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**PV Elite Vessel Analysis Program: Input Data**

**Exchanger Design Pressures and Temperatures**

Shell Side Design Pressure	100.00	psig
Channel Side Design Pressure	300.00	psig
Shell Side Design Temperature	212	F
Channel Side Design Temperature	295	F
Type of Hydrotest	UG99-b Note [34]	
Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0.0000	in.
Projection of Nozzle from Vessel Bottom	0.0000	in.
Minimum Design Metal Temperature	-20	F
Type of Construction	Welded	
Special Service	Air/Water/Steam	
Degree of Radiography	RT-3	
Miscellaneous Weight Percent	0.	
Use Higher Longitudinal Stresses (Flag)	Y	
Select t for Internal Pressure (Flag)	N	
Select t for External Pressure (Flag)	N	
Select t for Axial Stress (Flag)	N	
Select Location for Stiff. Rings (Flag)	N	
Use Hydrotest Allowable Unmodified	Y	
Consider Vortex Shedding	N	
Perform a Corroded Hydrotest	N	
Is this a Heat Exchanger	No	
User Defined Hydro. Press. (Used if > 0)	0.0000	psig
User defined MAWP	0.0000	psig
User defined MAPnc	0.0000	psig
Load Case 1	NP+EW+WI+FW+BW	
Load Case 2	NP+EW+EE+FS+BS	
Load Case 3	NP+OW+WI+FW+BW	
Load Case 4	NP+OW+EQ+FS+BS	
Load Case 5	NP+HW+HI	
Load Case 6	NP+HW+HE	
Load Case 7	IP+OW+WI+FW+BW	
Load Case 8	IP+OW+EQ+FS+BS	
Load Case 9	EP+OW+WI+FW+BW	
Load Case 10	EP+OW+EQ+FS+BS	
Load Case 11	HP+HW+HI	
Load Case 12	HP+HW+HE	
Load Case 13	IP+WE+EW	
Load Case 14	IP+WF+CW	
Load Case 15	IP+VO+OW	
Load Case 16	IP+VE+EW	
Load Case 17	NP+VO+OW	
Load Case 18	FS+BS+IP+OW	
Load Case 19	FS+BS+EP+OW	
Wind Design Code	ASCE-7 93	
Design Wind Speed	70.000	mile/hr
Exposure Constant	C	
Importance Factor	1.	
Roughness Factor	1	
Base Elevation	0.0000	ft.
Percent Wind for Hydrotest	33.	
Use Wind Profile (Y/N)	N	
Damping Factor (Beta) for Wind (Ope)	0.0100	
Damping Factor (Beta) for Wind (Empty)	0.0000	
Damping Factor (Beta) for Wind (Filled)	0.0000	

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Seismic Design Code	UBC 94
UBC Seismic Zone (1=1,2=2a,3=2b,4=3,5=4)	4.000
UBC Importance Factor	1.000
UBC Soil Type	S3
UBC Horizontal Force Factor	3.000
UBC Percent Seismic for Hydrotest	0.000

Design Nozzle for Des. Press. + St. Head	Y
Consider MAP New and Cold in Noz. Design	N
Consider External Loads for Nozzle Des.	Y
Consider Code Case 2168 for Nozzle Des.	N

Material Database Year Current w/Addenda or Code Year

**Complete Listing of Vessel Elements and Details:**

Element From Node	10
Element To Node	20
Element Type	Torisphe.
Description	Lft Head
Distance "FROM" to "TO"	0.1667 ft.
Inside Diameter	32.000 in.
Element Thickness	0.6875 in.
Internal Corrosion Allowance	0.06250 in.
Nominal Thickness	0.7500 in.
External Corrosion Allowance	0.0000 in.
Design Internal Pressure	300.00 psig
Design Temperature Internal Pressure	295 F
Design External Pressure	15.000 psig
Design Temperature External Pressure	295 F
Effective Diameter Multiplier	1.2
Material Name	SA-240 304
Allowable Stress, Ambient	20000. psi
Allowable Stress, Operating	15085. psi
Allowable Stress, Hydrotest	26000. psi
Material Density	0.2800 lb./cu.in.
P Number Thickness	0.0000 in.
Yield Stress, Operating	22520. psi
External Pressure Chart Name	HA-1
UNS Number	S30400
Product Form	Plate
Efficiency, Longitudinal Seam	1.
Efficiency, Circumferential Seam	0.85
Tori Head Crown Radius	33.375 in.
Tori Head Knuckle Radius	2.0025 in.

Element From Node	20
Element To Node	30
Element Type	Cylinder
Description	Channel
Distance "FROM" to "TO"	1.0000 ft.
Inside Diameter	32.000 in.
Element Thickness	0.7500 in.
Internal Corrosion Allowance	0.06250 in.
Nominal Thickness	0.7500 in.
External Corrosion Allowance	0.0000 in.
Design Internal Pressure	300.00 psig
Design Temperature Internal Pressure	295 F
Design External Pressure	15.000 psig
Design Temperature External Pressure	295 F
Effective Diameter Multiplier	1.2
Material Name	SA-240 304
Efficiency, Longitudinal Seam	0.85
Efficiency, Circumferential Seam	0.85

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Element From Node	30	
Element To Node	40	
Element Type	Flange	
Description	Flange 1	
Distance "FROM" to "TO"	0.3333	ft.
Flange Inside Diameter	32.000	in.
Element Thickness	4.0000	in.
Internal Corrosion Allowance	0.06250	in.
Nominal Thickness	0.0000	in.
External Corrosion Allowance	0.0000	in.
Design Internal Pressure	300.00	psig
Design Temperature Internal Pressure	295	F
Design External Pressure	15.000	psig
Design Temperature External Pressure	295	F
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Allowable Stress, Ambient	20000.	psi
Allowable Stress, Operating	20000.	psi
Allowable Stress, Hydrotest	26000.	psi
Material Density	0.2830	lb./cu.in.
P Number Thickness	1.2500	in.
Yield Stress, Operating	33660.	psi
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0.0000	lb.
Class of ANSI B16.5/B16.47 Flange	None	
Grade of ANSI B16.5/B16.47 Flange	None	
Element From Node	40	
Element To Node	50	
Element Type	Cylinder	
Description	Shell	
Distance "FROM" to "TO"	8.0000	ft.
Inside Diameter	32.000	in.
Element Thickness	0.5000	in.
Internal Corrosion Allowance	0.06250	in.
Nominal Thickness	0.5000	in.
External Corrosion Allowance	0.0000	in.
Design Internal Pressure	100.00	psig
Design Temperature Internal Pressure	212	F
Design External Pressure	15.000	psig
Design Temperature External Pressure	212	F
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	
Element From Node	50	
Element To Node	60	
Element Type	Flange	
Description	Flange 2	
Distance "FROM" to "TO"	0.3333	ft.
Flange Inside Diameter	32.000	in.
Element Thickness	4.0000	in.
Internal Corrosion Allowance	0.06250	in.
Nominal Thickness	0.0000	in.
External Corrosion Allowance	0.0000	in.
Design Internal Pressure	300.00	psig
Design Temperature Internal Pressure	295	F
Design External Pressure	15.000	psig
Design Temperature External Pressure	295	F
Effective Diameter Multiplier	1.2	

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Material Name	SA-516 70	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0.0000	lb.
Class of ANSI B16.5/B16.47 Flange		
Grade of ANSI B16.5/B16.47 Flange		
Element From Node	60	
Element To Node	70	
Element Type	Cylinder	
Description	RT Channel	
Distance "FROM" to "TO"	1.0000	ft.
Inside Diameter	32.000	in.
Element Thickness	0.7500	in.
Internal Corrosion Allowance	0.06250	in.
Nominal Thickness	0.7500	in.
External Corrosion Allowance	0.0000	in.
Design Internal Pressure	300.00	psig
Design Temperature Internal Pressure	295	F
Design External Pressure	15.000	psig
Design Temperature External Pressure	295	F
Effective Diameter Multiplier	1.2	
Material Name	SA-240 304	
Allowable Stress, Ambient	20000.	psi
Allowable Stress, Operating	15085.	psi
Allowable Stress, Hydrotest	26000.	psi
Material Density	0.2800	lb./cu.in.
P Number Thickness	0.0000	in.
Yield Stress, Operating	22520.	psi
External Pressure Chart Name	HA-1	
UNS Number	S30400	
Product Form	Plate	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	
Element From Node	70	
Element To Node	80	
Element Type	Torisphe.	
Description	RT Head	
Distance "FROM" to "TO"	0.1667	ft.
Inside Diameter	32.000	in.
Element Thickness	0.6875	in.
Internal Corrosion Allowance	0.06250	in.
Nominal Thickness	0.7500	in.
External Corrosion Allowance	0.0000	in.
Design Internal Pressure	100.00	psig
Design Temperature Internal Pressure	295	F
Design External Pressure	15.000	psig
Design Temperature External Pressure	295	F
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Allowable Stress, Ambient	20000.	psi
Allowable Stress, Operating	20000.	psi
Allowable Stress, Hydrotest	26000.	psi
Material Density	0.2830	lb./cu.in.
P Number Thickness	1.2500	in.
Yield Stress, Operating	33660.	psi
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.	
Efficiency, Circumferential Seam	0.85	
Tori Head Crown Radius	33.375	in.
Tori Head Knuckle Radius	2.0025	in.

