Sample Vessel Calculations

These calculation sheets are for educational purposes only. These calculation sheets are recommended for the following:

- Preliminary determination of wall thickness
- Preliminary material estimates
- Estimating volumes and weights

Not all ASME VIII-1 requirement are covered in the calculation sheets

Notes Regarding Sample Vessel Calculations:

- Nozzle N3 is not calculated due to its small size.
- Nozzle N2 uses a thin wall (SCH 5) to demonstrate the use of a repad.

PVE - 3247

17-Feb-09
Revision 0
Ben Vanderloo

Pressure Vessel Engineering Ltd.

Finite Element Analysis – ASME Code Calculations
Canadian Vessel Registration – Vessel Modeling and Drafting

Material Database ver E4.00

Material Properties:

400.0 **Temp** [°F] - maximum design temperature

Material		Ambient Strength	Design Strength	Max ºF	
SA-36	Plate	16,600	16,600	900	**Carbon Steels**
SA-106 B	Seamless Pipe	17,100	17,100	1,000	
SA-234 WPB	Fittings	17,100	17,100	1,000	
SA-105	Forging	20,000	20,000	1,000	
SA-516 70	Plate	20,000	20,000	1,000	
SA-414 G	Sheet	21,400	21,400	900	
SA-213 TP316L	Sms Tube	16,700	15,700	850	**Stainless Steel 316L**
SA-240 316L	Plate	16,700	15,700	850	
SA-312 TP316L	Sms. and Wld. Pipe	16,700	15,700	850	
SA-403 316L	Sms and Weld Fittings	16,700	15,700	850	
SA-479 316L	Bar	16,700	15,700	850	
SA-213 TP316	Sms Tube	20,000	19,300	1,500	**Stainless Steel 316**
SA-240 316	Plate	20,000	19,300	1,500	
SA-312 TP316	Sms. and Wld. Pipe	20,000	19,300	1,500	
SA-403 316	Sms and Weld Fittings	20,000	19,300	1,500	
SA-479 316	Bar	20,000	19,300	1,500	
SA-213 TP304L	Sms Tube	16,700	15,800	1,200	**Stainless Steel 304L**
SA-240 304L	Plate	16,700	15,800	1,200	
SA-312 TP304L	Sms. and Wld. Pipe	16,700	15,800	1,200	
SA-403 304L	Sms and Weld Fittings	16,700	15,800	1,200	
SA-479 304L	Bar	16,700	15,800	1,200	
SA-213 TP304	Sms Tube	20,000	13,800	1,500	**Stainless Steel 304**
SA-240 304	Plate	20,000	13,800	1,500	
SA-312 TP304	Sms. and Wld. Pipe	20,000	18,300	1,500	
SA-403 304	Sms and Weld Fittings	20,000	18,300	1,500	
SA-479 304	Bar	20,000	18,300	1,500	
SB-209 6061-T6 plate 0.051-0.249", wld		6,000	3,500	400	**Aluminum**
SB-209 6061-T651 plate 0.25-5", wld		6,000	3,500	400	
SB-209 6061-T6 plate 0.051-0.249"		10,900	4,000	400	
SB-209 6061-T651 plate 0.25-4.0"		10,900	4,000	400	
SB-209 6061-T651 plate 4.0-5.0"		10,300	4,000	400	
SB-211 A96061-T6 bar 0.125-0.249", wld		6,000	3,500	400	
SB-234 A96061-T6 tubes 0.025-0.200", wld		6,000	3,500	400	
SB-241 A96061-T6 sms. Pipe, wld		6,000	3,500	400	
SB-247 A96061-T6 forging, wld		6,000	3,500	400	
SB-308 A96061-T6 shapes, wld		6,000	3,200	400	

Material properties are compliant with ASME Section IID Table 1A

Fluid Properties:

200.0 **P** [psi] - pressure at top of vessel

3.31 **h** [ft] - fluid height

1.000 **SG** - fluid specific gravity

Pdesign [psi] = P+0.433*SG*h design pressure including static head 200+0.433*1*3.31 = **201.4**

Pdesign is to be used in the design of subsequent components (shell, head, nozzle, etc)

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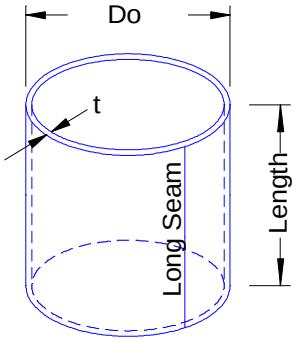
Pipe and Shell Design Tool ver E4.00

