter of head
1.370	**t** [in] - thickness after forming
0.030	**Corr** [in] - corrosion allowance
12.000	**Top** [°] - angle from CL to top
37.000	**Bottom** [°] - angle from CL to bottom

Material and Conditions:

SA-299	**Material**
21,400	**S** [psi] - allowable stress
1.00	**E** - head efficiency
157.0	**Pt** [psi] - interior pressure at top
0.58	**sg** [] - specific gravity of fluid (relative to water = 1.0)
15.0	**Pa** [psi] - Exterior pressure

Exterior Pressure Inputs:

CS2	**chart** - Select external pressure chart
150	**extTemp** [°F] - Temperature for external pressure

Variables:

L [in] =	Di/2+Corr	inside radius with corrosion allowance removed	720/2+0.03 = **360.030**
Ro [in] =	Di/2 + t		720/2 + 1.37 = **361.370**
h [in] =	(Di/2)*(1-cos(Radians(Bottom)))		(720/2)*(1-COS(RADIANS(37))) = **72.491**
P [psi] =	Pt + 0.4331*sg*h/12	pressure at bottom of segment	
			157 + 0.4331*0.58*72.491/12 = **158.517**

Interior Pressure - Required Thickness : UG-32(f)

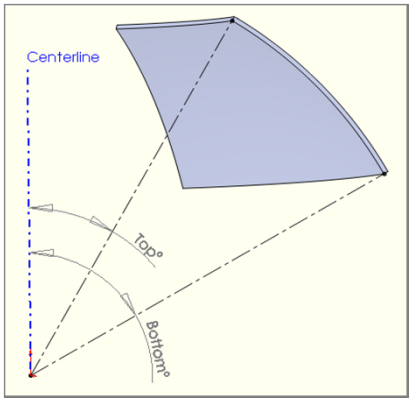
Tmin [in] =	(P*L)/(2*S*E-0.2*P)+Corr	required thickness at bottom of segment including corrosion allowance	
			(158.517*360.03)/(2*21400*1-0.2*158.517)+0.03 = **1.364**
Pmax [psi] =	(2*S*E*(t-Corr))/(L+0.2*(t-Corr))	maximum allowed pressure at bottom of corroded segment	
			(2*21400*1*(1.37-0.03))/(360.03+0.2*(1.37-0.03)) = **159.2**
CheckTmin =	t >= Tmin		1.37 >= 1.364 = **Acceptable**
CheckPMax =	Pmax >= P		159.2 >= 158.517 = **Acceptable**

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

Aa =	0.125/(Ro/(t-Corr))		0.125/(361.37/(1.37-0.03)) = **0.0005**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**6,721**
PaMax [psi] =	Ba/(Ro/(t-Corr))	Maximum allowed external pressure for segment in corroded state	
			6721/(361.37/(1.37-0.03)) = **24.9**
Bb =	PVELookup("BbChart","BbEHLookup",chart,extTemp,Ro,Pa)		**5,214**
TMinEC [in] =	(Pa*Ro)/Bb + Corr	required thickness for segment including corrosion allowance	
			(15*361.37)/5214 + 0.03 = **1.070**
CheckPaMax =	PaMax >= Pa		24.9 >= 15 = **Acceptable**
CheckTminEC =	TMinEC <= t		1.07 <= 1.37 = **Acceptable**

VIII-1-Segmented Sphere ver 5.01

Segment Z2 **Segment** Description



Dimensions:

720.000	**Di** [in] - inside diameter of head
1.400	**t** [in] - thickness after forming
0.030	**Corr** [in] - corrosion allowance
37.000	**Top** [°] - angle from CL to top
62.000	**Bottom** [°] - angle from CL to bottom

Material and Conditions:

SA-299	**Material**
21,400	**S** [psi] - allowable stress
1.00	**E** - head efficiency
157.0	**Pt** [psi] - interior pressure at top
0.58	**sg** [] - specific gravity of fluid (relative to water = 1.0)
15.0	**Pa** [psi] - Exterior pressure

Exterior Pressure Inputs:

CS2	**chart** - Select external pressure chart
150	**extTemp** [°F] - Temperature for external pressure

Variables:

L [in] =	Di/2+Corr	inside radius with corrosion allowance removed	720/2+0.03 = **360.030**
Ro [in] =	Di/2 + t		720/2 + 1.4 = **361.400**
h [in] =	(Di/2)*(1-cos(Radians(Bottom)))		(720/2)*(1-COS(RADIANS(62))) = **190.990**
P [psi] =	Pt + 0.4331*sg*h/12	pressure at bottom of segment	
			157 + 0.4331*0.58*190.99/12 = **160.998**

Interior Pressure - Required Thickness : UG-32(f)

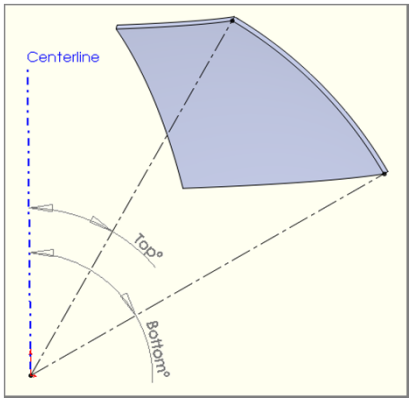
Tmin [in] =	(P*L)/(2*S*E-0.2*P)+Corr	required thickness at bottom of segment including corrosion allowance	
			(160.998*360.03)/(2*21400*1-0.2*160.998)+0.03 = **1.385**
Pmax [psi] =	(2*S*E*(t-Corr))/(L+0.2*(t-Corr))	maximum allowed pressure at bottom of corroded segment	
			(2*21400*1*(1.4-0.03))/(360.03+0.2*(1.4-0.03)) = **162.7**
CheckTmin =	t >= Tmin		1.4 >= 1.385 = **Acceptable**
CheckPMax =	Pmax >= P		162.7 >= 160.998 = **Acceptable**

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

Aa =	0.125/(Ro/(t-Corr))		0.125/(361.4/(1.4-0.03)) = **0.0005**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**6,871**
PaMax [psi] =	Ba/(Ro/(t-Corr))	Maximum allowed external pressure for segment in corroded state	
			6871/(361.4/(1.4-0.03)) = **26.0**
Bb =	PVELookup("BbChart","BbEHLookup",chart,extTemp,Ro,Pa)		**5,214**
TMinEC [in] =	(Pa*Ro)/Bb + Corr	required thickness for segment including corrosion allowance	
			(15*361.4)/5214 + 0.03 = **1.070**
CheckPaMax =	PaMax >= Pa		26 >= 15 = **Acceptable**
CheckTminEC =	TMinEC <= t		1.07 <= 1.4 = **Acceptable**

VIII-1-Segmented Sphere ver 5.01

Segment Z3 **Segment** Description



Dimensions:

720.000	**Di** [in] - inside diameter of head
1.420	**t** [in] - thickness after forming
0.030	**Corr** [in] - corrosion allowance
62.000	**Top** [°] - angle from CL to top
87.000	**Bottom** [°] - angle from CL to bottom

Material and Conditions:

SA-299	**Material**
21,400	**S** [psi] - allowable stress
1.00	**E** - head efficiency
157.0	**Pt** [psi] - interior pressure at top
0.58	**sg** [] - specific gravity of fluid (relative to water = 1.0)
15.0	**Pa** [psi] - Exterior pressure

Exterior Pressure Inputs:

CS2	**chart** - Select external pressure chart
150	**extTemp** [°F] - Temperature for external pressure

Variables:

L [in] =	Di/2+Corr	inside radius with corrosion allowance removed	720/2+0.03 = **360.030**
Ro [in] =	Di/2 + t		720/2 + 1.42 = **361.420**
h [in] =	(Di/2)*(1-cos(Radians(Bottom)))		(720/2)*(1-COS(RADIANS(87))) = **341.159**
P [psi] =	Pt + 0.4331*sg*h/12	pressure at bottom of segment	
			157 + 0.4331*0.58*341.159/12 = **164.142**

Interior Pressure - Required Thickness : UG-32(f)

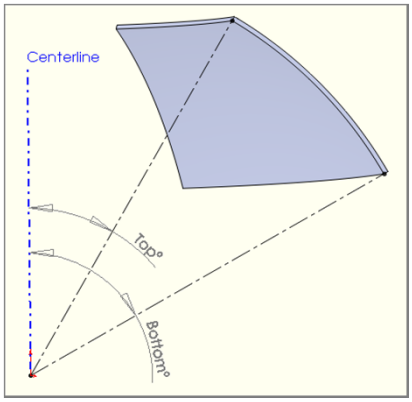
Tmin [in] =	(P*L)/(2*S*E-0.2*P)+Corr	required thickness at bottom of segment including corrosion allowance	
			(164.142*360.03)/(2*21400*1-0.2*164.142)+0.03 = **1.412**
Pmax [psi] =	(2*S*E*(t-Corr))/(L+0.2*(t-Corr))	maximum allowed pressure at bottom of corroded segment	
			(2*21400*1*(1.42-0.03))/(360.03+0.2*(1.42-0.03)) = **165.1**
CheckTmin =	t >= Tmin		1.42 >= 1.412 = **Acceptable**
CheckPMax =	Pmax >= P		165.1 >= 164.142 = **Acceptable**

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

Aa =	0.125/(Ro/(t-Corr))		0.125/(361.42/(1.42-0.03)) = **0.0005**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**6,971**
PaMax [psi] =	Ba/(Ro/(t-Corr))	Maximum allowed external pressure for segment in corroded state	
			6971/(361.42/(1.42-0.03)) = **26.8**
Bb =	PVELookup("BbChart","BbEHLookup",chart,extTemp,Ro,Pa)		**5,214**
TMinEC [in] =	(Pa*Ro)/Bb + Corr	required thickness for segment including corrosion allowance	
			(15*361.42)/5214 + 0.03 = **1.070**
CheckPaMax =	PaMax >= Pa		26.8 >= 15 = **Acceptable**
CheckTminEC =	TMinEC <= t		1.07 <= 1.42 = **Acceptable**

VIII-1-Segmented Sphere ver 5.01

Segment Z4 - Equator Plate **Segment** Description



Dimensions:

720.000	**Di** [in] - inside diameter of head
1.460	**t** [in] - thickness after forming
0.030	**Corr** [in] - corrosion allowance
87.000	**Top** [°] - angle from CL to top
132.000	**Bottom** [°] - angle from CL to bottom

Material and Conditions:

SA-299	**Material**
21,400	**S** [psi] - allowable stress
1.00	**E** - head efficiency
157.0	**Pt** [psi] - interior pressure at top
0.58	**sg** [] - specific gravity of fluid (relative to water = 1.0)
15.0	**Pa** [psi] - Exterior pressure

Exterior Pressure Inputs:

CS2	**chart** - Select external pressure chart
150	**extTemp** [°F] - Temperature for external pressure

Variables:

L [in] =	Di/2+Corr	inside radius with corrosion allowance removed	720/2+0.03 = **360.030**
Ro [in] =	Di/2 + t		720/2 + 1.46 = **361.460**
h [in] =	(Di/2)*(1-cos(Radians(Bottom)))		(720/2)*(1-COS(RADIANS(132))) = **600.887**
P [psi] =	Pt + 0.4331*sg*h/12	pressure at bottom of segment	
			157 + 0.4331*0.58*600.887/12 = **169.578**