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Flange Calculations Flange 1 Flng: 1 12:55p May 27,2008

Flange Input Data Values Description: Flange 1 :

Flange 1

Description of Flange Geometry (Type)		Loose Ring	
Description of Flange Analysis	Partial,	Thickness	
Design Pressure	P	300.00	psig
Design Temperature		295	F
Internal Corrosion Allowance	ci	0.0625	in.
External Corrosion Allowance	ce	0.0000	in.
Use Corrosion Allowance in Thickness Calcs.		No	
Flange Inside Diameter	B	32.000	in.
Flange Outside Diameter	A	38.400	in.
Flange Thickness	t	4.0000	in.
Flange Material		SA-516 70	
Flange Allowable Stress At Temperature	Sfo	20000.00	psi
Flange Allowable Stress At Ambient	Sfa	20000.00	psi
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	25000.00	psi
Bolt Allowable Stress At Ambient	Sa	25000.00	psi
Length of Weld Leg at Back of Ring	tw	0.0000	in.
Number of Splits in Ring Flange	n	0	
Diameter of Bolt Circle	C	36.000	in.
Nominal Bolt Diameter	dB	1.0000	in.
Type of Threads	TEMA Thread Series		
Number of Bolts		28	
Flange Face Outside Diameter	Fod	33.000	in.
Flange Face Inside Diameter	Fid	32.000	in.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	32.750	in.
Gasket Inside Diameter	Gi	32.000	in.
Gasket Factor	m	0.5000	
Gasket Design Seating Stress	y	0.00	psi
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	0.1250	in.

ASME Code, Section VIII, Division 1, 2007

Code R Dimension,	$R = (C-B)/2 - g1$	2.000	in.
Gasket Contact Width,	$N = (Go - Gi) / 2$	0.375	in.
Basic Gasket Width,	$bo = N / 2$	0.188	in.
Effective Gasket Width,	$b = bo$	0.188	in.
Gasket Reaction Diameter,	$G = (Go + Gi) / 2$	32.375	in.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

$$= 0.785 * G^2 * Peg$$

$$= 0.785 * 32.375^2 * 300.000$$

$$= 246962.328 \text{ lb.}$$

Contact Load on Gasket Surfaces [Hp]:

$$= 2 * b * Pi * G * m * P +$$

$$= 2 * 0.1875 * 3.1416 * 32.3750 * 0.5000 * 300.00$$

$$= 5721.135 \text{ lb.}$$

Hydrostatic End Load at Flange ID [Hd]:

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Flange Calculations Flange 1 Flng: 1 12:55p May 27,2008

$$= \text{Pi} * \text{Bcor}^2 * \text{P} / 4$$

$$= 3.1416 * 32.0000^2 * 300.0000 / 4$$

$$= 241274.328 \text{ lb.}$$

Pressure Force on Flange Face [Ht]:

$$= \text{H} - \text{Hd}$$

$$= 246962 - 241274$$

$$= 5688.000 \text{ lb.}$$

Operating Bolt Load [Wm1]:

$$= \text{max}( \text{H} + \text{Hp} + \text{H'p}, 0 )$$

$$= \text{max}( 246962 + 5721 + 0 , 0 )$$

$$= 252683.469 \text{ lb.}$$

Gasket Seating Bolt Load [Wm2]:

$$= \text{y} * \text{b} * \text{Pi} * \text{G} + \text{yPart} * \text{bPart} * \text{lp}$$

$$= 0.00 * 0.1875 * 3.141 * 32.375 + 0.00 * 0.0000 * 0.00$$

$$= 0.000 \text{ lb.}$$

Required Bolt Area [Am]:

$$= \text{Maximum of } \text{Wm1/Sb}, \text{ Wm2/Sa}$$

$$= \text{Maximum of } 252683 / 25000 , 0 / 25000$$

$$= 10.107 \text{ sq.in.}$$

**Bolting Information for TEMA Imperial Thread Series (Non Mandatory):**

	Minimum	Actual	Maximum
Bolt Area, sq.in.	10.107	15.428	
Radial distance bet. hub and bolts	1.062	2.000	
Radial distance bet. bolts and the edge	1.062	1.200	
Circumferential spacing between bolts	2.250	4.031	26.000

Flange Design Bolt Load, Gasket Seating [W]:

$$= \text{Sa} * ( \text{Am} + \text{Ab} ) / 2$$

$$= 25000.00 * ( 10.1073 + 15.4280 ) / 2$$

$$= 319191.72 \text{ lb.}$$

Gasket Seating Force [HG]:

$$= \text{Wm1} - \text{H}$$

$$= 252683 - 246962$$

$$= 5721.14 \text{ lb.}$$

**Moment Arm Calculations:**

Distance to Gasket Load Reaction [hg]:

$$= ( \text{C} - \text{G} ) / 2$$

$$= ( 36.0000 - 32.3750 ) / 2$$

$$= 1.8125 \text{ in.}$$

Distance to Face Pressure Reaction [ht]:

$$= ( \text{hD} + \text{hG} ) / 2$$

$$= ( 2.0000 + 1.8125 ) / 2$$

$$= 1.9062 \text{ in.}$$

Distance to End Pressure Reaction [hd]:

$$= ( \text{C} - \text{Bcor} ) / 2$$

$$= ( 36.0000 - 32.0000 ) / 2$$

$$= 2.0000 \text{ in.}$$

**Summary of Moments for Internal Pressure:**

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	241274.	2.0000	1.0000	40212. ft.lb.
Face Pressure, Mt	5688.	1.9062	1.0000	904. ft.lb.
Gasket Load, Mg	5721.	1.8125	1.0000	864. ft.lb.
Gasket Seating, Matm	319192.	1.8125	1.0000	48211. ft.lb.
Total Moment for Operation, Mop				41980. ft.lb.
Total Moment for Gasket seating, Matm				48211. ft.lb.
Effective Hub Length, ho =				0.000 in.
Hub Ratio, h/h0 = Defined as 0.0				0.000



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Flange Calculations Flange 1 Flng: 1 12:55p May 27,2008

Thickness Ratio,  $g1/g0 = \text{Defined as } 0.0$  0.000  
 Factors from Figure 2-7.1 K = 1.200  
 T = 1.839 U = 11.813  
 Y = 10.750 Z = 5.545

Tangential Flange Stress, Operating [Sto]:  
 $= ( Y * Mo ) / ( t^2 * Bcor )$   
 $= ( 10.7496 * 503760 ) / ( 4.0000^2 * 32.0000 )$   
 $= 10576.61 \text{ psi}$

Tangential Flange Stress, Seating [STa]:  
 $= ( Y * Matm ) / ( t^2 * Bcor )$   
 $= ( 10.7496 * 578535 ) / ( 4.0000^2 * 32.0000 )$   
 $= 12146.52 \text{ psi}$

Bolt Stress, Operating [BSo]:  
 $= ( Wm1 / Ab )$   
 $= ( 252683 / 15.4280 )$   
 $= 16378.24 \text{ psi}$

Bolt Stress, Seating [BSa]:  
 $= ( Wm2 / Ab )$   
 $= ( 0 / 15.4280 )$   
 $= 0.00 \text{ psi}$

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Tangential Flange	10577.	20000.	12147.	20000. psi
Bolting	16378.	25000.	0.	25000. psi

Minimum Required Flange Thickness [Rigidity] 3.912 in.  
 Flange Rigidity Index, Seating (should be  $\leq 1$ ) 0.935  
 Flange Rigidity Index Oper. (should be  $\leq 1$ ) 0.843  
 Estimated M.A.W.P. ( Operating ) 356.0 psig  
 Estimated M.A.W.P. ( Gasket Seating ) 352.5 psig  
 Estimated Finished Weight of Flange at given Thk. 400.6 lbm  
 Estimated Unfinished Weight of Forging at given Thk 400.6 lbm

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:  
 $= 109.4 * Ma * Cnv\_fac / ( Eamb * t^3 * \ln(K) * Kl )$   
 $= 109.4 * 48211 * 12.000 / ( 29000000 * 3.912^3 * 0.182 * 0.20 )$   
 $= 1.000 \text{ (should be } \leq 1)$

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:  
 $= 109.4 * Mo * Cnv\_fac / ( Eop * tc^3 * \ln(K) * Kl )$   
 $= 109.4 * 41980 * 12.000 / ( 28025000 * 3.912^3 * 0.182 * 0.20 )$   
 $= 0.901 \text{ (should be } \leq 1)$

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:  
 $= 109.4 * Ma * Cnv\_fac / ( Eamb * t^3 * \ln(K) * Kl )$   
 $= 109.4 * 48211 * 12.000 / ( 29000000 * 4.000^3 * 0.182 * 0.20 )$   
 $= 0.935 \text{ (should be } \leq 1)$

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:  
 $= 109.4 * Mo * Cnv\_fac / ( Eop * tc^3 * \ln(K) * Kl )$   
 $= 109.4 * 41980 * 12.000 / ( 28025000 * 4.000^3 * 0.182 * 0.20 )$   
 $= 0.843 \text{ (should be } \leq 1)$

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 Flange Calculations Flange 2 Flng: 2 12:55p May 27,2008

Flange Input Data Values Description: Flange 2 :

Flange 2

Description of Flange Geometry (Type)		Loose Ring	
Description of Flange Analysis	Partial, Thickness		
Design Pressure	P	300.00	psig
Design Temperature		295	F
Internal Corrosion Allowance	ci	0.0625	in.
External Corrosion Allowance	ce	0.0000	in.
Use Corrosion Allowance in Thickness Calcs.		No	
Flange Inside Diameter	B	32.000	in.
Flange Outside Diameter	A	38.400	in.
Flange Thickness	t	4.0000	in.
Flange Material		SA-516 70	
Flange Allowable Stress At Temperature	Sfo	20000.00	psi
Flange Allowable Stress At Ambient	Sfa	20000.00	psi
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	25000.00	psi
Bolt Allowable Stress At Ambient	Sa	25000.00	psi
Length of Weld Leg at Back of Ring	tw	0.0000	in.
Number of Splits in Ring Flange	n	0	
Diameter of Bolt Circle	C	36.000	in.
Nominal Bolt Diameter	dB	1.0000	in.
Type of Threads	TEMA Thread Series		
Number of Bolts		28	
Flange Face Outside Diameter	Fod	33.000	in.
Flange Face Inside Diameter	Fid	32.000	in.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	32.750	in.
Gasket Inside Diameter	Gi	32.000	in.
Gasket Factor	m	0.5000	
Gasket Design Seating Stress	y	0.00	psi
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	0.1250	in.