18" Shell **Description**

Dimensions:

18.000	**Do** [in]	- outside diameter
0.250	**t** [in]	- nominal wall thickness
24.000	**L** [in]	-length
0.010	**Corr** [in]	- corrosion allowance



Material and Conditions:

SA-516 70	**Material**	
20,000	**S** [psi]	- allowable stress
0.70	**El**	- long seam efficiency (circ stress)
0.85	**Ec**	- circ seam efficiency (long stress)
0.0%	**UTP** [%]	- undertolerance allowance
201.4	**P** [psi]	- interior pressure

Calculated Properties:

Volume [cuft] =	((Do/2-t)^2)*pi()*L/1728	((18/2-0.25)^2)*PI()*24/1728 =	**3.34**
Weight [lb] =	(Do-t)*pi()*L*t*40.84/144	(18-0.25)*PI()*24*0.25*40.84/144 =	**94.89**

Variables:

UT [in] =	t*UTP	0.25*0 =	**0.000**
nt [in] =	t-Corr-UT	0.25-0.01-0 =	**0.240**
Ri [in] =	Do/2-nt	18/2-0.24 =	**8.760**

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

ta [in] =	P*Ri/(S*El-0.6*P)	long sem	201.4*8.76/(20000*0.7-0.6*201.4) =	**0.127**
tb [in] =	P*Ri/(2*S*Ec+0.4*P)	circ seam	201.4*8.76/(2*20000*0.85+0.4*201.4) =	**0.052**
Treq [in] =	MAX(ta,tb)+Corr	required minimum thickness	MAX(0.127,0.052)+0.01 =	**0.137**
CheckTreq =	Treq <= nt		0.137 <= 0.24 =	**Acceptable**

Maximum Pressure: UG-27(c)(1,2)

Pint1 [psi] =	(S*El*nt)/(Ri+0.6*nt)	(20000*0.7*0.24)/(8.76+0.6*0.24) =	**377**
Pint2 [psi] =	(2*S*Ec*nt)/(Ri-0.4*nt)	(2*20000*0.85*0.24)/(8.76-0.4*0.24) =	**942**
PMax [psi] =	Min(Pint1,Pint2) maximum allowed design pressure	MIN(377,942) =	**377.4**
CheckP =	PMax >= P	377.4 >= 201.4 =	**Acceptable**

Treq provides a worst case required thickness for nozzle analysis for a nozzle located on the long seam or circ seam
This sheet will not calculate thick walled vessels **Check** → Not a thick walled vessel, calculations are valid
The UG-16(b) minimum thickness requirement has not been taken into consideration here.
This sheet cannot be used to check for allowable exterior pressure loads.
Use the Weld Efficiency program to calculate El and Ec
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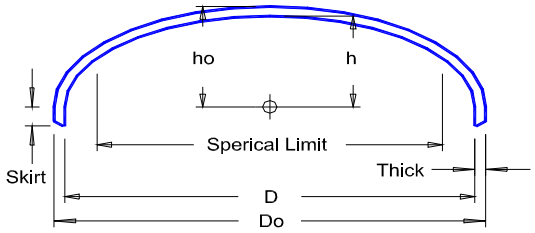
Elliptical Head Design Tool ver E4.00

Elliptical Head **Description**

Dimensions:

18.000	**Do** [in] - outside diameter of head
0.250	**tb** [in] - thickness before forming
0.188	**tf** [in] - thickness after forming (note 1)
0.010	**Corr** [in] - corrosion allowance
2.000	**Skirt** [in] - straight skirt length



Material and Conditions:

SA-516 70	**Material**
20,000	**S** [psi] - allowable stress
0.85	**E** - head longitudinal efficiency
201.4	**P** [psi] - interior pressure

Calculated Properties:

note 1: Suggested thickness after forming

0.1875 in

Approx. head weight based on steel, lbs = **35.28**

Approx. head volume including skirt, cuft = **0.70**

Variables:

nt [in] =	tf-Corr	thickness with corrosion allowance removed	0.188-0.01 = **0.178**
D [in] =	Do-2*nt	ID with corrosion allowance removed	18-2*0.178 = **17.645**
h [in] =	D/4	inside crown height	17.645/4 = **4.411**
ho [in] =	h+nt		4.411+0.178 = **4.589**
D/2h =	D/(2*h)		17.645/(2*4.411) = **2.000**
Do/2ho =	Do/(2*ho)		18/(2*4.589) = **1.961**
Ro [in]=	Kzero*Do		0.883*18 = **15.887**