Interior Pressure - Required Thickness : UG-32(f)

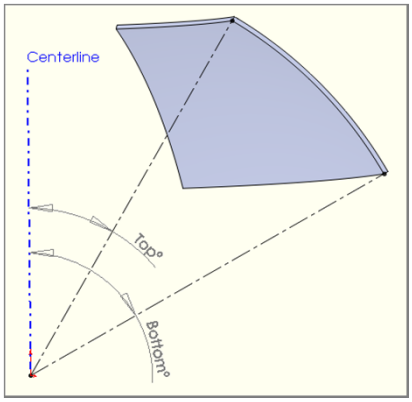
Tmin [in] =	(P*L)/(2*S*E-0.2*P)+Corr	required thickness at bottom of segment including corrosion allowance	
			(169.578*360.03)/(2*21400*1-0.2*169.578)+0.03 = **1.458**
Pmax [psi] =	(2*S*E*(t-Corr))/(L+0.2*(t-Corr))	maximum allowed pressure at bottom of corroded segment	
			(2*21400*1*(1.46-0.03))/(360.03+0.2*(1.46-0.03)) = **169.9**
CheckTmin =	t >= Tmin		1.46 >= 1.458 = **Acceptable**
CheckPMax =	Pmax >= P		169.9 >= 169.578 = **Acceptable**

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

Aa =	0.125/(Ro/(t-Corr))		0.125/(361.46/(1.46-0.03)) = **0.0005**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**7,171**
PaMax [psi] =	Ba/(Ro/(t-Corr))	Maximum allowed external pressure for segment in corroded state	
			7171/(361.46/(1.46-0.03)) = **28.4**
Bb =	PVELookup("BbChart","BbEHLookup",chart,extTemp,Ro,Pa)		**5,214**
TMinEC [in] =	(Pa*Ro)/Bb + Corr	required thickness for segment including corrosion allowance	
			(15*361.46)/5214 + 0.03 = **1.070**
CheckPaMax =	PaMax >= Pa		28.4 >= 15 = **Acceptable**
CheckTminEC =	TMinEC <= t		1.07 <= 1.46 = **Acceptable**

VIII-1-Segmented Sphere ver 5.01

Segment Z5 **Segment** Description



Dimensions:

720.000	**Di** [in] - inside diameter of head
1.480	**t** [in] - thickness after forming
0.030	**Corr** [in] - corrosion allowance
132.000	**Top** [°] - angle from CL to top
150.000	**Bottom** [°] - angle from CL to bottom

Material and Conditions:

SA-299	**Material**
21,400	**S** [psi] - allowable stress
1.00	**E** - head efficiency
157.0	**Pt** [psi] - interior pressure at top
0.58	**sg** [] - specific gravity of fluid (relative to water = 1.0)
15.0	**Pa** [psi] - Exterior pressure

Exterior Pressure Inputs:

CS2	**chart** - Select external pressure chart
150	**extTemp** [°F] - Temperature for external pressure

Variables:

L [in] =	Di/2+Corr	inside radius with corrosion allowance removed	720/2+0.03 = **360.030**
Ro [in] =	Di/2 + t		720/2 + 1.48 = **361.480**
h [in] =	(Di/2)*(1-cos(Radians(Bottom)))		(720/2)*(1-COS(RADIANS(150))) = **671.769**
P [psi] =	Pt + 0.4331*sg*h/12	pressure at bottom of segment	
			157 + 0.4331*0.58*671.769/12 = **171.062**

Interior Pressure - Required Thickness : UG-32(f)

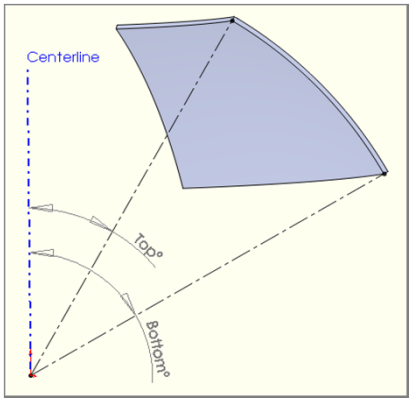
Tmin [in] =	(P*L)/(2*S*E-0.2*P)+Corr	required thickness at bottom of segment including corrosion allowance	
			(171.062*360.03)/(2*21400*1-0.2*171.062)+0.03 = **1.470**
Pmax [psi] =	(2*S*E*(t-Corr))/(L+0.2*(t-Corr))	maximum allowed pressure at bottom of corroded segment	
			(2*21400*1*(1.48-0.03))/(360.03+0.2*(1.48-0.03)) = **172.2**
CheckTmin =	t >= Tmin		1.48 >= 1.47 = **Acceptable**
CheckPMax =	Pmax >= P		172.2 >= 171.062 = **Acceptable**

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

Aa =	0.125/(Ro/(t-Corr))		0.125/(361.48/(1.48-0.03)) = **0.0005**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**7,270**
PaMax [psi] =	Ba/(Ro/(t-Corr))	Maximum allowed external pressure for segment in corroded state	
			7270/(361.48/(1.48-0.03)) = **29.2**
Bb =	PVELookup("BbChart","BbEHLookup",chart,extTemp,Ro,Pa)		**5,214**
TMinEC [in] =	(Pa*Ro)/Bb + Corr	required thickness for segment including corrosion allowance	
			(15*361.48)/5214 + 0.03 = **1.070**
CheckPaMax =	PaMax >= Pa		29.2 >= 15 = **Acceptable**
CheckTminEC =	TMinEC <= t		1.07 <= 1.48 = **Acceptable**

VIII-1-Segmented Sphere ver 5.01

Segment Z7 **Segment** Description



Dimensions:

720.000	**Di** [in] - inside diameter of head
1.480	**t** [in] - thickness after forming
0.030	**Corr** [in] - corrosion allowance
150.000	**Top** [°] - angle from CL to top
168.000	**Bottom** [°] - angle from CL to bottom

Material and Conditions:

SA-299	**Material**
21,400	**S** [psi] - allowable stress
1.00	**E** - head efficiency
157.0	**Pt** [psi] - interior pressure at top
0.58	**sg** [] - specific gravity of fluid (relative to water = 1.0)
15.0	**Pa** [psi] - Exterior pressure

Exterior Pressure Inputs:

CS2	**chart** - Select external pressure chart
150	**extTemp** [°F] - Temperature for external pressure

Variables:

L [in] =	Di/2+Corr	inside radius with corrosion allowance removed	720/2+0.03 = **360.030**
Ro [in] =	Di/2 + t		720/2 + 1.48 = **361.480**
h [in] =	(Di/2)*(1-cos(Radians(Bottom)))		(720/2)*(1-COS(RADIANS(168))) = **712.133**
P [psi] =	Pt + 0.4331*sg*h/12	pressure at bottom of segment	
			157 + 0.4331*0.58*712.133/12 = **171.907**

Interior Pressure - Required Thickness : UG-32(f)

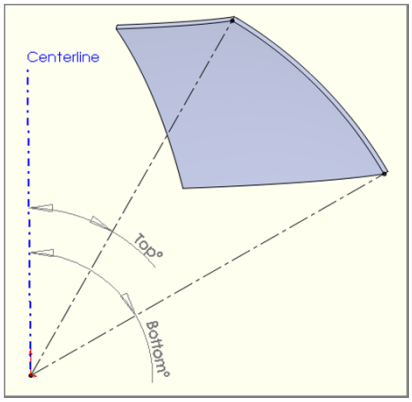
Tmin [in] =	(P*L)/(2*S*E-0.2*P)+Corr	required thickness at bottom of segment including corrosion allowance	
			(171.907*360.03)/(2*21400*1-0.2*171.907)+0.03 = **1.477**
Pmax [psi] =	(2*S*E*(t-Corr))/(L+0.2*(t-Corr))	maximum allowed pressure at bottom of corroded segment	
			(2*21400*1*(1.48-0.03))/(360.03+0.2*(1.48-0.03)) = **172.2**
CheckTmin =	t >= Tmin		1.48 >= 1.477 = **Acceptable**
CheckPMax =	Pmax >= P		172.2 >= 171.907 = **Acceptable**

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

Aa =	0.125/(Ro/(t-Corr))		0.125/(361.48/(1.48-0.03)) = **0.0005**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**7,270**
PaMax [psi] =	Ba/(Ro/(t-Corr))	Maximum allowed external pressure for segment in corroded state	
			7270/(361.48/(1.48-0.03)) = **29.2**
Bb =	PVELookup("BbChart","BbEHLookup",chart,extTemp,Ro,Pa)		**5,214**
TMinEC [in] =	(Pa*Ro)/Bb + Corr	required thickness for segment including corrosion allowance	
			(15*361.48)/5214 + 0.03 = **1.070**
CheckPaMax =	PaMax >= Pa		29.2 >= 15 = **Acceptable**
CheckTminEC =	TMinEC <= t		1.07 <= 1.48 = **Acceptable**

VIII-1-Segmented Sphere ver 5.01

Bottom Cap Segment Description



Dimensions:

720.000	**Di** [in] - inside diameter of head
1.480	**t** [in] - thickness after forming
0.030	**Corr** [in] - corrosion allowance
168.000	**Top** [°] - angle from CL to top
180.000	**Bottom** [°] - angle from CL to bottom

Material and Conditions:

SA-299	**Material**
21,400	**S** [psi] - allowable stress
1.00	**E** - head efficiency
157.0	**Pt** [psi] - interior pressure at top
0.58	**sg** [] - specific gravity of fluid (relative to water = 1.0)
15.0	**Pa** [psi] - Exterior pressure

Exterior Pressure Inputs:

CS2	**chart** - Select external pressure chart
150	**extTemp** [°F] - Temperature for external pressure

Variables:

L [in] =	Di/2+Corr	inside radius with corrosion allowance removed	720/2+0.03 = **360.030**
Ro [in] =	Di/2 + t		720/2 + 1.48 = **361.480**
h [in] =	(Di/2)*(1-cos(Radians(Bottom)))		(720/2)*(1-COS(RADIANS(180))) = **720.000**
P [psi] =	Pt + 0.4331*sg*h/12	pressure at bottom of segment	
			157 + 0.4331*0.58*720/12 = **172.072**

Interior Pressure - Required Thickness : UG-32(f)

Tmin [in] =	(P*L)/(2*S*E-0.2*P)+Corr	required thickness at bottom of segment including corrosion allowance	
			(172.072*360.03)/(2*21400*1-0.2*172.072)+0.03 = **1.479**
Pmax [psi] =	(2*S*E*(t-Corr))/(L+0.2*(t-Corr))	maximum allowed pressure at bottom of corroded segment	
			(2*21400*1*(1.48-0.03))/(360.03+0.2*(1.48-0.03)) = **172.2**
CheckTmin =	t >= Tmin		1.48 >= 1.479 = **Acceptable**
CheckPMax =	Pmax >= P		172.2 >= 172.072 = **Acceptable**