ASME Code, Section VIII, Division 1, 2007

Code R Dimension,	$R = (C-B)/2 - g1$	2.000	in.
Gasket Contact Width,	$N = (Go - Gi) / 2$	0.375	in.
Basic Gasket Width,	$bo = N / 2$	0.188	in.
Effective Gasket Width,	$b = bo$	0.188	in.
Gasket Reaction Diameter,	$G = (Go + Gi) / 2$	32.375	in.

**Basic Flange and Bolt Loads:**

Hydrostatic End Load due to Pressure [H]:

$$= 0.785 * G^2 * Peq$$

$$= 0.785 * 32.375^2 * 300.000$$

$$= 246962.328 \text{ lb.}$$

Contact Load on Gasket Surfaces [Hp]:

$$= 2 * b * Pi * G * m * P +$$

$$= 2 * 0.1875 * 3.1416 * 32.3750 * 0.5000 * 300.00$$

$$= 5721.135 \text{ lb.}$$

Hydrostatic End Load at Flange ID [Hd]:

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Flange Calculations Flange 2 Flng: 2 12:55p May 27,2008

$$= \text{Pi} * \text{Bcor}^2 * \text{P} / 4$$

$$= 3.1416 * 32.0000^2 * 300.0000 / 4$$

$$= 241274.328 \text{ lb.}$$

Pressure Force on Flange Face [Ht]:

$$= \text{H} - \text{Hd}$$

$$= 246962 - 241274$$

$$= 5688.000 \text{ lb.}$$

Operating Bolt Load [Wm1]:

$$= \text{max}( \text{H} + \text{Hp} + \text{H'p}, 0 )$$

$$= \text{max}( 246962 + 5721 + 0 , 0 )$$

$$= 252683.469 \text{ lb.}$$

Gasket Seating Bolt Load [Wm2]:

$$= \text{y} * \text{b} * \text{Pi} * \text{G} + \text{yPart} * \text{bPart} * \text{lp}$$

$$= 0.00 * 0.1875 * 3.141 * 32.375 + 0.00 * 0.0000 * 0.00$$

$$= 0.000 \text{ lb.}$$

Required Bolt Area [Am]:

$$= \text{Maximum of } \text{Wm1/Sb}, \text{ Wm2/Sa}$$

$$= \text{Maximum of } 252683 / 25000 , 0 / 25000$$

$$= 10.107 \text{ sq.in.}$$

**Bolting Information for TEMA Imperial Thread Series (Non Mandatory):**

	Minimum	Actual	Maximum
Bolt Area, sq.in.	10.107	15.428	
Radial distance bet. hub and bolts	1.062	2.000	
Radial distance bet. bolts and the edge	1.062	1.200	
Circumferential spacing between bolts	2.250	4.031	26.000

Flange Design Bolt Load, Gasket Seating [W]:

$$= \text{Sa} * ( \text{Am} + \text{Ab} ) / 2$$

$$= 25000.00 * ( 10.1073 + 15.4280 ) / 2$$

$$= 319191.72 \text{ lb.}$$

Gasket Seating Force [HG]:

$$= \text{Wm1} - \text{H}$$

$$= 252683 - 246962$$

$$= 5721.14 \text{ lb.}$$

**Moment Arm Calculations:**

Distance to Gasket Load Reaction [hg]:

$$= ( \text{C} - \text{G} ) / 2$$

$$= ( 36.0000 - 32.3750 ) / 2$$

$$= 1.8125 \text{ in.}$$

Distance to Face Pressure Reaction [ht]:

$$= ( \text{hD} + \text{hG} ) / 2$$

$$= ( 2.0000 + 1.8125 ) / 2$$

$$= 1.9062 \text{ in.}$$

Distance to End Pressure Reaction [hd]:

$$= ( \text{C} - \text{Bcor} ) / 2$$

$$= ( 36.0000 - 32.0000 ) / 2$$

$$= 2.0000 \text{ in.}$$

**Summary of Moments for Internal Pressure:**

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	241274.	2.0000	1.0000	40212. ft.lb.
Face Pressure, Mt	5688.	1.9062	1.0000	904. ft.lb.
Gasket Load, Mg	5721.	1.8125	1.0000	864. ft.lb.
Gasket Seating, Matm	319192.	1.8125	1.0000	48211. ft.lb.
Total Moment for Operation, Mop				41980. ft.lb.
Total Moment for Gasket seating, Matm				48211. ft.lb.
Effective Hub Length, ho =				0.000 in.
Hub Ratio, h/h0 = Defined as 0.0				0.000

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Flange Calculations Flange 2 Flng: 2 12:55p May 27,2008

Thickness Ratio,  $g1/g0 =$  Defined as 0.0 0.000  
 Factors from Figure 2-7.1 K = 1.200  
 T = 1.839 U = 11.813  
 Y = 10.750 Z = 5.545

Tangential Flange Stress, Operating [Sto]:  
 $= ( Y * Mo ) / ( t^2 * Bcor )$   
 $= ( 10.7496 * 503760 ) / ( 4.0000^2 * 32.0000 )$   
 $= 10576.61$  psi

Tangential Flange Stress, Seating [STa]:  
 $= ( Y * Matm ) / ( t^2 * Bcor )$   
 $= ( 10.7496 * 578535 ) / ( 4.0000^2 * 32.0000 )$   
 $= 12146.52$  psi

Bolt Stress, Operating [BSo]:  
 $= ( Wm1 / Ab )$   
 $= ( 252683 / 15.4280 )$   
 $= 16378.24$  psi

Bolt Stress, Seating [BSa]:  
 $= ( Wm2 / Ab )$   
 $= ( 0 / 15.4280 )$   
 $= 0.00$  psi

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Tangential Flange	10577.	20000.	12147.	20000. psi
Bolting	16378.	25000.	0.	25000. psi

Minimum Required Flange Thickness [Rigidity] 3.912 in.  
 Flange Rigidity Index, Seating (should be  $\leq 1$ ) 0.935  
 Flange Rigidity Index Oper. (should be  $\leq 1$ ) 0.843  
 Estimated M.A.W.P. ( Operating ) 356.0 psig  
 Estimated M.A.W.P. ( Gasket Seating ) 352.5 psig  
 Estimated Finished Weight of Flange at given Thk. 400.6 lbm  
 Estimated Unfinished Weight of Forging at given Thk 400.6 lbm

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:  
 $= 109.4 * Ma * Cnv\_fac / ( Eamb * t^3 * ln(K) * Kl )$   
 $= 109.4 * 48211 * 12.000 / ( 29000000 * 3.912^3 * 0.182 * 0.20 )$   
 $= 1.000$  (should be  $\leq 1$ )

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:  
 $= 109.4 * Mo * Cnv\_fac / ( Eop * tc^3 * ln(K) * Kl )$   
 $= 109.4 * 41980 * 12.000 / ( 28025000 * 3.912^3 * 0.182 * 0.20 )$   
 $= 0.901$  (should be  $\leq 1$ )

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:  
 $= 109.4 * Ma * Cnv\_fac / ( Eamb * t^3 * ln(K) * Kl )$   
 $= 109.4 * 48211 * 12.000 / ( 29000000 * 4.000^3 * 0.182 * 0.20 )$   
 $= 0.935$  (should be  $\leq 1$ )

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:  
 $= 109.4 * Mo * Cnv\_fac / ( Eop * tc^3 * ln(K) * Kl )$   
 $= 109.4 * 41980 * 12.000 / ( 28025000 * 4.000^3 * 0.182 * 0.20 )$   
 $= 0.843$  (should be  $\leq 1$ )

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**Element Thickness, Pressure, Diameter and Allowable Stress :**

From	To	Int. Press + Liq. Hd psig	Nominal Thickness in.	Total Corr Allowance in.	Element Diameter in.	Allowable Stress(SE) psi
Lft Head		300.000	0.75000	0.062500	32.0000	15085.0
Channel		300.000	0.75000	0.062500	32.0000	12822.2
Flange 1		300.000	...	0.062500	32.0000	17000.0
Shell		100.000	0.50000	0.062500	32.0000	17000.0
Flange 2		300.000	...	0.062500	32.0000	17000.0
RT Channel		300.000	0.75000	0.062500	32.0000	12822.2
RT Head		100.000	0.75000	0.062500	32.0000	20000.0

**Element Required Thickness and MAWP :**

From	To	Design Pressure psig	M.A.W.P. Corroded psig	M.A.P. New & Cold psig	Actual Thickness in.	Required Thickness in.
Lft Head		300.000	320.460	464.276	0.68750	0.64752
Channel		300.000	535.071	775.076	0.75000	0.44366
Flange 1		300.000	352.520	335.190	4.00000	3.91200
Shell		100.000	455.590	521.472	0.50000	0.15732
Flange 2		300.000	352.520	335.190	4.00000	3.91200
RT Channel		300.000	535.071	775.076	0.75000	0.44366
RT Head		100.000	424.873	464.276	0.68750	0.20936

**Summary of Heat Exchanger Maximum Allowable Working Pressures :**

Note: For ASME UHX designs, the following values include MAWPs that consider the tubesheet, tubes, tube/tubesheet joint etc. These values were determined by iteration. Review the tubesheet analysis report for more information.