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

App1-4(f) = tf/(Kone*D) 0.188/(0.9*17.645) = **0.0118**

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

Treq [in] = (P*D*K)/(2*S*E-0.2*P)+Corr required minimum thickness

(201.4*17.645*1)/(2*20000*0.85-0.2*201.4)+0.01 = **0.115**

CheckTreq = Treq<=tf 0.115<=0.188 = **Acceptable**

Maximum Pressure: App. 1-4(c), UG-37(a)(1)

Pmax [psi] = (2*S*E*nt)/(K*D+0.2*nt) maximum allowed design pressure

(2*20000*0.85*0.178)/(1*17.645+0.2*0.178) = **341.3**

CheckPMax = Pmax >= P 341.3 >= 201.4 = **Acceptable**

App. 1-4(f) calculation is not included on this sheet
The UG-16(b) minimum thickness requirement has not been taken into consideration here.
Nozzles may be subject to a smaller required thickness depending on location in the head.
Only the knuckle required thickness is calculated on this sheet
Heads may be subject to stress relief if large elongation occurs - UCS-79(d), UNF-79(d), UHA-44(d)
Use the Weld Efficiency program to calculate E
This sheet cannot be used to check for allowable exterior pressure loads.
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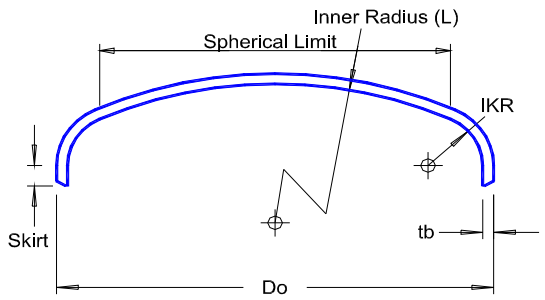
F&D Head Design Tool ver E4.00

F&D Head **Description**

Dimensions:

18.000	**Do** [in] - outside diameter of head
18.000	**L** [in] - inside crown radius (note 1)
1.080	**IKR** [in] - inside knuckle radius (note 2)
0.250	**tb** [in] - thickness before forming
0.218	**tf** [in] - thickness after forming (note 3)
0.010	**Corr** [in] - corrosion allowance
1.500	**Skirt** [in] - straight skirt length



Material and Conditions:

SA-516 70	**Material**
20,000	**S** [psi] - allowable stress
0.85	**E** - head longitudinal efficiency
201.4	**P** [psi] - interior pressure

Calculated Properties:

note 1:Suggested radius L per UG-32(j)	**18.00**
note 2:Suggested radius IKR per UG-32(j)	**1.080**
note 3:Suggested thickness after forming	**0.2180**

Approx. head weight based on steel, lbs =	**28.71**
Approx. head volume including skirt, cuft =	**0.46**

Variables:

nt [in] =	tf-Corr	thickness with corrosion allowance removed	0.218-0.01 = **0.208**
D [in] =	Do-2*nt	ID with corrosion allowance removed	18-2*0.208 = **17.584**
L/r =	L/IKR		18/1.08 = **16.667**
M =	0.25*(3+sqrt(L/IKR))		0.25*(3+SQRT(18/1.08)) = **1.771**
Ro [in] =	L+tb		18+0.25 = **18.250**

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

App1-4(f) = tf/L — 0.218/18 = **0.012**

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

Treq [in] = (P*L*M)/(2*S*E-0.2*P)+Corr — required minimum thickness

(201.4*18*1.771)/(2*20000*0.85-0.2*201.4)+0.01 = **0.199**

CheckTreq = Treq<=tf — 0.199<=0.218 = **Acceptable**

Maximum Pressure: App. 1-4(a), App. 1-4(d)

Pmax [psi] = (2*S*E*nt)/(L*M+0.2*nt) — maximum allowed design pressure

(2*20000*0.85*0.208)/(18*1.771+0.2*0.208) = **221.6**

CheckPMax = Pmax >= P — 221.6 >= 201.4 = **Acceptable**

App. 1-4(f) calculation is not included on this sheet
Nozzles may be subject to a smaller required thickness depending on location in the head.
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Nozzle Design Tool ver E4.00