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

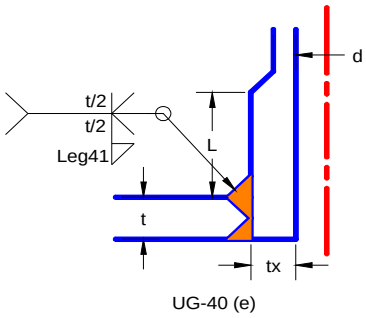
Aa =	0.125/(Ro/(t-Corr))		0.125/(361.48/(1.48-0.03)) = **0.0005**
Ba =	PVELookup("ExtChart","ExtLookup",chart,extTemp,Aa)		**7,270**
PaMax [psi] =	Ba/(Ro/(t-Corr))	Maximum allowed external pressure for segment in corroded state	
			7270/(361.48/(1.48-0.03)) = **29.2**
Bb =	PVELookup("BbChart","BbEHLookup",chart,extTemp,Ro,Pa)		**5,214**
TMinEC [in] =	(Pa*Ro)/Bb + Corr	required thickness for segment including corrosion allowance	
			(15*361.48)/5214 + 0.03 = **1.070**
CheckPaMax =	PaMax >= Pa		29.2 >= 15 = **Acceptable**
CheckTminEC =	TMinEC <= t		1.07 <= 1.48 = **Acceptable**

VIII-1-Nozzle Reinforcement ver 4.00

M1 - Bottom Manway **Description**

Shell Inputs:

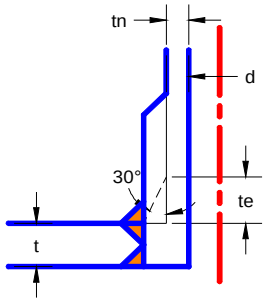
SA-299	**Material**
21,400	**Sv** [psi] - allowable stress
1.00	**E1** - efficiency of shell at nozzle
720.000	**Ds** [in] - inside diameter of shell
1.480	**t** [in] - nominal shell wall thickness
1.479	**Treq** [in] - required shell wall thickness
1.070	**Treqe** [in] - required shell wall thickness external
0.030	**sca** [in] - shell corrosion allowance
0.094	**tUG16(b)** [in] - minimum thickness per UG-16 b



UG-40 (e)

Nozzle Inputs:

No Projection	**Internal** Projection
SA-350 LF2	**Material**
20,000	**Sn** [psi] - allowable stress
1.00	**E** - nozzle efficiency
4.25	**tx** [in] - nozzle thickness
6.00	**L** [in] - length of larger diameter section
24.00	**d** [in] - I.D. of nozzle
26.25	**ds** [in] - O.D. of nozzle (reduced)
10.000	**Lp** [in] - exterior projection of nozzle
0.000	**lp** [in] - interior projection of nozzle
0.030	**nca** [in] - nozzle corrosion allowance
0.0%	**UTP** [%] - undertolerance allowance
172.1	**P** [psi] - interior pressure
15.0	**Pa** [psi] - exterior pressure
CS2	**Chart** - external pressure chart
300.0	**Temp** [F] - temperature for external pressure



UG-40 (e-1)

Reinforcement:

0.375	**Leg41** [in] - fillet size		
e1 =	if(L<(2.5*tx),"e-1","e-2")		**e-1**
e-1	**Configuration**		
tn =	((ds-d)/2)-nca	((26.25-24)/2)-0.03 =	**1.095**
Do =	ds	26.25 =	**26.250**
Di =	Do-2*tn	26.25-2*1.095 =	**24.060**
te =	MIN(((TAN(60*PI()/180))*(tx-tn)), L) Repad Thickness		
		MIN(((TAN(60*PI()/180))*(4.25-1.095)), 6) =	**5.465**
Dp =	MIN(d + (tx *2),2*Di) Repad OD	MIN(24 + (4.25 *2),2*24.06) =	**33**

Variables:

UT [in] =	tn*UTP	1.095*0 = **0.000**
Rn [in] =	Do/2 - (tn-nca) + UT	26.25/2 - (1.095-0.03) + 0 = **12.060**
ti [in] =	tn-nca	1.095-0.03 = **1.065**
h [in] =	MIN(lp-sca,2.5*(t-sca),2.5*ti)	MIN(0-0.03,2.5*(1.48-0.03),2.5*1.065) = **-0.030**

Required Thickness: UG-27(c)(1,2)

TreqN [in] =	(P*Rn)/(Sn*E - 0.6*P) required minimum thickness		
		(172.1*12.06)/(20000*1 - 0.6*172.1) =	**0.104**
trnR [in] =	(P*Rn)/(Sn*1 - 0.6*P)	(172.1*12.06)/(20000*1 - 0.6*172.1) =	**0.104**
B =	PVELookup("BbChart","BbLookup",Chart,Temp,Do,Pa,Lp/Do)		**5278**
TreqNE [in] =	(3*Do*Pa)/(4*B) required minimum external	(3*26.25*15)/(4*5278) =	**0.056**
CheckTreqN =	MIN(TreqN,TreqNE) <= tn	MIN(0.104,0.056) <= 1.095 =	**Acceptable**

UG-45:

Tstd [in] =	vlookup(Do,PipeWall,2)	vlookup(26.25,PIpeWall,2) =	**0.375**
Nact [in] =	(tn+nca) * (1-UTP)	(1.095+0.03) * (1-0) =	**1.125**
Swre [in] =	Treq*Pa/P	1.479*15/172.1 =	**0.129**
UG45b4 [in] =	Tstd*0.875 + nca	0.375*0.875 + 0.03 =	**0.358**
UG45b3 [in] =	Max(UG45b1,UG45b2)	MAX(1.509,0.159) =	**1.509**
UG45b2 [in] =	Max(Swre+sca,tUG16(b)+sca)	MAX(0.129+0.03,0.094+0.03) =	**0.159**
UG45b1 [in] =	Max(Treq+sca,tUG16(b) + sca)	MAX(1.479+0.03,0.094 + 0.03) =	**1.509**
UG45b [in] =	Min(UG45b3,UG45b4)	MIN(1.509,0.358) =	**0.358**
UG45a [in] =	MAX(TreqN,TreqNE) + nca	MAX(0.104,0.056) + 0.03 =	**0.134**
UG45 [in] =	Max(UG45a, UG45b) required thickness per UG-45	MAX(0.134, 0.358) =	**0.358**
CheckUG45 =	UG45 <= Nact	0.358 <= 1.125 =	**Acceptable**
		Minimum thickness per UG-45 [in] = **Acceptable**	**0.358**

Area Replacement:

Ar [in^2] =	Di*Treq*1+2*tn*Treq*1*(1-fr1) required area for internal pressure		
		24.06*1.479*1+2*1.095*1.479*1*(1-0.935) =	**35.787**
A11 [in^2] =	Di*(E1*(t-sca)-1*Treq)-2*tn*(E1*(t-sca)-1*Treq)*(1-fr1)		
	24.06*(1*(1.48-0.03)-1*1.479)-2*1.095*(1*(1.48-0.03)-1*1.479)*(1-0.935) =		**-0.684**
A12 [in^2] =	2*(t-sca+tn)*(E1*(t-sca)-1*Treq)-2*tn*(E1*(t-sca)-1*Treq)*(1-fr1)		
	2*(1.48-0.03+1.095)*(1*(1.48-0.03)-1*1.479)-2*1.095*(1*(1.48-0.03)-1*1.479)*(1-0.935) =		**-0.142**
A1 [in^2] =	MAX(0,A11,A12)	MAX(0,-0.684,-0.142) =	**0.000**
A21 [in^2] =	5*(tn-trnR)*fr2*(t-sca)		
		5*(1.095-0.104)*0.935*(1.48-0.03) =	**6.713**
A22 [in^2] =	2*(tn-trnR)*(2.5*tn+te)*fr2		
		2*(1.095-0.104)*(2.5*1.095+5.465)*0.935 =	**15.189**
A2 [in^2] =	MIN(A21,A22)	MIN(6.713,15.189) =	**6.713**
A3 [in^2] =	MAX(0,MIN(5*(t-sca)*ti*fr2,5*ti*ti*fr2,2*h*ti*fr2))		
	MAX(0,MIN(5*(1.48-0.03)*1.065*0.935,5*1.065*1.065*0.935,2*-0.03*1.065*0.935)) =		**0**
A5 [in^2] =	(Dp-Di-2*tn)*te*fr4	(33-24.06-2*1.095)*5.465*0.935 =	**31.920**
A41 [in^2] =	Leg41^2*fr3	0.375^2*0.935 =	**0.131**
A42 [in^2] =	0	0 =	**0.000**
A43 [in^2] =	0	0 =	**0.000**
Aa [in^2] =	A1+A2+A3+A5+A41+A42+A43 actual area for internal pressure		
		0+6.713+0+31.92+0.131+0+0 =	**38.764**
CheckA =	Aa >= Ar check area replacement	38.764 >= 35.787 =	**Acceptable**
Are [in^2] =	0.5*(Di*Treqe*1+2*tn*Treqe*1*(1-fr1)) required area for external presure		
		0.5*(24.06*1.07*1+2*1.095*1.07*1*(1-0.935)) =	**12.948**
A11e [in^2] =	Di*(E1*(t-sca)-1*Treqe)-2*tn*(E1*(t-sca)-1*Treqe)*(1-fr1)		
	24.06*(1*(1.48-0.03)-1*1.07)-2*1.095*(1*(1.48-0.03)-1*1.07)*(1-0.935) =		**9.091**
A12e [in^2] =	2*(t-sca+tn)*(E1*(t-sca)-1*Treqe)-2*tn*(E1*(t-sca)-1*Treqe)*(1-fr1)		
	2*(1.48-0.03+1.095)*(1*(1.48-0.03)-1*1.07)-2*1.095*(1*(1.48-0.03)-1*1.07)*(1-0.935) =		**1.880**
A1e [in^2] =	MAX(0,A11e,A12e)	MAX(0,9.091,1.88) =	**9.091**
A21e [in^2] =	5*(tn-TreqNE)*fr2*(t-sca)		
		5*(1.095-0.056)*0.935*(1.48-0.03) =	**7.040**
A22e [in^2] =	2*(tn-TreqNE)*(2.5*tn+te)*fr2		
		2*(1.095-0.056)*(2.5*1.095+5.465)*0.935 =	**15.930**
A2e [in^2] =	MIN(A21e,A22e)	MIN(7.04,15.93) =	**7.040**
Aae [in^2] =	A1e+A2e+A3+A5+A41+A42+A43 actual area for external pressure		
		9.091+7.04+0+31.92+0.131+0+0 =	**48.182**
CheckA =	Aae >= Are check area replacement	48.182 >= 12.948 =	**Acceptable**

Weld Check:

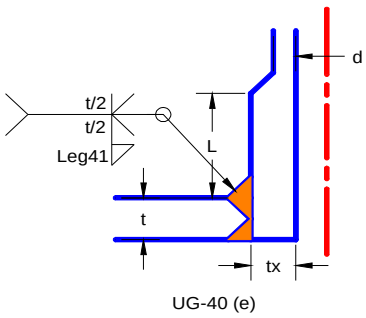
tc41 [in] =	MIN(0.25,0.7*MIN(0.75,tn,te))	MIN(0.25,0.7*MIN(0.75,1.095,5.465)) =	**0.250**
Check41 =	0.7*Leg41 >= tc41	0.7*0.375 >= 0.25 =	**Acceptable**