Shell Side MAWP = 425.634 psig  
 Shell Side MAPnc = 521.472 psig  
 Channel Side MAWP = 320.460 psig  
 Channel Side MAPnc = 335.190 psig

**Internal Pressure Calculation Results :**

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**Torispherical Head From 10 To 20 SA-240 304 at 295 F**

**Lft Head**

Inside Corroded Head Depth [h]:

$$= L - \sqrt{(L - D_i / 2) * (L + D_i / 2 - 2 * r)}$$

$$= 33.44 - \sqrt{(33.44 - 32.12 / 2) * (33.44 + 32.12 / 2 - 2 * 2.06)}$$

$$= 5.361 \text{ in.}$$

M factor for Torispherical Heads ( Corroded ):

$$= (3 + \sqrt{(L+C)/(r+C)}) / 4 \text{ per Appendix 1-4 (b \& d)}$$

$$= (3 + \sqrt{(33.375 + 0.0625) / (2.002 + 0.0625)}) / 4$$

$$= 1.7560$$

Thickness Due to Internal Pressure [Tr]:

$$= (P * L * M) / (2 * S * E - 0.2 * P) \text{ per Appendix 1-4 (d)}$$

$$= (300.000 * 33.4375 * 1.7560) / (2 * 15085.00 * 1.00 - 0.2 * 300.000)$$

$$= 0.5850 + 0.0625 = 0.6475 \text{ in.}$$

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:

$$= (2 * S * E * t) / (M * L + 0.2 * t) \text{ per Appendix 1-4 (d)}$$

$$= (2 * 15085.00 * 1.00 * 0.6250) / (1.7560 * 33.4375 + 0.2 * 0.6250)$$

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$$= 320.460 \text{ psig}$$

M factor for Torispherical Heads ( New & Cold ):

$$= (3 + \sqrt{L/r})/4 \text{ per Appendix 1-4 (b \& d)}$$

$$= (3 + \sqrt{33.375/2.002})/4$$

$$= 1.7706$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$= (2 * S * E * t) / (M * L + 0.2 * t) \text{ per Appendix 1-4 (d)}$$

$$= (2 * 20000.00 * 1.00 * 0.6875) / (1.7706 * 33.3750 + 0.2 * 0.6875)$$

$$= 464.276 \text{ psig}$$

Actual stress at given pressure and thickness, corroded [Sact]:

$$= (P * (M * L + 0.2 * t)) / (2 * E * t)$$

$$= (300.000 * (1.7560 * 33.4375 + 0.2 * 0.6250)) / (2 * 1.00 * 0.6250)$$

$$= 14121.880 \text{ psi}$$

Required Thickness of Straight Flange = 0.386 in.

Percent Elongation per UHA-44  $(75 * t_{nom} / R_f) * (1 - R_f / R_o)$  23.659 %

### Cylindrical Shell From 20 To 30 SA-240 304 at 295 F

#### Channel

Thickness Due to Internal Pressure [Tr]:

$$= (P * R) / (S * E - 0.6 * P) \text{ per UG-27 (c)(1)}$$

$$= (300.000 * 16.0625) / (15085.00 * 0.85 - 0.6 * 300.000)$$

$$= 0.3812 + 0.0625 = 0.4437 \text{ in.}$$

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:

$$= (S * E * t) / (R + 0.6 * t) \text{ per UG-27 (c)(1)}$$

$$= (15085.00 * 0.85 * 0.6875) / (16.0625 + 0.6 * 0.6875)$$

$$= 535.071 \text{ psig}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$= (S * E * t) / (R + 0.6 * t) \text{ per UG-27 (c)(1)}$$

$$= (20000.00 * 0.85 * 0.7500) / (16.0000 + 0.6 * 0.7500)$$

$$= 775.076 \text{ psig}$$

Actual stress at given pressure and thickness, corroded [Sact]:

$$= (P * (R + 0.6 * t)) / (E * t)$$

$$= (300.000 * (16.0625 + 0.6 * 0.6875)) / (0.85 * 0.6875)$$

$$= 8457.754 \text{ psi}$$

Percent Elongation per UHA-44  $(50 * t_{nom} / R_f) * (1 - R_f / R_o)$  2.290 %

### Cylindrical Shell From 40 To 50 SA-516 70 , UCS-66 Crv. B at 212 F

#### Shell

Thickness Due to Internal Pressure [Tr]:

$$= (P * R) / (S * E - 0.6 * P) \text{ per UG-27 (c)(1)}$$

$$= (100.000 * 16.0625) / (20000.00 * 0.85 - 0.6 * 100.000)$$

$$= 0.0948 + 0.0625 = 0.1573 \text{ in.}$$

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:

$$= (S * E * t) / (R + 0.6 * t) \text{ per UG-27 (c)(1)}$$

$$= (20000.00 * 0.85 * 0.4375) / (16.0625 + 0.6 * 0.4375)$$

$$= 455.590 \text{ psig}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$= (S * E * t) / (R + 0.6 * t) \text{ per UG-27 (c)(1)}$$

$$= (20000.00 * 0.85 * 0.5000) / (16.0000 + 0.6 * 0.5000)$$

$$= 521.472 \text{ psig}$$

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Actual stress at given pressure and thickness, corroded [Sact]:

$$= (P*(R+0.6*t))/(E*t)$$

$$= (100.000*(16.0625+0.6*0.4375))/(0.85*0.4375)$$

$$= 4389.916 \text{ psi}$$

Percent Elongation per UCS-79  $(50*t_{nom}/R_f)*(1-R_f/R_o)$  1.538 %

Min Metal Temp. w/o impact per UCS-66	-6	F
Min Metal Temp. at Rqd thickness (UCS 66.1)[rat 0.18]	-146	F
Min Metal Temp. w/o impact per UG-20(f)	-20	F

**Cylindrical Shell From 60 To 70 SA-240 304 at 295 F**

**RT Channel**

Thickness Due to Internal Pressure [Tr]:

$$= (P*R)/(S*E-0.6*P) \text{ per UG-27 (c)(1)}$$

$$= (300.000*16.0625)/(15085.00*0.85-0.6*300.000)$$

$$= 0.3812 + 0.0625 = 0.4437 \text{ in.}$$

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:

$$= (S*E*t)/(R+0.6*t) \text{ per UG-27 (c)(1)}$$

$$= (15085.00*0.85*0.6875)/(16.0625+0.6*0.6875)$$

$$= 535.071 \text{ psig}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$= (S*E*t)/(R+0.6*t) \text{ per UG-27 (c)(1)}$$

$$= (20000.00*0.85*0.7500)/(16.0000+0.6*0.7500)$$

$$= 775.076 \text{ psig}$$

Actual stress at given pressure and thickness, corroded [Sact]:

$$= (P*(R+0.6*t))/(E*t)$$

$$= (300.000*(16.0625+0.6*0.6875))/(0.85*0.6875)$$

$$= 8457.754 \text{ psi}$$

Percent Elongation per UHA-44  $(50*t_{nom}/R_f)*(1-R_f/R_o)$  2.290 %

**Torispherical Head From 70 To 80 SA-516 70, UCS-66 Crv. B at 295 F**

**RT Head**

Inside Corroded Head Depth [h]:

$$= L - \sqrt{(L - D_i / 2) * (L + D_i / 2 - 2 * r)}$$

$$= 33.44 - \sqrt{(33.44 - 32.12/2) * (33.44 + 32.12/2 - 2*2.06)}$$

$$= 5.361 \text{ in.}$$

M factor for Torispherical Heads ( Corroded ):

$$= (3 + \sqrt{(L+C)/(r+C)})/4 \text{ per Appendix 1-4 (b \& d)}$$

$$= (3 + \sqrt{(33.375 + 0.0625)/(2.002 + 0.0625)})/4$$

$$= 1.7560$$

Thickness Due to Internal Pressure [Tr]:

$$= (P*L*M)/(2*S*E-0.2*P) \text{ per Appendix 1-4 (d)}$$

$$= (100.000*33.4375*1.7560)/(2*20000.00*1.00-0.2*100.000)$$

$$= 0.1469 + 0.0625 = 0.2094 \text{ in.}$$

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:

$$= (2*S*E*t)/(M*L+0.2*t) \text{ per Appendix 1-4 (d)}$$

$$= (2*20000.00*1.00*0.6250)/(1.7560*33.4375+0.2*0.6250)$$

$$= 424.873 \text{ psig}$$

M factor for Torispherical Heads ( New & Cold ):

$$= (3 + \sqrt{L/r})/4 \text{ per Appendix 1-4 (b \& d)}$$

$$= (3 + \sqrt{33.375/2.002})/4$$

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= 1.7706

Maximum Allowable Pressure, New and Cold [MAPNC]:

= (2\*S\*E\*t)/(M\*L+0.2\*t) per Appendix 1-4 (d)  
 = (2\*20000.00\*1.00\*0.6875)/(1.7706\*33.3750+0.2\*0.6875)  
 = 464.276 psig

Actual stress at given pressure and thickness, corroded [Sact]:

= (P\*(M\*L+0.2\*t))/(2\*E\*t)  
 = (100.000\*(1.7560\*33.4375+0.2\*0.6250))/(2\*1.00\*0.6250)  
 = 4707.293 psi

Required Thickness of Straight Flange = 0.143 in.