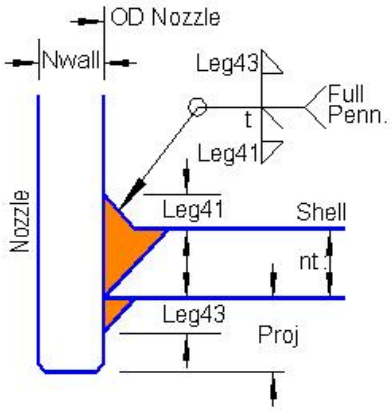
N1 - 4" SCH ? **Description**

Shell Inputs:

SA-516 70	**Material**
20,000	**Sv** [psi] - allowable stress
1.00	**E1** - efficiency of shell at nozzle
17.500	**Ds** [in] - inside diameter of shell
0.250	**nt** [in] - nominal shell wall thickness
0.137	**Treq** [in] - required shell wall thickness
0.010	**sca** [in] - head or shell corrosion allowance

Nozzle Inputs:

SA-106 B	**Material**
17,100	**Sn** [psi] - allowable stress
1.00	**E** - nozzle efficiency
4.500	**Do** [in] - outside diameter of nozzle
0.237	**Nwall** [in] - nominal wall thickness of nozzle
6.000	**Lp** [in] - exterior projection of nozzle
3.750	**lp** [in] - interior projection of nozzle
0.010	**nca** [in] - nozzle corrosion allowance
12.5%	**UTP** [%] - undertolerance allowance
201.4	**Pn** [psi] - interior pressure
0.125	**Leg41** [in] - fillet size
0.125	**Leg43** [in] - fillet size



UW-16.1 (c) modified

Variables:

UT [in] =	Nwall*UTP	0.237*0.1 = **0.030**
Rn [in] =	Do/2 - (Nwall-nca) + UT	4.5/2 - (0.237-0.01) + 0.03 = **2.053**
tn [in] =	Nwall-nca	0.237-0.01 = **0.227**
ti [in] =	Nwall-2*nca	0.237-2*0.01 = **0.217**
d [in] =	Do-2*tn	4.5-2*0.227 = **4.046**
h [in] =	MIN(lp-sca,2.5*nt,2.5*ti)	MIN(3.75-0.01,2.5*0.25,2.5*0.217) = **0.543**
fr1 =	MIN(Sn/Sv,1)	MIN(17100/20000,1) = **0.855**
fr2 =	MIN(Sn/Sv,1)	MIN(17100/20000,1) = **0.855**

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

TreqN [in] = (Pn*Rn)/(Sn*E - 0.6*Pn)+nca required minimum thickness

(201.4*2.053)/(17100*1 - 0.6*201.4)+0.01 = **0.034**

CheckTreqN = TreqN <= Nwall 0.034 <= 0.237 = **Acceptable**

Minimum thickness per UG-45 [in] = **Acceptable** **0.147**

Area Replacement:

Ar [in^2] = 1*d*Treq*1+2*tn*Treq*1*(1-fr1) required Area

1*4.046*0.137*1+2*0.227*0.137*1*(1-0.855) = **0.564**

A1 [in^2] = max(d, 2*(nt+tn))*(E1*nt-1*Treq)-2*tn*(E1*nt-1*Treq)*(1-fr1)

MAX(4.046, 2*(0.25+0.227))*(1*0.25-1*0.137)-2*0.227*(1*0.25-1*0.137)*(1-0.855) = **0.449**

A2 [in^2] = min((tn-trnR)*fr2*Min(5*nt,2*Lp) , (tn-trnR)*fr2*Min(5*tn,2*Lp))

MIN((0.227-0.024)*0.855*MIN(5*0.25,2*6) , (0.227-0.024)*0.855*MIN(5*0.227,2*6)) = **0.197**

A3 [in^2] = Min(5*nt*ti*fr2,5*ti*ti*fr2,2*h*ti*fr2)