VIII-1-Nozzle Reinforcement ver 4.00

M2 - Top Manway **Description**

Shell Inputs:

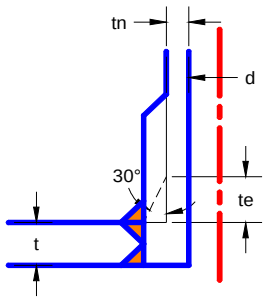
SA-299	**Material**	
21,400	**Sv** [psi] - allowable stress	
1.00	**E1** - efficiency of shell at nozzle	
720.000	**Ds** [in] - inside diameter of shell	
1.480	**t** [in] - nominal shell wall thickness	
1.353	**Treq** [in] - required shell wall thickness	
1.070	**Treqe** [in] - required shell wall thickness external	
0.030	**sca** [in] - shell corrosion allowance	
0.094	**tUG16(b)** [in] - minimum thickness per UG-16 b	



UG-40 (e)

Nozzle Inputs:

No Projection	**Internal** Projection
SA-350 LF2	**Material**
20,000	**Sn** [psi] - allowable stress
1.00	**E** - nozzle efficiency
4.25	**tx** [in] - nozzle thickness
6.00	**L** [in] - length of larger diameter section
24.00	**d** [in] - I.D. of nozzle
26.25	**ds** [in] - O.D. of nozzle (reduced)
10.000	**Lp** [in] - exterior projection of nozzle
0.000	**lp** [in] - interior projection of nozzle
0.030	**nca** [in] - nozzle corrosion allowance
0.0%	**UTP** [%] - undertolerance allowance
112.0	**P** [psi] - interior pressure
15.0	**Pa** [psi] - exterior pressure
CS2	**Chart** - external pressure chart
300.0	**Temp** [F] - temperature for external pressure



UG-40 (e-1)

Reinforcement:

0.375	**Leg41** [in] - fillet size		
e1 =	if(L<(2.5*tx),"e-1","e-2")		**e-1**
e-1	**Configuration**		
tn =	((ds-d)/2)-nca	((26.25-24)/2)-0.03 =	**1.095**
Do =	ds	26.25 =	**26.250**
Di =	Do-2*tn	26.25-2*1.095 =	**24.060**
te =	MIN(((TAN(60*PI()/180))*(tx-tn)), L) Repad Thickness		
		MIN(((TAN(60*PI()/180))*(4.25-1.095)), 6) =	**5.465**
Dp =	MIN(d + (tx *2),2*Di) Repad OD	MIN(24 + (4.25 *2),2*24.06) =	**33**

Variables:

UT [in] =	tn*UTP	1.095*0 =	**0.000**
Rn [in] =	Do/2 - (tn-nca) + UT	26.25/2 - (1.095-0.03) + 0 =	**12.060**
ti [in] =	tn-nca	1.095-0.03 =	**1.065**
h [in] =	MIN(lp-sca,2.5*(t-sca),2.5*ti)	MIN(0-0.03,2.5*(1.48-0.03),2.5*1.065) =	**-0.030**

Required Thickness: UG-27(c)(1,2)

TreqN [in] =	(P*Rn)/(Sn*E - 0.6*P) required minimum thickness		
		(112*12.06)/(20000*1 - 0.6*112) =	**0.068**
trnR [in] =	(P*Rn)/(Sn*1 - 0.6*P)	(112*12.06)/(20000*1 - 0.6*112) =	**0.068**
B =	PVELookup("BbChart","BbLookup",Chart,Temp,Do,Pa,Lp/Do)		**5278**
TreqNE [in] =	(3*Do*Pa)/(4*B) required minimum external	(3*26.25*15)/(4*5278) =	**0.056**
CheckTreqN =	MIN(TreqN,TreqNE) <= tn	MIN(0.068,0.056) <= 1.095 =	**Acceptable**

UG-45:

Tstd [in] =	vlookup(Do,PipeWall,2)	vlookup(26.25,PIpeWall,2) =	**0.375**
Nact [in] =	(tn+nca) * (1-UTP)	(1.095+0.03) * (1-0) =	**1.125**
Swre [in] =	Treq*Pa/P	1.353*15/112 =	**0.181**
UG45b4 [in] =	Tstd*0.875 + nca	0.375*0.875 + 0.03 =	**0.358**
UG45b3 [in] =	Max(UG45b1,UG45b2)	MAX(1.383,0.211) =	**1.383**
UG45b2 [in] =	Max(Swre+sca,tUG16(b)+sca)	MAX(0.181+0.03,0.094+0.03) =	**0.211**
UG45b1 [in] =	Max(Treq+sca,tUG16(b) + sca)	MAX(1.353+0.03,0.094 + 0.03) =	**1.383**
UG45b [in] =	Min(UG45b3,UG45b4)	MIN(1.383,0.358) =	**0.358**
UG45a [in] =	MAX(TreqN,TreqNE) + nca	MAX(0.068,0.056) + 0.03 =	**0.098**
UG45 [in] =	Max(UG45a, UG45b) required thickness per UG-45	MAX(0.098, 0.358) =	**0.358**
CheckUG45 =	UG45 <= Nact	0.358 <= 1.125 =	**Acceptable**
		Minimum thickness per UG-45 [in] = **Acceptable**	**0.358**

Area Replacement:

Ar [in^2] =	Di*Treq*1+2*tn*Treq*1*(1-fr1) required area for internal pressure		
		24.06*1.353*1+2*1.095*1.353*1*(1-0.935) =	**32.748**
A11 [in^2] =	Di*(E1*(t-sca)-1*Treq)-2*tn*(E1*(t-sca)-1*Treq)*(1-fr1)		
	24.06*(1*(1.48-0.03)-1*1.353)-2*1.095*(1*(1.48-0.03)-1*1.353)*(1-0.935) =		**2.319**
A12 [in^2] =	2*(t-sca+tn)*(E1*(t-sca)-1*Treq)-2*tn*(E1*(t-sca)-1*Treq)*(1-fr1)		
	2*(1.48-0.03+1.095)*(1*(1.48-0.03)-1*1.353)-2*1.095*(1*(1.48-0.03)-1*1.353)*(1-0.935) =		**0.480**
A1 [in^2] =	MAX(0,A11,A12)	MAX(0,2.319,0.48) =	**2.319**
A21 [in^2] =	5*(tn-trnR)*fr2*(t-sca)		
		5*(1.095-0.068)*0.935*(1.48-0.03) =	**6.960**
A22 [in^2] =	2*(tn-trnR)*(2.5*tn+te)*fr2		
		2*(1.095-0.068)*(2.5*1.095+5.465)*0.935 =	**15.749**
A2 [in^2] =	MIN(A21,A22)	MIN(6.96,15.749) =	**6.960**
A3 [in^2] =	MAX(0,MIN(5*(t-sca)*ti*fr2,5*ti*ti*fr2,2*h*ti*fr2))		
	MAX(0,MIN(5*(1.48-0.03)*1.065*0.935,5*1.065*1.065*0.935,2*-0.03*1.065*0.935)) =		**0**
A5 [in^2] =	(Dp-Di-2*tn)*te*fr4	(33-24.06-2*1.095)*5.465*0.935 =	**31.920**
A41 [in^2] =	Leg41^2*fr3	0.375^2*0.935 =	**0.131**
A42 [in^2] =	0	0 =	**0.000**
A43 [in^2] =	0	0 =	**0.000**
Aa [in^2] =	A1+A2+A3+A5+A41+A42+A43 actual area for internal pressure		
		2.319+6.96+0+31.92+0.131+0+0 =	**41.330**
CheckA =	Aa >= Ar check area replacement	41.33 >= 32.748 =	**Acceptable**
Are [in^2] =	0.5*(Di*Treqe*1+2*tn*Treqe*1*(1-fr1)) required area for external presure		
		0.5*(24.06*1.07*1+2*1.095*1.07*1*(1-0.935)) =	**12.948**
A11e [in^2] =	Di*(E1*(t-sca)-1*Treqe)-2*tn*(E1*(t-sca)-1*Treqe)*(1-fr1)		
	24.06*(1*(1.48-0.03)-1*1.07)-2*1.095*(1*(1.48-0.03)-1*1.07)*(1-0.935) =		**9.091**
A12e [in^2] =	2*(t-sca+tn)*(E1*(t-sca)-1*Treqe)-2*tn*(E1*(t-sca)-1*Treqe)*(1-fr1)		
	2*(1.48-0.03+1.095)*(1*(1.48-0.03)-1*1.07)-2*1.095*(1*(1.48-0.03)-1*1.07)*(1-0.935) =		**1.880**
A1e [in^2] =	MAX(0,A11e,A12e)	MAX(0,9.091,1.88) =	**9.091**
A21e [in^2] =	5*(tn-TreqNE)*fr2*(t-sca)		
		5*(1.095-0.056)*0.935*(1.48-0.03) =	**7.040**
A22e [in^2] =	2*(tn-TreqNE)*(2.5*tn+te)*fr2		
		2*(1.095-0.056)*(2.5*1.095+5.465)*0.935 =	**15.930**
A2e [in^2] =	MIN(A21e,A22e)	MIN(7.04,15.93) =	**7.040**
Aae [in^2] =	A1e+A2e+A3+A5+A41+A42+A43 actual area for external pressure		
		9.091+7.04+0+31.92+0.131+0+0 =	**48.182**
CheckA =	Aae >= Are check area replacement	48.182 >= 12.948 =	**Acceptable**

Weld Check:

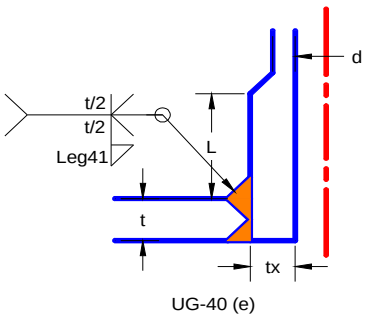
tc41 [in] =	MIN(0.25,0.7*MIN(0.75,tn,te))	MIN(0.25,0.7*MIN(0.75,1.095,5.465)) =	**0.250**
Check41 =	0.7*Leg41 >= tc41	0.7*0.375 >= 0.25 =	**Acceptable**

VIII-1-Nozzle Reinforcement ver 4.00

N1 In Top Cap **Description**

Shell Inputs:

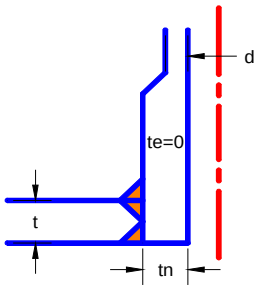
SA-299	**Material**
21,400	**Sv** [psi] - allowable stress
1.00	**E1** - efficiency of shell at nozzle
720.000	**Ds** [in] - inside diameter of shell
1.480	**t** [in] - nominal shell wall thickness
1.353	**Treq** [in] - required shell wall thickness
1.070	**Treqe** [in] - required shell wall thickness external
0.030	**sca** [in] - shell corrosion allowance
0.094	**tUG16(b)** [in] - minimum thickness per UG-16 b



UG-40 (e)

Nozzle Inputs:

No Projection	**Internal** Projection
SA-350 LF2	**Material**
20,000	**Sn** [psi] - allowable stress
1.00	**E** - nozzle efficiency
1.37	**tx** [in] - nozzle thickness
5.00	**L** [in] - length of larger diameter section
5.76	**d** [in] - I.D. of nozzle
8.50	**ds** [in] - O.D. of nozzle (reduced)
4.000	**Lp** [in] - exterior projection of nozzle
0.000	**lp** [in] - interior projection of nozzle
0.030	**nca** [in] - nozzle corrosion allowance
0.0%	**UTP** [%] - undertolerance allowance
112.0	**P** [psi] - interior pressure
15.0	**Pa** [psi] - exterior pressure
CS2	**Chart** - external pressure chart
300.0	**Temp** [F] - temperature for external pressure



UG-40 (e-2)

Reinforcement:

0.375	**Leg41** [in] - fillet size	
e1 =	if(L<(2.5*tx),"e-1","e-2")	**e-2**
e-2	**Configuration**	
tn =	tx-nca	1.37-0.03 = **1.340**
Do =	d+(tx * 2)	5.76+(1.37 * 2) = **8.500**
Di =	Do-2*tn	8.5-2*1.34 = **5.820**
te =	0 Repad Thickness	
Dp =	0 Repad OD	0 = **0**

Variables:

UT [in] =	tn*UTP	1.34*0 = **0.000**
Rn [in] =	Do/2 - (tn-nca) + UT	8.5/2 - (1.34-0.03) + 0 = **2.940**
ti [in] =	tn-nca	1.34-0.03 = **1.310**
h [in] =	MIN(lp-sca,2.5*(t-sca),2.5*ti)	MIN(0-0.03,2.5*(1.48-0.03),2.5*1.31) = **-0.030**

Required Thickness: UG-27(c)(1,2)

TreqN [in] =	(P*Rn)/(Sn*E - 0.6*P) required minimum thickness	(112*2.94)/(20000*1 - 0.6*112) = **0.017**
trnR [in] =	(P*Rn)/(Sn*1 - 0.6*P)	(112*2.94)/(20000*1 - 0.6*112) = **0.017**
B =	PVELookup("BbChart","BbLookup",Chart,Temp,Do,Pa,Lp/Do)	**4864**
TreqNE [in] =	(3*Do*Pa)/(4*B) required minimum external	(3*8.5*15)/(4*4864) = **0.020**
CheckTreqN =	MIN(TreqN,TreqNE) <= tn	MIN(0.017,0.02) <= 1.34 = **Acceptable**

UG-45:

Tstd [in] =	vlookup(Do,PipeWall,2)	vlookup(8.5,PIpeWall,2) =	**0.280**
Nact [in] =	(tn+nca) * (1-UTP)	(1.34+0.03) * (1-0) =	**1.370**
Swre [in] =	Treq*Pa/P	1.353*15/112 =	**0.181**
UG45b4 [in] =	Tstd*0.875 + nca	0.28*0.875 + 0.03 =	**0.275**
UG45b3 [in] =	Max(UG45b1,UG45b2)	MAX(1.383,0.211) =	**1.383**
UG45b2 [in] =	Max(Swre+sca,tUG16(b)+sca)	MAX(0.181+0.03,0.094+0.03) =	**0.211**
UG45b1 [in] =	Max(Treq+sca,tUG16(b) + sca)	MAX(1.353+0.03,0.094 + 0.03) =	**1.383**
UG45b [in] =	Min(UG45b3,UG45b4)	MIN(1.383,0.275) =	**0.275**
UG45a [in] =	MAX(TreqN,TreqNE) + nca	MAX(0.017,0.02) + 0.03 =	**0.050**
UG45 [in] =	Max(UG45a, UG45b) required thickness per UG-45	MAX(0.05, 0.275) =	**0.275**
CheckUG45 =	UG45 <= Nact	0.275 <= 1.37 =	**Acceptable**
		Minimum thickness per UG-45 [in] =	**Acceptable** **0.275**

Area Replacement:

Ar [in^2] =	Di*Treq*1+2*tn*Treq*1*(1-fr1) required area for internal pressure	5.82*1.353*1+2*1.34*1.353*1*(1-0.935) =	**8.112**
A11 [in^2] =	Di*(E1*(t-sca)-1*Treq)-2*tn*(E1*(t-sca)-1*Treq)*(1-fr1)	5.82*(1*(1.48-0.03)-1*1.353)-2*1.34*(1*(1.48-0.03)-1*1.353)*(1-0.935) =	**0.547**
A12 [in^2] =	2*(t-sca+tn)*(E1*(t-sca)-1*Treq)-2*tn*(E1*(t-sca)-1*Treq)*(1-fr1)	2*(1.48-0.03+1.34)*(1*(1.48-0.03)-1*1.353)-2*1.34*(1*(1.48-0.03)-1*1.353)*(1-0.935) =	**0.524**
A1 [in^2] =	MAX(0,A11,A12)	MAX(0,0.547,0.524) =	**0.547**
A21 [in^2] =	5*(tn-trnR)*fr2*(t-sca)	5*(1.34-0.017)*0.935*(1.48-0.03) =	**8.968**
A22 [in^2] =	2*(tn-trnR)*(2.5*tn+te)*fr2	2*(1.34-0.017)*(2.5*1.34+0)*0.935 =	**8.287**
A2 [in^2] =	MIN(A21,A22)	MIN(8.968,8.287) =	**8.287**
A3 [in^2] =	MAX(0,MIN(5*(t-sca)*ti*fr2,5*ti*ti*fr2,2*h*ti*fr2))	MAX(0,MIN(5*(1.48-0.03)*1.31*0.935,5*1.31*1.31*0.935,2*-0.03*1.31*0.935)) =	**0**
A5 [in^2] =	(Dp-Di-2*tn)*te*fr4	(0-5.82-2*1.34)*0*0.935 =	**0.000**
A41 [in^2] =	Leg41^2*fr3	0.375^2*0.935 =	**0.131**
A42 [in^2] =	0	0 =	**0.000**
A43 [in^2] =	0	0 =	**0.000**
Aa [in^2] =	A1+A2+A3+A5+A41+A42+A43 actual area for internal pressure	0.547+8.287+0+0+0.131+0+0 =	**8.966**
CheckA =	Aa >= Ar check area replacement	8.966 >= 8.112 =	**Acceptable**
Are [in^2] =	0.5*(Di*Treqe*1+2*tn*Treqe*1*(1-fr1)) required area for external presure	0.5*(5.82*1.07*1+2*1.34*1.07*1*(1-0.935)) =	**3.207**
A11e [in^2] =	Di*(E1*(t-sca)-1*Treqe)-2*tn*(E1*(t-sca)-1*Treqe)*(1-fr1)	5.82*(1*(1.48-0.03)-1*1.07)-2*1.34*(1*(1.48-0.03)-1*1.07)*(1-0.935) =	**2.146**
A12e [in^2] =	2*(t-sca+tn)*(E1*(t-sca)-1*Treqe)-2*tn*(E1*(t-sca)-1*Treqe)*(1-fr1)	2*(1.48-0.03+1.34)*(1*(1.48-0.03)-1*1.07)-2*1.34*(1*(1.48-0.03)-1*1.07)*(1-0.935) =	**2.054**
A1e [in^2] =	MAX(0,A11e,A12e)	MAX(0,2.146,2.054) =	**2.146**
A21e [in^2] =	5*(tn-TreqNE)*fr2*(t-sca)	5*(1.34-0.02)*0.935*(1.48-0.03) =	**8.946**
A22e [in^2] =	2*(tn-TreqNE)*(2.5*tn+te)*fr2	2*(1.34-0.02)*(2.5*1.34+0)*0.935 =	**8.268**
A2e [in^2] =	MIN(A21e,A22e)	MIN(8.946,8.268) =	**8.268**
Aae [in^2] =	A1e+A2e+A3+A5+A41+A42+A43 actual area for external pressure	2.146+8.268+0+0+0.131+0+0 =	**10.545**
CheckA =	Aae >= Are check area replacement	10.545 >= 3.207 =	**Acceptable**

Weld Check:

tc41 [in] =	MIN(0.25,0.7*MIN(0.75,tn,te))	MIN(0.25,0.7*MIN(0.75,1.34,0)) =	**0.250**
Check41 =	0.7*Leg41 >= tc41	0.7*0.375 >= 0.25 =	**Acceptable**

Propane/Butane Sphere <- Vessel

N2 in Top Cap <- Description

Shell:

SA-299 <- Shell Material

21,400 <- Sv, shell allowable stress level, PSI

1.00 <- E1, efficiency of shell at nozzle

1.480 <- Vt, shell wall thick, uncorroded, UT removed

1.353 <- tr, required shell wall thickness int. press.(E=1)

1.070 <- trE, required shell wall thickness ext. press.(E=1)

0.0300 <- sca, shell corrosion allowance

0.094 <- tmin16b, Min allowed wall per UG-16(b)

Nozzle:

SA-106 B <- Nozzle Material

17,100 <- Sn, allowable stress level (Sn)

1.00 <- E, nozzle efficiency

112.0 <- P, internal design pressure

15.0 <- Pa, external design pressure

1.900 <- Do, outside diameter

0.200 <- Nt, wall thick, uncorroded

12.5% <- UTp, undertolerance (%)

0.0300 <- nca, nozzle corrosion allowance

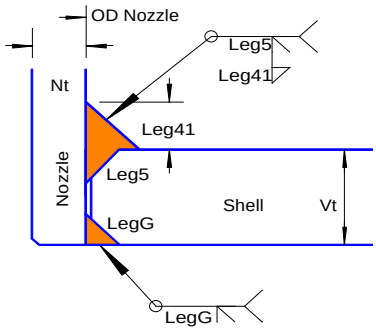
5.000 <- L, exterior Projection

Reinforcing:

0.250 <- Leg41, size of weld fillet

0.125 <- LegG, depth of groove

0.000 <- Leg5, depth of groove



UW-16.1 (j) modified

Variables:

UT =	Nt*UTp	= 0.2 * 0.125	*Undertolerance*	UT =	***0.025***
Rn =	Do/2 - (Nt-nca) + UT	= 1.9/2 - (0.2-0.03) + 0.025	*Effective Radius*	Rn =	***0.805***
t =	Vt-sca	= 1.48 - 0.03	*Effective Shell Thickness*	t =	***1.450***
ti =	Nt-2*nca	= 0.2 - 2 * 0.03	*Nom Thick of Int. Proj.*	ti =	***0.140***
tn =	Nt-nca	= 0.2-0.03	*Avail. Nozzle Thick. No UT*	tn =	***0.170***
d =	Do-2*tn	= 1.9 - 2*0.17	*Opening Dia.*	d =	***1.560***
fr1 =	MIN(Sn/Sv,1)	= MIN(17100/21400, 1)		fr1 =	***0.799***
fr2 =	MIN(Sn/Sv,1)	= MIN(17100/21400, 1)		fr2 =	***0.799***
h =	MIN(lp-sca,2.5*t,2.5*ti)	= MIN(0-0.03,2.5*1.45,2.5*0.14)		h =	***-0.030***
F =	1.000			F =	***1.000***
Tmin =	Min(0.75,t,tn)	= Min(0.75,1.45,0.17)		Tmin =	***0.170***