Percent Elongation per UCS-79 (75\*tnom/Rf)\*(1-Rf/Ro) 23.659 %

Min Metal Temp. w/o impact per UCS-66 11 F  
 Min Metal Temp. at Rqd thickness (UCS 66.1)[rat 0.23] -129 F  
 Min Metal Temp. w/o impact per UG-20(f) -20 F

**MINIMUM METAL DESIGN TEMPERATURE RESULTS :**

Minimum Metal Temp. w/o impact per UCS-66 11. F  
 Minimum Metal Temp. at Required thickness -129. F

Note: Heads and Shells Exempted to -20F (-29C) by paragraph UG-20F

Minimum Design Metal Temperature ( Entered by User ) -20. F

**Hydrostatic Test Pressure Results:**

**Exchanger Shell Side Hydrostatic Test Pressures:**

Pressure per UG99b = 1.3 \* M.A.W.P. \* Sa/S 553.324 psig  
 Pressure per UG99b[34] = 1.3 \* Design Pres \* Sa/S 130.000 psig  
 Pressure per UG99c = 1.3 \* M.A.P. - Head(Hyd) 677.914 psig  
 Pressure per UG100 = 1.1 \* M.A.W.P. \* Sa/S 468.197 psig

**Exchanger Channel Side Hydrostatic Test Pressures:**

Pressure per UG99b = 1.3 \* M.A.W.P. \* Sa/S 416.598 psig  
 Pressure per UG99b[34] = 1.3 \* Design Pres \* Sa/S 130.000 psig  
 Pressure per UG99c = 1.3 \* M.A.P. - Head(Hyd) 435.747 psig  
 Pressure per UG100 = 1.1 \* M.A.W.P. \* Sa/S 352.506 psig

UG-99(b) Note 34, Test Pressure Calculation [Shell Side]:

= Test Factor \* Design Pressure \* Stress Ratio  
 = 1.3 \* 100.000 \* 1.000  
 = 130.000 psig

UG-99(b) Note 34, Test Pressure Calculation [Channel Side]:

= Test Factor \* Design Pressure \* Stress Ratio  
 = 1.3 \* 100.000 \* 1.000  
 = 130.000 psig

Horizontal Hydrotest performed in accordance with: UG-99b (Note 34)

**Stresses on Elements due to Hydrostatic Test Pressure:**

From To	Stress	Allowable	Ratio	Pressure
Lft Head	5649.9	26000.0	0.217	131.16
Channel	3384.3	26000.0	0.130	131.16
Shell	5030.2	26000.0	0.193	131.16
RT Channel	3384.3	26000.0	0.130	131.16
RT Head	5649.9	26000.0	0.217	131.16



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Elements Suitable for Internal Pressure.

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External Pressure Calculations Step: 6 12:55p May 27,2008

**External Pressure Calculation Results :**

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**Torispherical Head From 10 to 20 Ext. Chart: HA-1 at 295 F**

**Lft Head**

Elastic Modulus from Chart: HA-1 at 295 F : 0.26635E+08 psi

Results for Maximum Allowable External Pressure (MAEP):

Tca	Sph. Rad	Ro/t	Factor A	B
0.625	34.06	54.50	0.0022936	9769.50

EMAP = B/(Ro/t) = 9769.5029 /54.5000 = 179.2569 psig

Results for Required Thickness (Tca):

Tca	Sph. Rad	Ro/t	Factor A	B
0.102	34.06	333.12	0.0003752	4997.22

EMAP = B/(Ro/t) = 4997.2236 /333.1225 = 15.0012 psig

**Cylindrical Shell From 20 to 30 Ext. Chart: HA-1 at 295 F**

**Channel**

Elastic Modulus from Chart: HA-1 at 295 F : 0.26635E+08 psi

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
0.688	33.50	15.77	48.73	0.4706	0.0094099	11995.05

EMAP = (4\*B)/(3\*(D/t)) = (4\*11995.0469)/(3\*48.7273 ) = 328.2227 psig

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
0.081	33.50	15.77	411.34	0.4706	0.0003475	4627.71

EMAP = (4\*B)/(3\*(D/t)) = (4\*4627.7085)/(3\*411.3354 ) = 15.0006 psig

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
0.688	33.50	0.60E+28	48.73	.5000E+02	0.0004633	5905.10

EMAP = (4\*B)/(3\*(D/t)) = (4\*5905.0981)/(3\*48.7273 ) = 161.5823 psig

**Cylindrical Shell From 40 to 50 Ext. Chart: CS-2 at 212 F**

**Shell**

Elastic Modulus from Chart: CS-2 at 300 F : 0.29000E+08 psi

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
0.438	33.00	96.00	75.43	2.9091	0.0006945	10070.59

EMAP = (4\*B)/(3\*(D/t)) = (4\*10070.5938)/(3\*75.4286 ) = 178.0155 psig

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
0.163	33.00	96.00	202.33	2.9091	0.0001570	2276.28

EMAP = (4\*B)/(3\*(D/t)) = (4\*2276.2771)/(3\*202.3260 ) = 15.0007 psig

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
0.438	33.00	0.85E+21	75.43	.5000E+02	0.0001933	2803.42

EMAP = (4\*B)/(3\*(D/t)) = (4\*2803.4248)/(3\*75.4286 ) = 49.5555 psig

**Cylindrical Shell From 60 to 70 Ext. Chart: HA-1 at 295 F**

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**RT Channel**

Elastic Modulus from Chart: HA-1 at 295 F : 0.26635E+08 psi

**Results for Maximum Allowable External Pressure (MAEP):**

Tca	OD	SLEN	D/t	L/D	Factor A	B
0.688	33.50	15.77	48.73	0.4706	0.0094099	11995.05

EMAP = (4\*B)/(3\*(D/t)) = (4\*11995.0469)/(3\*48.7273 ) = 328.2227 psig

**Results for Required Thickness (Tca):**

Tca	OD	SLEN	D/t	L/D	Factor A	B
0.081	33.50	15.77	411.34	0.4706	0.0003475	4627.71

EMAP = (4\*B)/(3\*(D/t)) = (4\*4627.7085)/(3\*411.3354 ) = 15.0006 psig

**Results for Maximum Stiffened Length (Slen):**

Tca	OD	SLEN	D/t	L/D	Factor A	B
0.688	33.50	0.60E+28	48.73	.5000E+02	0.0004633	5905.10

EMAP = (4\*B)/(3\*(D/t)) = (4\*5905.0981)/(3\*48.7273 ) = 161.5823 psig

**Torispherical Head From 70 to 80 Ext. Chart: CS-2 at 295 F**

**RT Head**

Elastic Modulus from Chart: CS-2 at 300 F : 0.29000E+08 psi

**Results for Maximum Allowable External Pressure (MAEP):**

Tca	Sph. Rad	Ro/t	Factor A	B
0.625	34.06	54.50	0.0022936	15478.99

EMAP = B/(Ro/t) = 15478.9912 /54.5000 = 284.0182 psig

**Results for Required Thickness (Tca):**

Tca	Sph. Rad	Ro/t	Factor A	B
0.098	34.06	347.60	0.0003596	5214.37

EMAP = B/(Ro/t) = 5214.3677 /347.5973 = 15.0012 psig

**External Pressure Calculations**

From	To	Section Length ft.	Outside Diameter in.	Corroded Thickness in.	Factor A	Factor B psi
10	20	No Calc	34.0625	0.62500	0.0022936	9769.50
20	30	1.31384	33.5000	0.68750	0.0094099	11995.0
30	40	No Calc	0.00000	3.93750	No Calc	No Calc
40	50	8.00000	33.0000	0.43750	0.00069452	10070.6
50	60	No Calc	0.00000	3.93750	No Calc	No Calc
60	70	1.31384	33.5000	0.68750	0.0094099	11995.0
70	80	No Calc	34.0625	0.62500	0.0022936	15479.0

**External Pressure Calculations**

From	To	External Actual T. in.	External Required T. in.	External Des. Press. psig	External M.A.W.P. psig
10	20	0.68750	0.16475	15.0000	179.257
20	30	0.75000	0.14394	15.0000	328.223
30	40	4.00000	3.30700	15.0000	No Calc
40	50	0.50000	0.22560	15.0000	178.016
50	60	4.00000	3.30700	15.0000	No Calc
60	70	0.75000	0.14394	15.0000	328.223
70	80	0.68750	0.16049	15.0000	284.018
Minimum					178.016

**External Pressure Calculations**

	Actual Len.	Allow. Len.	Ring Inertia	Ring Inertia
--	-------------	-------------	--------------	--------------

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External Pressure Calculations Step: 6 12:55p May 27,2008

From	To	Bet. Stiff. ft.	Bet. Stiff. ft.	Required in**4	Available in**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	1.31384	496.5E+24	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	8.00000	70.76E+18	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc
60	70	1.31384	496.5E+24	No Calc	No Calc
70	80	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