MIN(5*0.25*0.217*0.855,5*0.217*0.217*0.855,2*0.543*0.217*0.855) = **0.201**

A41 [in^2] =	Leg41^2*fr2		0.125^2*0.855 =	**0.013**
A43 [in^2] =	(Leg43-nca)^2*fr2		(0.125-0.01)^2*0.855 =	**0.011**
Aa [in^2] =	A1+A2+A3+A41+A43	actual area	0.449+0.197+0.201+0.013+0.011 =	**0.872**
CheckA =	Aa >= Ar	check area replacement	0.872 >= 0.564 =	**Acceptable**

The UG-16(b) minimum thickness requirement has not been taken into consideration here.
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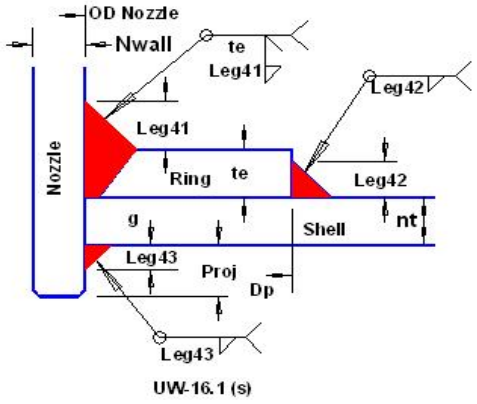
Nozzle and Repad Design Tool ver E4.00

N2 - 8" SCH 5 **Description**

Shell Inputs:

SA-516 70	**Material**
20,000	**Sv** [psi] - allowable stress
1.00	**E1** - efficiency of shell at nozzle
17.500	**Ds** [in] - inside diameter of shell
0.250	**nt** [in] - nominal shell wall thickness
0.137	**Treq** [in] - required shell wall thickness
0.010	**sca** [in] - shell corrosion allowance



Nozzle Inputs:

SA-106 B	**Material**
17,100	**Sn** [psi] - allowable stress
1.00	**E** - nozzle efficiency
8.625	**Do** [in] - outside diameter of nozzle
0.109	**Nwall** [in] - nominal wall thickness of nozzle
2.000	**Lp** [in] - exterior projection of nozzle
0.000	**Ip** [in] - interior projection of nozzle
0.010	**nca** [in] - nozzle corrosion allowance
12.5%	**UTP** [%] - undertolerance allowance
201.4	**Pn** [psi] - interior pressure

Reinforcement:

SA-516 70	**Material**
20,000	**Sp** [psi] - allowable stress of repad
0.250	**te** [in] - repad thickness
11.000	**Dp** [in] - outside diameter
0.250	**Leg41** [in] - fillet size
0.250	**Leg42** [in] - fillet size
0.250	**Leg43** [in] - fillet size
0.250	**LegG** [in] - depth of groove

Variables:

UT [in] =	Nwall*UTP	0.109*0.1 = **0.014**
Rn [in] =	Do/2 - (Nwall-nca) + UT	8.625/2 - (0.109-0.01) + 0.014 = **4.227**
ti [in] =	Nwall-2*nca	0.109-2*0.01 = **0.089**
h [in] =	MIN(Ip-sca,2.5*nt,2.5*ti)	MIN(0-0.01,2.5*0.25,2.5*0.089) = **-0.010**
tn [in] =	Nwall-nca	0.109-0.01 = **0.099**
d [in] =	Do-2*tn	8.625-2*0.099 = **8.427**

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

TreqN [in] = (Pn*Rn)/(Sn*E - 0.6*Pn)+nca required minimum thickness

(201.4*4.227)/(17100*1 - 0.6*201.4)+0.01 = **0.060**

CheckTreqN = TreqN <= Nwall 0.06 <= 0.109 = **Acceptable**

Minimum thickness per UG-45 [in] = **Acceptable** **0.147**

Area Replacement:

Ar [in^2] = 1*d*Treq*1+2*tn*Treq*1*(1-fr1) required Area		1*8.427*0.137*1+2*0.099*0.137*1*(1-0.855) =	**1.160**
A1 [in^2] = max(d, 2*(nt+tn)) * (E1*nt-1*Treq)-2*tn*(E1*nt-1*Treq)*(1-fr1)		MAX(8.427, 2*(0.25+0.099)) * (1*0.25-1*0.137)-2*0.099*(1*0.25-1*0.137)*(1-0.855) =	**0.948**
A2 [in^2] = min((tn-trnR)*fr2*min(5*nt,2*Lp),(tn-trnR)*(Min(2.5*tn+te,2*Lp)*fr2*2))		MIN((0.099-0.05)*0.855*MIN(5*0.25,2*2),(0.099-0.05)*(MIN(2.5*0.099+0.25,2*2)*0.855*2)) =	**0.042**
A3 [in^2] = Min(5*nt*ti*fr2,5*ti*ti*fr2,2*h*ti*fr2)		MIN(5*0.25*0.089*0.855,5*0.089*0.089*0.855,2*-0.01*0.089*0.855) =	**-0.002**
A5 [in^2] = (Dp-d-2*tn)*te*fr4		(11-8.427-2*0.099)*0.25*1 =	**0.594**
A41 [in^2] = Leg41^2*fr3		0.25^2*0.855 =	**0.053**
A42 [in^2] = Leg42^2*fr4		0.25^2*1 =	**0.063**
A43 [in^2] = (Leg43-nca)^2*fr2		(0.25-0.01)^2*0.855 =	**0.049**
Aa [in^2] = A1+A2+A3+A5+A41+A42+A43 actual area		0.948+0.042+-0.002+0.594+0.053+0.063+0.049 =	**1.747**
CheckA = Aa >= Ar check area replacement		1.747 >= 1.16 =	**Acceptable**

The UG-16(b) minimum thickness requirement is not checked.
The required weld size is not checked on this sheet
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Pressure Vessel Engineering Ltd.

Finite Element Analysis – ASME Code Calculations
Canadian Vessel Registration – Vessel Modeling and Drafting

Vessel Weld Efficiency ver 2.00

ASME VIII-1 Section UW-11 & UG-116(e)

Web Example Project

Left Head: [Category A] - long seam weld in head, not head to shell weld

Semi-Elliptical	Left **head**	*UW12 Column for this weld*	**a**
Seamless	Left head **weld type**	*UW12 Column for joining circ weld*	**c**
Seamless	Left head weld **radiography**	*Weld Type Number*	**0**
UW-11(a) is met		*Isolated long seam efficiency*	**1.00**
		Allowed UW12 Column	**b**
UW-11(a)(5)(b) is NOT met		*Allowed **Head Longitudinal Efficiency***	***0.85***

Left Circ Weld: [Category A, B, C or D] head to shell weld

Double	Left head to body circ-**weld type**	*UW12 Column for this weld*	**c**
None	Left head to body circ-weld **radiography**	*Circ seam type number*	**1**
		*Left **circ weld efficiency***	***0.70***

Body Long Seam: [Category A]

Double	Body long **weld type**			*UW12 column for the body long seam*	**c**
None	Body long-weld **radiography**			*UW12 column for left circ weld*	**c**
UW-11(a) is NOT				*UW12 column for right circ weld*	**c**
				Long seam type number	**1**
UW-11(a)(5)(b) is NOT met		*left circ efficiency*	**0.7**	*Isolated long seam efficiency*	**0.70**
		right circ efficiency	**0.7**	*Allowed UW12 Column*	**c**
		*Allowed **Circ Efficiency***	***0.70***	*Allowed **Long Seam Efficiency***	***0.70***

Right Circ Weld: [Category A, B, C or D] head to shell weld

Double	Right head to body circ-**weld type**	*UW12 Column*	**c**
None	Right head to body circ-weld **radiography**	*Circ seam type number*	**1**
		*Right **circ weld efficiency***	***0.70***

Right Head: [Category A] - long seam weld in head, not head to shell weld

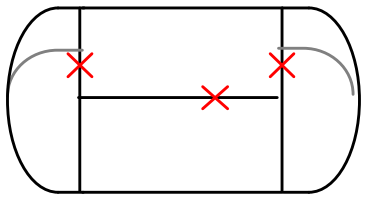
F&D	Right **head**	*UW12 Column for this weld*	**a**
Seamless	Right head **weld type**	*UW12 Column for joining circ weld*	**c**
Seamless	Right head weld **radiography**	*Weld Type Number*	**0**
UW-11(a) is met		*Isolated long seam efficiency*	**1.00**
		Allowed UW12 Column	**b**
UW-11(a)(5)(b) is NOT met		*Allowed **Head Longitudinal Efficiency***	***0.85***

Notes:

Left head efficiency is reduced by left circ-weld efficiency

Right head efficiency is reduced by right head to body weld

Sketch:



Comments:

This sheet is for educational use only. Only ASME can make code interpretations.
This program will not work for ERW pipe.

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