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

B =	PVELookup("BbChart","BbLookup",chart,extTemp,Do,Pa,Ldo)			B =	**2,399**	
trn =	(P*Rn)/(Sn*E - 0.6*P) <= tn-UT	= (112*0.805)/(17100*1 - 0.6*112)		trn =	***0.005***	**Acceptable**
trnR =	(P*Rn)/(Sn*1 - 0.6*P)	= (112*0.805)/(17100*1 - 0.6*112)	*E=1*	trnR =	***0.005***	
trnE =	(3*Do*Pa)/(4*B) <= tn-ut	= (3*1.9*15)/(4*2399)		trnE =	***0.009***	**Acceptable**

Geometry Constraints:

0.7*Leg41 >=	Min(0.25,0.7*Tmin)	0.7*0.25 >=	Min(0.25,0.7*0.17)	***0.175***	>=	***0.119***	**Acceptable**
LegG >=	Min(0.25,0.7*Tmin)	0.125 >=	Min(0.25,0.7*0.17)	***0.125***	>=	***0.119***	**Acceptable**
Tmin*1.25 <=	0.7*Leg41+LegG	0.17 * 1.25 <=	0.7*0.25 + 0.125	***0.213***	<=	***0.300***	**Acceptable**

Area reinforcement calculation exemptions: UG-36(c)(3)(a)

d = 1.56 *net opening diameter* ***Not Required*** d = ***1.560***

IF(Max(tr,trE)>0.375", if(d>2.375", "reinforcement calculations required", "not required"), if(d>3.5", "required", "not required"))

Internal Weld Load: (UG-41)

WmaxI = (A - A1 + 2*Tn*Fr1*(E1*t-F*tr))*Sv, min0 = (0 - 0 + 2*0.17*0.799*(1*1.45-1*1.353))*21400 WmaxI = ***564***

W_{1-1} = MIN((A2 + A5 + A41 + A42)*Sv,WmaxI) = MIN((0 + 0 + 0 + 0)*21400,564) W_{1-1} = ***0***

W_{2-2} = Min((A2 + A3 + A41 + A43 + 2*Tn*t*frone)*Sv,WmaxI) = Min((0 + 0 + 0 + 0 + 2*0.17*1.45*0.799)* W_{2-2} = ***564***

External Weld Load: (UG-41)

WmaxE = (Ae - A1e + 2*Tn*Fr1*(E1*t-F*tr))*Sv, min0 = (0 - 0 + 2*0.17*0.799*(1*1.45-1*1.353))*21400 WmaxE = ***564***

W1-1 = MIN((A2e + A5 + A41 + A42)*Sv,WmaxE) *Weld load* W_{1-1e} = ***0***

= MIN((0 + 0 + 0 + 0)*21400,563.797)

W_{2-2} = Min((A2e + A3 + A41 + A43 + 2*Tn*t*frone)*Sv,WmaxE) = Min((0 + 0 + 0 + 0 + 2*0.17*1.45*0.799)* W_{2-2e} = ***564***

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

A2 shear = PI()/2*(Do-tn)*tn*Sn*0.7 = PI()/2*(1.9-0.17)*0.17*17100*0.7 A2s = ***5,530***

g tension = PI()/2*Do*LegG*Min(Sv,Sn)*0.74 = PI()/2*1.9*0.125*Min(21400,17100)*0.74 gt = ***4,721***

A41 shear = PI()/2*Do*Leg41*Min(Sv,Sn)*0.49 = PI()/2*1.9*0.25*Min(21400,17100)*0.49 A41s = ***6,252***

Leg 5 tens = PI()/2*Do*Leg5*Min(Sv,Sn)*0.74 = PI()/2*1.9*0*Min(21400,17100)*0.74 Leg5t = ***0***

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

S_{1-1} = A41s + A2s >= W1-1 **Acceptable** S_{1-1} = **11,782**

= 6252 + 5530 >= 0

S_{2-2} = A41s + gt + Leg5t + A43s >= W2-2 **Acceptable** S_{2-2} = **10,222**

= 6252 + 4721 + 0 + -750 >= 564

Tstd = Standard pipe wall thickness from chart Tstd = ***0.145***

Swre = tr * Pa / P = 1.353 * 15 / 112 *Req. Exterior pressure* Swre = ***0.181***

Nact = Nt * (1-UTp) = 0.2 * (1-0.125) *Actual Wall Thick.* Nact = ***0.175***

Tt = 0.8/Nth = 0.8/0 *Ug-31(c)(2) threads* Tt = ***0.000***

UG-45 **Acceptable**

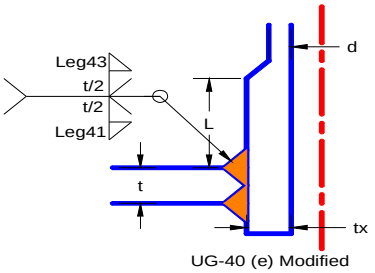
UG45 =	Max(UG45a, UG45b) <= Nact	= Max(0.039, 0.157) <= 0.175	UG45 = ***0.157***
UG45a =	Max(trn,trnE) + Nca + Tt	= Max(0.005,0.009) + 0.03 + 0	UG45a = ***0.039***
UG45b =	Min(UG45b3,UG45b4)	= Min(1.383, 0.157)	UG45b = ***0.157***
UG45b1 =	Max(tr + Sca, tmin16b + Sca)	= Max(1.353 + 0.03, 0.094 + 0.03)	UG45b1 = ***1.383***
UG45b2 =	Max(Swre + Sca,tmin16b + Sca)	= Max(0.181 + 0.03,0.094 + 0.03)	UG45b2 = ***0.211***
UG45b3 =	Max(UG45b1,UG45b2)	= Max(1.383,0.211)	UG45b3 = ***1.383***
UG45b4 =	Tstd*0.875 + Nca	= 0.145*0.875 + 0.03	UG45b4 = ***0.157***

VIII-1-Nozzle Reinforcement ver 4.00

N3 In Top Cap **Description**

Shell Inputs:

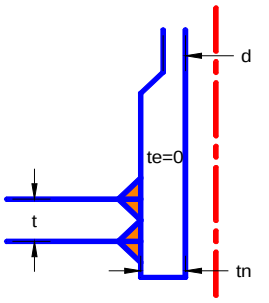
SA-299	**Material**	
21,400	**Sv** [psi] - allowable stress	
1.00	**E1** - efficiency of shell at nozzle	
720.000	**Ds** [in] - inside diameter of shell	
1.480	**t** [in] - nominal shell wall thickness	
1.353	**Treq** [in] - required shell wall thickness	
1.070	**Treqe** [in] - required shell wall thickness external	
0.030	**sca** [in] - shell corrosion allowance	
0.094	**tUG16(b)** [in] - minimum thickness per UG-16 b	



UG-40 (e) Modified

Nozzle Inputs:

Projection	**Internal** Projection	
SA-350 LF2	**Material**	
20,000	**Sn** [psi] - allowable stress	
1.00	**E** - nozzle efficiency	
1.37	**tx** [in] - nozzle thickness	
5.00	**L** [in] - length of larger diameter section	
5.76	**d** [in] - I.D. of nozzle	
6.63	**ds** [in] - O.D. of nozzle (reduced)	
4.000	**Lp** [in] - exterior projection of nozzle	
0.438	**Ip** [in] - interior projection of nozzle	
0.030	**nca** [in] - nozzle corrosion allowance	
0.0%	**UTP** [%] - undertolerance allowance	
112.0	**P** [psi] - interior pressure	
15.0	**Pa** [psi] - exterior pressure	
CS2	**Chart** - external pressure chart	
300.0	**Temp** [F] - temperature for external pressure	



UG-40 (e-2) Modified

Reinforcement:

0.375	**Leg41** [in] - fillet size		
0.438	**Leg43** [in] - fillet size		
e1 =	if(L<(2.5*tx),"e-1","e-2")		**e-2**
e-2	**Configuration**		
tn =	tx-nca	1.37-0.03 =	**1.340**
Do =	d+(tx * 2)	5.76+(1.37 * 2) =	**8.500**
Di =	Do-2*tn	8.5-2*1.34 =	**5.821**
te =	0 Repad Thickness		
Dp =	0 Repad OD	0 =	**0**

Variables:

UT [in] =	tn*UTP	1.34*0 =	**0.000**
Rn [in] =	Do/2 - (tn-nca) + UT	8.5/2 - (1.34-0.03) + 0 =	**2.941**
ti [in] =	tn-nca	1.34-0.03 =	**1.310**
h [in] =	MIN(Ip-sca,2.5*(t-sca),2.5*ti)		
		MIN(0.438-0.03,2.5*(1.48-0.03),2.5*1.31) =	**0.408**

Required Thickness: UG-27(c)(1,2)

TreqN [in] =	(P*Rn)/(Sn*E - 0.6*P) required minimum thickness		
		(112*2.941)/(20000*1 - 0.6*112) =	**0.017**
trnR [in] =	(P*Rn)/(Sn*1 - 0.6*P)	(112*2.941)/(20000*1 - 0.6*112) =	**0.017**
B =	PVELookup("BbChart","BbLookup",Chart,Temp,Do,Pa,Lp/Do)		**4864**
TreqNE [in] =	(3*Do*Pa)/(4*B) required minimum external	(3*8.5*15)/(4*4864) =	**0.020**
CheckTreqN =	MIN(TreqN,TreqNE) <= tn	MIN(0.017,0.02) <= 1.34 =	**Acceptable**

UG-45:

Tstd [in] =	vlookup(Do,PipeWall,2)	vlookup(8.5,PIpeWall,2) =	**0.280**
Nact [in] =	(tn+nca) * (1-UTP)	(1.34+0.03) * (1-0) =	**1.370**
Swre [in] =	Treq*Pa/P	1.353*15/112 =	**0.181**
UG45b4 [in] =	Tstd*0.875 + nca	0.28*0.875 + 0.03 =	**0.275**
UG45b3 [in] =	Max(UG45b1,UG45b2)	MAX(1.383,0.211) =	**1.383**
UG45b2 [in] =	Max(Swre+sca,tUG16(b)+sca)	MAX(0.181+0.03,0.094+0.03) =	**0.211**
UG45b1 [in] =	Max(Treq+sca,tUG16(b) + sca)	MAX(1.353+0.03,0.094 + 0.03) =	**1.383**
UG45b [in] =	Min(UG45b3,UG45b4)	MIN(1.383,0.275) =	**0.275**
UG45a [in] =	MAX(TreqN,TreqNE) + nca	MAX(0.017,0.02) + 0.03 =	**0.050**
UG45 [in] =	Max(UG45a, UG45b) required thickness per UG-45	MAX(0.05, 0.275) =	**0.275**
CheckUG45 =	UG45 <= Nact	0.275 <= 1.37 =	**Acceptable**
		Minimum thickness per UG-45 [in] = **Acceptable**	**0.275**

Area Replacement:

Ar [in^2] =	Di*Treq*1+2*tn*Treq*1*(1-fr1) required area for internal pressure	5.821*1.353*1+2*1.34*1.353*1*(1-0.935) =	**8.113**
A11 [in^2] =	Di*(E1*(t-sca)-1*Treq)-2*tn*(E1*(t-sca)-1*Treq)*(1-fr1)	5.821*(1*(1.48-0.03)-1*1.353)-2*1.34*(1*(1.48-0.03)-1*1.353)*(1-0.935) =	**0.547**
A12 [in^2] =	2*(t-sca+tn)*(E1*(t-sca)-1*Treq)-2*tn*(E1*(t-sca)-1*Treq)*(1-fr1)	2*(1.48-0.03+1.34)*(1*(1.48-0.03)-1*1.353)-2*1.34*(1*(1.48-0.03)-1*1.353)*(1-0.935) =	**0.524**
A1 [in^2] =	MAX(0,A11,A12)	MAX(0,0.547,0.524) =	**0.547**
A21 [in^2] =	5*(tn-trnR)*fr2*(t-sca)	5*(1.34-0.017)*0.935*(1.48-0.03) =	**8.964**
A22 [in^2] =	2*(tn-trnR)*(2.5*tn+te)*fr2	2*(1.34-0.017)*(2.5*1.34+0)*0.935 =	**8.281**
A2 [in^2] =	MIN(A21,A22)	MIN(8.964,8.281) =	**8.281**
A3 [in^2] =	MAX(0,MIN(5*(t-sca)*ti*fr2,5*ti*ti*fr2,2*h*ti*fr2))	MAX(0,MIN(5*(1.48-0.03)*1.31*0.935,5*1.31*1.31*0.935,2*0.408*1.31*0.935)) =	**0.997422897**
A5 [in^2] =	(Dp-Di-2*tn)*te*fr4	(0-5.821-2*1.34)*0*0.935 =	**0.000**
A41 [in^2] =	Leg41^2*fr3	0.375^2*0.935 =	**0.131**
A42 [in^2] =	0	0 =	**0.000**
A43 [in^2] =	(Leg43-nca)^2*fr2	(0.438-0.03)^2*0.935 =	**0.155**
Aa [in^2] =	A1+A2+A3+A5+A41+A42+A43 actual area for internal pressure	0.547+8.281+1+0+0.131+0+0.155 =	**10.112**
CheckA =	Aa >= Ar check area replacement	10.112 >= 8.113 =	**Acceptable**
Are [in^2] =	0.5*(Di*Treqe*1+2*tn*Treqe*1*(1-fr1)) required area for external presure	0.5*(5.821*1.07*1+2*1.34*1.07*1*(1-0.935)) =	**3.208**
A11e [in^2] =	Di*(E1*(t-sca)-1*Treqe)-2*tn*(E1*(t-sca)-1*Treqe)*(1-fr1)	5.821*(1*(1.48-0.03)-1*1.07)-2*1.34*(1*(1.48-0.03)-1*1.07)*(1-0.935) =	**2.146**
A12e [in^2] =	2*(t-sca+tn)*(E1*(t-sca)-1*Treqe)-2*tn*(E1*(t-sca)-1*Treqe)*(1-fr1)	2*(1.48-0.03+1.34)*(1*(1.48-0.03)-1*1.07)-2*1.34*(1*(1.48-0.03)-1*1.07)*(1-0.935) =	**2.054**
A1e [in^2] =	MAX(0,A11e,A12e)	MAX(0,2.146,2.054) =	**2.146**
A21e [in^2] =	5*(tn-TreqNE)*fr2*(t-sca)	5*(1.34-0.02)*0.935*(1.48-0.03) =	**8.943**
A22e [in^2] =	2*(tn-TreqNE)*(2.5*tn+te)*fr2	2*(1.34-0.02)*(2.5*1.34+0)*0.935 =	**8.261**
A2e [in^2] =	MIN(A21e,A22e)	MIN(8.943,8.261) =	**8.261**
Aae [in^2] =	A1e+A2e+A3+A5+A41+A42+A43 actual area for external pressure	2.146+8.261+1+0+0.131+0+0.155 =	**11.691**
CheckA =	Aae >= Are check area replacement	11.691 >= 3.208 =	**Acceptable**

Weld Check:

tc41 [in] =	MIN(0.25,0.7*MIN(0.75,tn,te))	MIN(0.25,0.7*MIN(0.75,1.34,0)) =	**0.250**
Check41 =	0.7*Leg41 >= tc41	0.7*0.375 >= 0.25 =	**Acceptable**
tc43 [in] =	MIN(0.25,0.7*MIN(0.75,tn))	MIN(0.25,0.7*MIN(0.75,1.34)) =	**0.250**

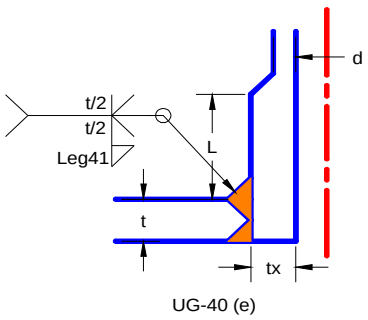
1 **Check43** = 0.7*Leg43-nca >= tc43 0.7*0.438-0.03 >= 0.25 = **Acceptable**

VIII-1-Nozzle Reinforcement ver 4.00

N4 In Bottom Cap **Description**

Shell Inputs:

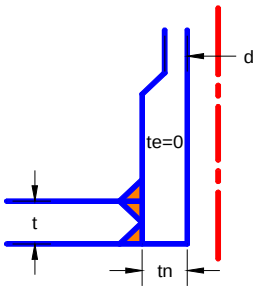
SA-299	**Material**
21,400	**Sv** [psi] - allowable stress
1.00	**E1** - efficiency of shell at nozzle
720.000	**Ds** [in] - inside diameter of shell
1.480	**t** [in] - nominal shell wall thickness
1.479	**Treq** [in] - required shell wall thickness
1.070	**Treqe** [in] - required shell wall thickness external
0.030	**sca** [in] - shell corrosion allowance
0.094	**tUG16(b)** [in] - minimum thickness per UG-16 b



UG-40 (e)

Nozzle Inputs:

No Projection	**Internal** Projection
SA-350 LF2	**Material**
20,000	**Sn** [psi] - allowable stress
1.00	**E** - nozzle efficiency
1.75	**tx** [in] - nozzle thickness
4.50	**L** [in] - length of larger diameter section
1.50	**d** [in] - I.D. of nozzle
2.63	**ds** [in] - O.D. of nozzle (reduced)
5.000	**Lp** [in] - exterior projection of nozzle
0.000	**lp** [in] - interior projection of nozzle
0.030	**nca** [in] - nozzle corrosion allowance
0.0%	**UTP** [%] - undertolerance allowance
172.1	**P** [psi] - interior pressure
15.0	**Pa** [psi] - exterior pressure
CS2	**Chart** - external pressure chart
300.0	**Temp** [F] - temperature for external pressure



UG-40 (e-2)

Reinforcement:

0.375	**Leg41** [in] - fillet size		
e1 =	if(L<(2.5*tx),"e-1","e-2")		**e-2**
e-2	**Configuration**		
tn =	tx-nca	1.75-0.03 =	**1.720**
Do =	d+(tx * 2)	1.5+(1.75 * 2) =	**5.000**
Di =	Do-2*tn	5-2*1.72 =	**1.560**
te =	0 Repad Thickness		
Dp =	0 Repad OD	0 =	**0**

Variables:

UT [in] =	tn*UTP	1.72*0 =	**0.000**
Rn [in] =	Do/2 - (tn-nca) + UT	5/2 - (1.72-0.03) + 0 =	**0.810**
ti [in] =	tn-nca	1.72-0.03 =	**1.690**
h [in] =	MIN(lp-sca,2.5*(t-sca),2.5*ti)		
		MIN(0-0.03,2.5*(1.48-0.03),2.5*1.69) =	**-0.030**

Required Thickness: UG-27(c)(1,2)

TreqN [in] =	(P*Rn)/(Sn*E - 0.6*P) required minimum thickness		
		(172.1*0.81)/(20000*1 - 0.6*172.1) =	**0.007**
trnR [in] =	(P*Rn)/(Sn*1 - 0.6*P)	(172.1*0.81)/(20000*1 - 0.6*172.1) =	**0.007**
B =	PVELookup("BbChart","BbLookup",Chart,Temp,Do,Pa,Lp/Do)		**3505**
TreqNE [in] =	(3*Do*Pa)/(4*B) required minimum external	(3*5*15)/(4*3505) =	**0.016**
CheckTreqN =	MIN(TreqN,TreqNE) <= tn	MIN(0.007,0.016) <= 1.72 =	**Acceptable**

UG-45:

Tstd [in] =	vlookup(Do,PipeWall,2)	vlookup(5,PIpeWall,2) =	**0.237**
Nact [in] =	(tn+nca) * (1-UTP)	(1.72+0.03) * (1-0) =	**1.750**
Swre [in] =	Treq*Pa/P	1.479*15/172.1 =	**0.129**
UG45b4 [in] =	Tstd*0.875 + nca	0.237*0.875 + 0.03 =	**0.237**
UG45b3 [in] =	Max(UG45b1,UG45b2)	MAX(1.509,0.159) =	**1.509**
UG45b2 [in] =	Max(Swre+sca,tUG16(b)+sca)	MAX(0.129+0.03,0.094+0.03) =	**0.159**
UG45b1 [in] =	Max(Treq+sca,tUG16(b) + sca)	MAX(1.479+0.03,0.094 + 0.03) =	**1.509**
UG45b [in] =	Min(UG45b3,UG45b4)	MIN(1.509,0.237) =	**0.237**
UG45a [in] =	MAX(TreqN,TreqNE) + nca	MAX(0.007,0.016) + 0.03 =	**0.046**
UG45 [in] =	Max(UG45a, UG45b) required thickness per UG-45	MAX(0.046, 0.237) =	**0.237**
CheckUG45 =	UG45 <= Nact	0.237 <= 1.75 =	**Acceptable**
		Minimum thickness per UG-45 [in] = **Acceptable**	**0.237**

Area Replacement:

Ar [in^2] =	Di*Treq*1+2*tn*Treq*1*(1-fr1) required area for internal pressure	1.56*1.479*1+2*1.72*1.479*1*(1-0.935) =	**2.639**
A11 [in^2] =	Di*(E1*(t-sca)-1*Treq)-2*tn*(E1*(t-sca)-1*Treq)*(1-fr1)	1.56*(1*(1.48-0.03)-1*1.479)-2*1.72*(1*(1.48-0.03)-1*1.479)*(1-0.935) =	**-0.038**
A12 [in^2] =	2*(t-sca+tn)*(E1*(t-sca)-1*Treq)-2*tn*(E1*(t-sca)-1*Treq)*(1-fr1)	2*(1.48-0.03+1.72)*(1*(1.48-0.03)-1*1.479)-2*1.72*(1*(1.48-0.03)-1*1.479)*(1-0.935) =	**-0.175**
A1 [in^2] =	MAX(0,A11,A12)	MAX(0,-0.038,-0.175) =	**0.000**
A21 [in^2] =	5*(tn-trnR)*fr2*(t-sca)	5*(1.72-0.007)*0.935*(1.48-0.03) =	**11.607**
A22 [in^2] =	2*(tn-trnR)*(2.5*tn+te)*fr2	2*(1.72-0.007)*(2.5*1.72+0)*0.935 =	**13.768**
A2 [in^2] =	MIN(A21,A22)	MIN(11.607,13.768) =	**11.607**
A3 [in^2] =	MAX(0,MIN(5*(t-sca)*ti*fr2,5*ti*ti*fr2,2*h*ti*fr2))	MAX(0,MIN(5*(1.48-0.03)*1.69*0.935,5*1.69*1.69*0.935,2*-0.03*1.69*0.935)) =	**0**
A5 [in^2] =	(Dp-Di-2*tn)*te*fr4	(0-1.56-2*1.72)*0*0.935 =	**0.000**
A41 [in^2] =	Leg41^2*fr3	0.375^2*0.935 =	**0.131**
A42 [in^2] =	0	0 =	**0.000**
A43 [in^2] =	0	0 =	**0.000**
Aa [in^2] =	A1+A2+A3+A5+A41+A42+A43 actual area for internal pressure	0+11.607+0+0+0.131+0+0 =	**11.738**
CheckA =	Aa >= Ar check area replacement	11.738 >= 2.639 =	**Acceptable**
Are [in^2] =	0.5*(Di*Treqe*1+2*tn*Treqe*1*(1-fr1)) required area for external presure	0.5*(1.56*1.07*1+2*1.72*1.07*1*(1-0.935)) =	**0.955**
A11e [in^2] =	Di*(E1*(t-sca)-1*Treqe)-2*tn*(E1*(t-sca)-1*Treqe)*(1-fr1)	1.56*(1*(1.48-0.03)-1*1.07)-2*1.72*(1*(1.48-0.03)-1*1.07)*(1-0.935) =	**0.507**
A12e [in^2] =	2*(t-sca+tn)*(E1*(t-sca)-1*Treqe)-2*tn*(E1*(t-sca)-1*Treqe)*(1-fr1)	2*(1.48-0.03+1.72)*(1*(1.48-0.03)-1*1.07)-2*1.72*(1*(1.48-0.03)-1*1.07)*(1-0.935) =	**2.324**
A1e [in^2] =	MAX(0,A11e,A12e)	MAX(0,0.507,2.324) =	**2.324**
A21e [in^2] =	5*(tn-TreqNE)*fr2*(t-sca)	5*(1.72-0.016)*0.935*(1.48-0.03) =	**11.545**
A22e [in^2] =	2*(tn-TreqNE)*(2.5*tn+te)*fr2	2*(1.72-0.016)*(2.5*1.72+0)*0.935 =	**13.695**
A2e [in^2] =	MIN(A21e,A22e)	MIN(11.545,13.695) =	**11.545**
Aae [in^2] =	A1e+A2e+A3+A5+A41+A42+A43 actual area for external pressure	2.324+11.545+0+0+0.131+0+0 =	**14.001**
CheckA =	Aae >= Are check area replacement	14.001 >= 0.955 =	**Acceptable**

Weld Check:

tc41 [in] =	MIN(0.25,0.7*MIN(0.75,tn,te))	MIN(0.25,0.7*MIN(0.75,1.72,0)) =	**0.250**
Check41 =	0.7*Leg41 >= tc41	0.7*0.375 >= 0.25 =	**Acceptable**

Propane/Butane Sphere <- Vessel

N5 in Bottom Cap <- Description

Shell:

SA-299 <- Shell Material

21,400 <- Sv, shell allowable stress level, PSI

1.00 <- E1, efficiency of shell at nozzle

1.480 <- Vt, shell wall thick, uncorroded, UT removed

1.479 <- tr, required shell wall thickness int. press.(E=1)

1.070 <- trE, required shell wall thickness ext. press.(E=1)

0.0300 <- sca, shell corrosion allowance

0.094 <- tmin16b, Min allowed wall per UG-16(b)

Nozzle:

SA-106 B <- Nozzle Material

17,100 <- Sn, allowable stress level (Sn)

1.00 <- E, nozzle efficiency

172.1 <- P, internal design pressure

15.0 <- Pa, external design pressure

8.625 <- Do, outside diameter

0.406 <- Nt, wall thick, uncorroded

12.5% <- UTp, undertolerance (%)

0.0300 <- nca, nozzle corrosion allowance

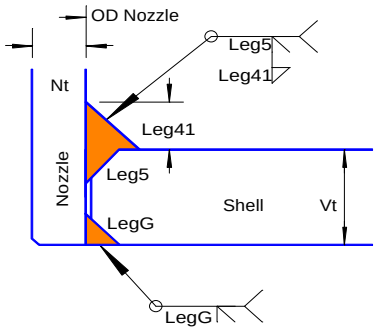
12.000 <- L, exterior Projection

Reinforcing:

0.375 <- Leg41, size of weld fillet

0.375 <- LegG, depth of groove

0.000 <- Leg5, depth of groove



UW-16.1 (j) modified

Variables:

UT =	Nt*UTp	= 0.406 * 0.125	*Undertolerance*	UT =	***0.051***
Rn =	Do/2 - (Nt-nca) + UT	= 8.625/2 - (0.406-0.03) + 0.051	*Effective Radius*	Rn =	***3.987***
t =	Vt-sca	= 1.48 - 0.03	*Effective Shell Thickness*	t =	***1.450***
ti =	Nt-2*nca	= 0.406 - 2 * 0.03	*Nom Thick of Int. Proj.*	ti =	***0.346***
tn =	Nt-nca	= 0.406-0.03	*Avail. Nozzle Thick. No UT*	tn =	***0.376***
d =	Do-2*tn	= 8.625 - 2*0.376	*Opening Dia.*	d =	***7.873***
fr1 =	MIN(Sn/Sv,1)	= MIN(17100/21400, 1)		fr1 =	***0.799***
fr2 =	MIN(Sn/Sv,1)	= MIN(17100/21400, 1)		fr2 =	***0.799***
h =	MIN(lp-sca,2.5*t,2.5*ti)	= MIN(0-0.03,2.5*1.45,2.5*0.346)		h =	***-0.030***
F =	1.000			F =	***1.000***
Tmin =	Min(0.75,t,tn)	= Min(0.75,1.45,0.376)		Tmin =	***0.376***

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

B =	PVELookup("BbChart","BbLookup",chart,extTemp,Do,Pa,Ldo)			B =	**3,133**	
trn =	(P*Rn)/(Sn*E - 0.6*P) <= tn-UT	= (172.1*3.987)/(17100*1 - 0.6*172.1)		trn =	***0.040***	**Acceptable**
trnR =	(P*Rn)/(Sn*1 - 0.6*P)	= (172.1*3.987)/(17100*1 - 0.6*172.1)	*E=1*	trnR =	***0.040***	
trnE =	(3*Do*Pa)/(4*B) <= tn-ut	= (3*8.625*15)/(4*3133)		trnE =	***0.031***	**Acceptable**

Geometry Constraints:

0.7*Leg41 >=	Min(0.25,0.7*Tmin)	0.7*0.375 >=	Min(0.25,0.7*0.376)	***0.263***	>=	***0.250***	**Acceptable**
LegG >=	Min(0.25,0.7*Tmin)	0.375 >=	Min(0.25,0.7*0.376)	***0.375***	>=	***0.250***	**Acceptable**
Tmin*1.25 <=	0.7*Leg41+LegG	0.376 * 1.25 <=	0.7*0.375 + 0.375	***0.470***	<=	***0.638***	**Acceptable**

Area reinforcement calculation exemptions: UG-36(c)(3)(a)

d = 7.873 *net opening diameter* ***Required*** d = ***7.873***

IF(Max(tr,trE)>0.375", if(d>2.375", "reinforcement calculations required", "not required"), if(d>3.5", "required", "not required"))

Internal Weld Load: (UG-41)

WmaxI = (A - A1 + 2*Tn*Fr1*(E1*t-F*tr))*Sv, min0 = (0 - 0 + 2*0.376*0.799*(1*1.45-1*1.479))*21400 WmaxI = ***0***

W_{1-1} = MIN((A2 + A5 + A41 + A42)*Sv,WmaxI) = MIN((0 + 0 + 0 + 0)*21400,0) W_{1-1} = ***0***

W_{2-2} = Min((A2 + A3 + A41 + A43 + 2*Tn*t*frone)*Sv,WmaxI) = Min((0 + 0 + 0 + 0 + 2*0.376*1.45*0.799) W_{2-2} = ***0***

External Weld Load: (UG-41)

WmaxE = (Ae - A1e + 2*Tn*Fr1*(E1*t-F*tr))*Sv, min0 = (0 - 0 + 2*0.376*0.799*(1*1.45-1*1.479))*21400 WmaxE = ***0***

W1-1 = MIN((A2e + A5 + A41 + A42)*Sv,WmaxE) *Weld load* W_{1-1e} = ***0***

= MIN((0 + 0 + 0 + 0)*21400,0)

W_{2-2} = Min((A2e + A3 + A41 + A43 + 2*Tn*t*frone)*Sv,WmaxE) = Min((0 + 0 + 0 + 0 + 2*0.376*1.45*0.799) W_{2-2e} = ***0***

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

A2 shear = PI()/2*(Do-tn)*tn*Sn*0.7 = PI()/2*(8.625-0.376)*0.376*17100*0.7 A2s = ***58,318***

g tension = PI()/2*Do*LegG*Min(Sv,Sn)*0.74 = PI()/2*8.625*0.375*Min(21400,17100)*0.74 gt = ***64,289***

A41 shear = PI()/2*Do*Leg41*Min(Sv,Sn)*0.49 = PI()/2*8.625*0.375*Min(21400,17100)*0.49 A41s = ***42,570***

Leg 5 tens = PI()/2*Do*Leg5*Min(Sv,Sn)*0.74 = PI()/2*8.625*0*Min(21400,17100)*0.74 Leg5t = ***0***

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

S_{1-1} = A41s + A2s >= W1-1 **Acceptable** S_{1-1} = **100,888**

= 42570 + 58318 >= 0

S_{2-2} = A41s + gt + Leg5t + A43s >= W2-2 **Acceptable** S_{2-2} = **103,453**

= 42570 + 64289 + 0 + -3406 >= 0

Tstd = Standard pipe wall thickness from chart Tstd = ***0.322***

Swre = tr * Pa / P = 1.479 * 15 / 172.072 *Req. Exterior pressure* Swre = ***0.129***

Nact = Nt * (1-UTp) = 0.406 * (1-0.125) *Actual Wall Thick.* Nact = ***0.355***

Tt = 0.8/Nth = 0.8/0 *Ug-31(c)(2) threads* Tt = ***0.000***

UG-45 **Acceptable**

UG45 =	Max(UG45a, UG45b) <= Nact	= Max(0.07, 0.312) <= 0.355	UG45 = ***0.312***
UG45a =	Max(trn,trnE) + Nca + Tt	= Max(0.04,0.031) + 0.03 + 0	UG45a = ***0.070***
UG45b =	Min(UG45b3,UG45b4)	= Min(1.509, 0.312)	UG45b = ***0.312***
UG45b1 =	Max(tr + Sca, tmin16b + Sca)	= Max(1.479 + 0.03, 0.094 + 0.03)	UG45b1 = ***1.509***
UG45b2 =	Max(Swre + Sca,tmin16b + Sca)	= Max(0.129 + 0.03,0.094 + 0.03)	UG45b2 = ***0.159***
UG45b3 =	Max(UG45b1,UG45b2)	= Max(1.509,0.159)	UG45b3 = ***1.509***
UG45b4 =	Tstd*0.875 + Nca	= 0.322*0.875 + 0.03	UG45b4 = ***0.312***