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ASMETube Analysis : Tubesheet Case: 1 12:55p May 27,2008

Input Echo, Tubesheet Number 1, Description: Tubesheet

Main Shell Description: Shell

Shell Design Pressure	Ps	100.00	psig
Shell Thickness	ts	0.5000	in.
Shell Corrosion Allowance	cas	0.0625	in.
Inside Diameter of Shell	Ds	32.0000	in.
Shell Temperature for Internal Pressure	Ts	212.00	F
Shell Material		SA-516 70	

Note: Using 2 \* Yield for Discontinuity Stress Allowable (UG-23(e)). Make sure that material properties at this temperature are not time-dependent for: SA-516 70

Shell Material UNS Number		K02700	
Shell Allowable Stress at Temperature	Ss	20000.00	psi
Shell Allowable Stress at Ambient		20000.00	psi

Channel Description: Channel

Channel Type:		Cylinder	
Channel Design Pressure	Pt	300.00	psig
Channel Thickness	tc	0.7500	in.
Channel Corrosion Allowance	cac	0.0625	in.
Inside Diameter of Channel	Dc	32.0000	in.
Channel Design Temperature	TEMPC	295.00	F
Channel Material		SA-240 304	
Channel Material UNS Number		S30400	
Channel Allowable Stress at Temperature	Sc	15085.00	psi
Channel Allowable Stress at Ambient		20000.00	psi

Number of Tubes Holes	Nt	348	
Tube Wall Thickness	t	0.0625	in.
Tube Outside Diameter	D	0.7500	in.
Total Straight Tube Length	Lt	90.00	in.
Straight Tube Length (bet. inner tubsht faces) L		86.00	in.
Design Temperature of the Tubes		295.00	F
Tube Material		SA-214	
Tube Material UNS Number		K01807	
Is This a Welded Tube		No	
Tube Material Specification used		Wld. tube	
Tube Allowable Stress at Temperature		11400.00	psi
Tube Allowable Stress At Ambient		11400.00	psi
Tube Yield Stress At Operating Temperature	Syt	23040.00	psi
Tube Pitch (Center to Center Spacing)	P	1.1250	in.
Tube Layout Pattern		Triangular	

Fillet Weld Leg	af	0.0000	in.
Groove Weld Leg	ag	0.0000	in.
Tube-Tubesheet Joint Weld Type		Seal/No Weld	
Method for Tube-Tubesheet Jt. Allow.		App. A	
Tube-Tubesheet Joint Classification		i	
Is Tube-Tubesheet Joint Tested		No	
ASME Tube Joint Reliability Factor	fr	0.70	
Interface Pressure, after tube expansion	Po	0.00	psig
Interface Pressure, due to diff. thermal exp.	PT	0.00	psig

Radius to Outermost Tube Hole Center	ro	12.0000	in.
Largest Center-to-Center Tube Distance	Ul	0.0000	in.
Length of Expanded Portion of Tube	ltx	1.5000	in.
Tube-side pass partition groove depth	hg	0.0000	in.

Tubesheet TYPE: Fixed Tubesheet Exchanger, Conf B

Tubesheet Design Metal Temperature	T	295.00	F
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ASMETube Analysis : Tubesheet Case: 1 12:55p May 27,2008

Tubesheet Material Specification SA-516 70

Note: Using 2 \* Yield for Discontinuity Stress Allowable (UG-23(e)). Make sure that material properties at this temperature are not time-dependent for Material: SA51670

Tubesheet Material UNS Number		K02700	
Tubesheet Allowable Stress at Temperature	S	20000.00	psi
Tubesheet Allowable Stress at Ambient	Tt	20000.00	psi
Thickness of Tubesheet	h	2.0000	in.
Tubesheet Corr. Allowance (Shell side)	Cats	0.0625	in.
Tubesheet Corr. Allowance (Channel side)	Catc	0.0625	in.
Tubesheet Outside Diameter	A	38.4000	in.
Area of The Untubed Lanes	AL	0.000	sq.in.
Is Exchanger in Creep range (skip EP, Use 3S for Sps)			NO

Additional Data for Fixed/Floating Tubesheet Exchangers:

Unsupported Tube Span under consideration	l	12.000	in.
Tube End condition corresponding to Span (l)	k	1.00	
Tubesheet Metal Temp. at Rim	T'	70.00	F
Shell Metal Temp. at Tubesheet	T'S	212.00	F
Channel Metal Temp. at Tubesheet	T'C	295.00	F
Perform Differential Pressure Design			N
Run Multiple Load Cases			YES

Mean Shell Metal Temp. along Shell len.	Tsm	180.00	F
Mean Tube Metal Temp. along Tube length	Ttm	248.00	F

Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side		Channel	
Flange Outside Diameter	A	38.4000	in.
Flange Inside Diameter	B	32.0000	in.
Flange Face Outside Diameter	Fod	33.0000	in.
Flange Face Inside Diameter	Fid	32.0000	in.
Gasket Outside Diameter	Go	32.7500	in.
Gasket Inside Diameter	Gi	32.0000	in.
Gasket Factor,	m	0.50	
Gasket Design Seating Stress	y	0.00	psi
Flange Facing Sketch	Code	Sketch 1a	
Column for Gasket Seating	Code	Column II	
Gasket Thickness	tg	0.1250	in.
Full face Gasket Flange Option		Program Selects	

Bolting Information:

Diameter of Bolt Circle	C	36.0000	in.
Nominal Bolt Diameter	dB	1.0000	in.
Type of Thread Series		TEMA Thread Series	
Number of Bolts	n	28	
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	25000.00	psi
Bolt Allowable Stress At Ambient	Sa	25000.00	psi
Weld between Flange and Shell/Channel		0.0000	in.

Tubesheet Integral with		Shell	
Tubesheet Extended as Flange		Yes	
Thickness of Extended Portion of Tubesheet	Tf	2.0000	in.
Is Bolt Load Transferred to the Tubesheet		Yes	

Notes/Error Messages/Warnings for Tubesheet number 1

Note - Tube-Tubesheet Joint Interface pressures are 0, its effect will be ignored [App. A(2)].

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ASMETube Analysis : Tubesheet Case: 1 12:55p May 27,2008

Elasticity/Expansion Material Properties:

Shell - C-Mn-Si, 1-1/4Cr-1/2Mo & 3Cr-1M  
 Th. Exp. Coeff. Metal Temp. along Len 180.0 F 0.0000058180 /F  
 Elastic Mod. at Design Temp. 212.0 F 0.28440E+08 psi  
 Th. Exp. Coeff. Metal Temp. at Tubsht 212.0 F 0.0000059344 /F  
 Elastic Mod. at Metal Temp. along Len 180.0 F 0.28577E+08 psi

Channel - TP304  
 Th. Exp. Coeff. Metal Temp. at Tubsht 295.0 F 0.0000089895 /F  
 Elastic Mod. at Design Temp. 295.0 F 0.27025E+08 psi

Tubes - Plain Carbon Stl & C-Mn Stl.  
 Th. Exp. Coeff. Metal Temp. along Len 248.0 F 0.0000067660 /F  
 Elastic Mod. at Design Temp. 295.0 F 0.28025E+08 psi  
 Elastic Mod. at Metal Temp. along Len 248.0 F 0.28260E+08 psi  
 Elastic Mod. at Tubsht. Design Temp. 295.0 F 0.28025E+08 psi

TubeSheet - C-Mn-Si, 1-1/4Cr-1/2Mo & 3Cr-1M  
 Th. Exp. Coeff. Metal Temp. at Rim 70.0 F 0.0000055300 /F  
 Elastic Mod. at Design Temp. 295.0 F 0.28025E+08 psi  
 Elastic Mod. at Metal Temp. at Rim 70.0 F 0.29000E+08 psi

Note:

The Elasticity and Alpha values are taken from Tables in ASME II D or TEMA. Please insure these properties are consistent with the type of Material for the tubes, shell, channel etc.

Tube Required Thickness under Internal Pressure (Tubeside pressure) :

Thickness Due to Internal Pressure:  
 = (P\*(D/2-CAE)) / (S\*E+0.4\*P) per Appendix 1-1 (a)(1)  
 = (300.00\*(0.7500/2-0.000))/(11400.00\*1.00+0.4\*300.00)  
 = 0.0098 + 0.0000 = 0.0098 in.

Tube Required Thickness under External Pressure (Shellside pressure) :

External Pressure Chart CS-1 at 295.00 F  
 Elastic Modulus for Material 29000000.00 psi

Results for Max. Allowable External Pressure (Emawp):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.0625	0.75	86.00	12.00	50.0000	0.0076389	13895.75

EMAWP = (4\*B)/(3\*(D/T)) = ( 4 \*13895.7520 )/( 3 \*12.0000 ) = 1543.9724 psig

Results for Req'd Thickness for Ext. Pressure (Tca):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.0126	0.75	86.00	59.69	50.0000	0.0003087	4476.81

EMAWP = (4\*B)/(3\*(D/T)) = ( 4 \*4476.8086 )/( 3 \*59.6892 ) = 100.0026 psig

Summary of Tube Required Thickness Results:

Total Required Thickness including Corrosion all.	0.0126 in.
Allowable Internal Pressure at Corroded thickness	2035.71 psig
Required Internal Design Pressure	300.00 psig
Allowable External Pressure at Corroded thickness	1543.97 psig
Required External Design Pressure	100.00 psig

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII, Div. 1, 2007

Gasket Contact Width,	N = (Goc-Gic) / 2	0.375 in.
Basic Gasket Width,	b0 = N / 2.0	0.188 in.
Effective Gasket Width,	b = b0	0.188 in.
Gasket Reaction Diameter,	G = (Go+Gi) / 2.0	32.375 in.

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ASMETube Analysis : Tubesheet

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**Bolting Information for TEMA Imperial Thread Series (Non Mandatory):**

Distance Across Corners for Nuts 1.796 in.

Circular Wrench End Diameter a 2.562 in.

	Minimum	Actual	Maximum
Bolt Area, sq.in.	10.107	15.428	
Radial distance bet. hub and bolts	1.062	1.500	
Radial distance bet. bolts and the edge	1.062	1.200	
Circumferential spacing between bolts	2.250	4.031	14.000

Flange Design Bolt Load W 319191.72 lb.

Required Tubesheet Flanged Extension thk. per UHX-9 (operating) [hr\_opr]:

$$= \text{SQRT}( 1.9 * \text{WM1} * \text{hg} / ( \text{S} * \text{G} ) )$$

$$= \text{SQRT}( 1.9 * 252683.47 * 1.812 / ( 20000.00 * 32.375 ) )$$

$$= 1.159 \text{ in.}$$

Required Tubesheet Flanged Extension thk. per UHX-9 (seating) [hr\_seat]:

$$= \text{SQRT}( 1.9 * \text{W} * \text{hg} / ( \text{Sa} * \text{G} ) )$$

$$= \text{SQRT}( 1.9 * 319191.72 * 1.812 / ( 20000.00 * 32.375 ) )$$

$$= 1.303 \text{ in.}$$

**Detailed Tubesheet Results for load Case 3uc (Ps+Pt-Th)**

**Results for ASME Fixed Tubesheet Calculations for Configuration b,**

**Results for Tubesheet Calculations Original Thickness :**

**UHX-13.5.1 Step 1:**

Compute the Tube Expansion Depth Ratio [rho]:

$$= \text{ltx} / \text{h} \text{ ( modified for corrosion if present )}$$

$$= 1.5000 / 2.0000 = 0.7500 \text{ ( must be } 0 \leq \text{rho} \leq 1 \text{ )}$$

Compute the Effective Tube Hole Diameter [d\*]:

$$= \text{Max}( \text{dt} - 2\text{tt} * ( \text{Et}/\text{E} ) ( \text{St}/\text{S} ) ( \text{rho} ), \text{dt} - 2\text{tt} )$$

$$= \text{Max}( 0.7500 - 2 * 0.0625 * ( .28025\text{E}+08 / .28025\text{E}+08 ) * ( 11400 / 20000 ) * ( 0.750 ), 0.7500 - 2 * 0.0625 )$$

$$= 0.6966 \text{ in.}$$

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:

$$= 2 * \text{ro} + \text{dt} = 2 * 12.000 + 0.750 = 24.750 \text{ in.}$$

Determine the Basic Ligament Efficiency for Shear [mu]:

$$= (\text{p} - \text{dt}) / \text{p} = (1.1250 - 0.7500) / 1.1250 = 0.3333$$

Compute the Equivalent Outer Tube Limit Radius [ao]:

$$= \text{Do} / 2 = 24.7500 / 2 = 12.3750 \text{ in.}$$

Compute the Effective Tube Pitch [p\*]:

$$= \text{p} / \text{sqrt}( 1 - 4 * \text{min}( \text{AL}, 4 * \text{Do} * \text{p} ) / ( \text{Pi} * \text{Do}^2 ) )$$

$$= 1.1250 / \text{sqrt}( 1 - 4 * \text{min}( 0.00 , 4 * 24.750 * 1.125 ) / ( 3.141 * 24.750^2 ) )$$

$$= 1.1250 \text{ in.}$$

Compute the Effective Ligament Efficiency for Bending [mu\*]:

$$= (\text{p}^* - \text{d}^*) / \text{p}^* = (1.1250 - 0.6966) / 1.1250 = 0.3808$$



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Compute the Ratio [Rhos]:

$$= a_s / a_o = 16.0000 / 12.3750 = 1.292929$$

Compute the Ratio [Rhoc]:

$$= a_c / a_o = 16.1875 / 12.3750 = 1.308081$$

Compute Parameter [xt]:

$$= 1 - N_t * ((d_t - 2 * t_t) / (2 * a_o))^2$$

$$= 1 - 348 * ((0.7500 - 2 * 0.0625) / (2 * 12.3750))^2 = 0.7781$$

Determine Parameter [xs]:

$$= 1 - N_t * (d_t / (2 * a_o))^2$$

$$= 1 - 348 * (0.7500 / (2 * 12.3750))^2 = 0.6804$$

Determine the Value [h'g]:

$$= \text{Max}((h_g - \text{CATC}), 0) \quad (\text{For pressure only cases})$$

$$= \text{Max}(0.000 - 0.000), 0 = 0.000 \text{ in.}$$

**UHX-13.5.2 Step 2:**

Determine the Axial Shell Stiffness [Ks]:

$$= \pi * t_s (D_s + t_s) E_s / L$$

$$= 3.1416 * 0.5000 (32.0000 + 0.5000) .28440E+08 / 86.000$$

$$= 16882408.0000 \text{ psi} * \text{in.}$$

Determine the Axial Tube Stiffness [Kt]:

$$= \pi * t_t (D_t - t_t) E_t / L$$

$$= 3.1416 * 0.0625 (0.7500 - 0.0625) .28025E+08 / 86.000$$

$$= 43989.5742 \text{ psi} * \text{in.}$$

Compute the Stiffness Factor [Kst]:

$$= K_s / (N_t * K_t) = .16882E+08 / (348 * 43989.574) = 1.10282$$

Compute Factor [J]:

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

$$= 1 / (1 + .16882E+08 / 0.000) = 1.0000000 \quad (= 1 \text{ if No Exp. Jt.})$$

Compute Shell Coefficient [betas]:

$$= ((12 * (1 - \text{nus}^2))^{0.25}) / ((D_s + t_s) * t_s)^{0.5}$$

$$= ((12 * (1 - 0.30^2))^{0.25}) / ((32.0000 + 0.5000) * 0.5000)^{0.5}$$

$$= 0.4510 \text{ 1/in.}$$

Determine Shell Coefficient [ks]:

$$= \text{betas} * E_s * t_s^3 / (6 * (1 - \text{nus}^2))$$

$$= 0.451 * .28440E+08 * 0.500^3 / (6 * (1 - 0.300^2))$$

$$= 293613.4375 \text{ psig} * \text{in.}^2$$

Determine Shell Coefficient [Lambdas]:

$$= (6 * D_s * k_s) / (h^3) * (1 + h * \text{betas} + 0.5 * (h * \text{betas})^2)$$

$$= 6 * 32.000 * 293613.438 / (2.000^3) * (1 + 2.000 * 0.451 + 0.407)$$

$$= 16268163.0000 \text{ psig}$$

Determine Shell Coefficient [deltaS]:

$$= D_s^2 / (4 * E_s * T_s) * (1 - \text{nus} / 2)$$

$$= 32.000^2 / (4 * .28440E+08 * 0.500) * (1 - 0.3 / 2)$$

$$= 0.0000153024 \text{ in./psi}$$

Intermediate parameters for Tubesheet Gasketed on the Channel Side:

betac, kc, deltaC, Lambdac = 0

**UHX-13.5.3 Step 3:**

Looking up E\*/E and nu\* from Table UHX-11.2 using h/p = 1.77778

$$E^*/E = 0.396923 ; \quad \text{nu}^* = 0.310175 ; \quad E^* = 11123767. \text{ psi}$$

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Compute the Tube Bundle Stiffness Factor [Xa]:

$$= ((24 * (1 - \nu^2) * N_t * E_t * t_t * (d_t - t_t) * a_o^2) / (E * L * H^3))^{0.25}$$

$$= ((24 * (1 - 0.310^2) * 348 * .28025E+08 * 0.0625 * (0.7500 - 0.0625) * 12.3750^2) / (.11124E+08 * 86.00 * 2.000^3))^{0.25}$$

$$= 3.6724$$

Values from Table UHX-13.1

$$Z_d = 0.031149 ; Z_V = 0.076156 ; Z_M = 0.412984$$

UHX-13.5.4 Step 4:

Compute the Diameter Ratio [K]:

$$= A / D_o = 38.4000 / 24.7500 = 1.5515$$

Compute Coefficient [F]:

$$= (1 - \nu^*) / (E^*) * (\Lambda_{d,s} + \Lambda_{d,c} + E * \ln(K))$$

$$= (1 - 0.31) / (.11124E+08) * (.16268E+08 + 0.00 + .28025E+08 * \ln(1.55))$$

$$= 1.7722$$

Compute Parameter [Phi]:

$$= (1 + \nu^*) * F = (1 + 0.3102) * 1.7722 = 2.3219$$

Compute Parameter [Q1]:

$$= (R_{hos} - 1 - \Phi * Z_V) / (1 + \Phi * Z_M)$$

$$= (1.2929 - 1 - 2.3219 * 0.0762) / (1 + 2.3219 * 0.4130)$$

$$= 0.059269361$$

Compute Parameter [Qz1]:

$$= (Z_d + Q_1 * Z_V) / 2 * X_a^4$$

$$= (0.03115 + 0.05927 * 0.07616) / 2 * 3.67242^4 = 3.2433$$

Compute Parameter [Qz2]:

$$= (Z_V + Q_1 * Z_M) / 2 * X_a^4$$

$$= (0.07616 + 0.05927 * 0.41298) / 2 * 3.67242^4 = 9.1521$$

Compute Parameter [U]:

$$= (Z_V + (R_{hos} - 1) * Z_M) * X_a^4 / (1 + \Phi * Z_M)$$

$$= (0.0762 + (1.2929 - 1) * 0.4130) * 3.67242^4 / (1 + 2.3219 * 0.4130)$$

$$= 18.3041$$

UHX-13.5.5 Step 5:

Determine factor [gamab]:

$$= (G_c - C) / D_o \text{ (config b)}$$

$$= (32.3750 - 36.0000) / 24.7500 = -0.14646$$

Compute Parameter [gamma]:

$$= (\alpha_{tm} * (T_{tm} - A_{MB\_TEMP}) - \alpha_{sm} * (T_{sm} - A_{MB\_TEMP})) * L$$

$$= (0.677E-05 * (70.0 - 70.0) - 0.582E-05 * (70.0 - 70.0)) * 86.00$$

$$= 0.000 \text{ in. (For Pressure only cases)}$$

Calculate Parameter [OmegaS]:

$$= \rho_{hos} * k_s * \beta_{tas} * \delta_{tas} (1 + h * \beta_{tas})$$

$$= 1.2929 * 293613.44 * 0.4510 * 0.000015 (1 + 2.0000 * 0.4510)$$

$$= 4.9823 \text{ in.}^2$$

Calculate Parameter [Omega\*S]:

$$= A_o^2 * (\rho_{hos}^2 - 1) * (\rho_{hos} - 1) / 4 - \Omega_{tas}$$

$$= 12.375^2 * (1.293^2 - 1) * (1.293 - 1) / 4 - 4.982$$

$$= 2.5504 \text{ in.}^2$$

Calculate Parameter [OmegaC]:

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$$= \text{rhoc} * \text{kc} * \text{Betac} * \text{deltaC} ( 1 + \text{h} * \text{Betac} )$$

$$= 1.3081 * 0.00 * 0.0000 * 0.000000 ( 1 + 2.0000 * 0.0000 )$$

$$= 0.0000 \text{ in.}^2$$

Calculate Parameter [Omega\*C]:

$$= \text{ao}^2 [ ( \text{Rhoc}^2 + 1 ) * ( \text{Rhoc} - 1 ) / 4 - ( \text{Rhos} - 1 ) / 2 ] - \text{OmegaC}$$

$$= 12.37500^2 [ ( 1.30808^2 + 1 ) * ( 1.30808 - 1 ) / 4 - ( 1.29293 - 1 ) / 2 ] - 0.00000$$

$$= 9.5472 \text{ in.}^2$$

Compute the Pressure [P\*S]:

$$= 0.000 \text{ psig}$$

= 0 For Pressure only cases or Configurations d,e,f,A,B,C,D

Compute the Pressure [P\*C]:

$$= 0.000 \text{ psig}$$

= 0 For Pressure only cases or Configurations b,c,d,B,C,D

UHX-13.5.6 Step 6:

Compute the Pressure [P's]:

$$= \text{Ps} * \{ \text{xs} + 2( 1 - \text{xs} ) \text{nut} + [ 2 / \text{Kst} ( \text{Ds} / \text{Do} )^2 ] \text{nus} -$$

$$[ ( \text{rhos}^2 - 1 ) / ( \text{J} * \text{Kst} ) ] - [ ( 1 - \text{J} ) / ( 2 \text{J} * \text{Kst} ) ] [ ( \text{Dj}^2 - ( 2 \text{As} )^2 ) / \text{Do}^2 ] \}$$

$$= 100.000 * \{ 0.680 + 2( 1 - 0.680 ) 0.300 +$$

$$[ 2 / 1.103 ( 32.000 / 24.750 )^2 ] 0.300 -$$

$$[ ( 1.293^2 - 1 ) / ( 1.000 * 1.103 ) ] -$$

$$[ ( 1 - 1.000 ) / ( 2 * 1.000 * 1.103 ) ] [ ( 0.000^2 - ( 2 * 16.000 )^2 ) / 24.750^2 ] \}$$

$$= 117.2618 \text{ psig}$$

Compute the Pressure [P't]:

$$= [ \text{xt} + 2( 1 - \text{xt} ) \text{nut} + 1 / ( \text{J} * \text{Kst} ) ] * \text{Pt}$$

$$= [ 0.778 + 2( 1 - 0.778 ) 0.300 +$$

$$1 / ( 1.00000 * 1.103 ) ] * 300.000$$

$$= 545.3995 \text{ psig}$$

Compute the Pressure [Pgama]:

$$= \text{Nt} * \text{Kt} * \text{gama} / ( \text{pi} * \text{ao}^2 )$$

$$= 348 * 43989.574 * 0.000 / ( 3.142 * 12.375^2 ) = 0.000 \text{ psig}$$

Compute the Pressure [Pw]:

$$= -\text{gamab} * \text{U} * \text{W} / ( 2 * \text{pi} * \text{ao}^2 )$$

$$= --0.146 * 18.304 * 319191.72 / ( 2 * 3.142 * 12.375^2 ) = 889.330 \text{ psig}$$

Calculate the Pressure [Prim]:

$$= - ( \text{U} / \text{ao}^2 ) ( \text{Omega} * \text{S} * \text{Ps} - \text{Omega} * \text{C} * \text{Pt} )$$

$$= - ( 18.304 / 12.375^2 ) ( 2.550 * 100.000 - 9.547 * 300.000 )$$

$$= 311.8563 \text{ psig}$$

Calculate the Pressure [POmega]:

$$= \text{U} / \text{ao}^2 ( \text{Omega} * \text{S} * \text{P*s} - \text{Omega} * \text{C} * \text{P*c} )$$

$$= 18.304 / 12.375^2 ( 4.9823 * 0.0000 - 0.0000 * 0.0000 )$$

$$= 0.0000 \text{ psig}$$

Determine the Effective Pressure [Pe]:

$$= \text{J} * \text{Kst} / ( 1 + \text{J} * \text{Kst} * ( \text{Qz1} + ( \text{Rhos} - 1 ) * \text{Qz2} ) ) *$$

$$( \text{P's} - \text{P't} + \text{Pgama} + \text{Pw} + \text{Prim} )$$

$$= 0.1000\text{E}+01 * 1.103 / ( 1 + 1.000 * 1.103 * ( 3.243 + ( 1.293 -$$

$$1 ) * 9.152 ) ) * ( 117.262 - 545.399 + 0.000 + 889.330 + 311.856 )$$

$$= 113.1683 \text{ psig}$$

UHX-13.5.7 Step 7:

Determine Factor [Q2]:

$$= [ ( ( \text{Omega} * \text{S} * \text{Ps} - \text{Omega} * \text{C} * \text{Pt} ) - ( \text{Omega} * \text{S} * \text{P*s} - \text{Omega} * \text{C} * \text{P*c} ) ) * \text{CNV\_FAC} +$$

$$\text{W} * \text{gamab} / ( 2 * \text{pi} ) ] / ( 1 + \text{Phi} * \text{Zm} )$$

$$= [ ( ( 2.550 * 100.000 - 9.547 * 300.000 ) -$$

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$$\begin{aligned} & ( 4.982 * 0.000 - 0.000 * 0.000 ) ) * 1.000 + \\ & 319191.7 * -0.146 / (2*3.14159) ] / (1 + 2.32190 * 0.41298 ) \\ & = -5130.250976562 \text{ lb.} \end{aligned}$$

Calculate Factor [Q3]:

$$\begin{aligned} & = Q1 + 2 * Q2 / ( Pe * ao^2 \\ & = 0.059 + 2 * -5130.251 / ( 113.168 * 12.375^2 = -0.532774 \end{aligned}$$

Fm Value from Table UHX-13.1 = 0.266387

The Tubesheet Bending Stress - Original Thickness [Sigma]:

$$\begin{aligned} & = (1.5 * Fm / mu^* ) * ( 2 * ao / (H - h'g)^2 * Pe \\ & = (1.5 * 0.2664 / 0.3808 ) * ( 2 * 12.3750 / (2.000 - 0.000 ) )^2 * 113.17 \\ & = 18183.7910 \text{ psi} \end{aligned}$$

The Allowable Tubesheet Bending Stress [Sigma allowed]:

$$= 1.5 * S = 1.5 * 20000.00 = 30000.00 \text{ psi}$$

The Tubesheet Bending Stress - Final Thickness [Sigmaaf]:

$$\begin{aligned} & = (1.5 * Fm/mu^* ) * ( 2 * ao / ( h - h'g )^2 * Pe \\ & = (1.5 * 0.1570 / 0.3808 ) * ( 2 * 12.3750 / (1.431 - 0.000 ) )^2 * 162.21 \\ & = 29999.5137 \text{ psi} \end{aligned}$$

Reqd Tubesheet Thickness, for Bending Stress (Including CA ) [HReqB]:

$$= h + Cats + Catc = 1.4312 + 0.0000 + 0.0000 = 1.4312 \text{ in.}$$

UHX-13.5.8 Step 8:

The Tubesheet Average Shear Stress - Original Thickness [Tau]:

$$\begin{aligned} & = ( 1 / (2 * mu) ) * ( ao / h ) * Pe \\ & = ( 1 / (2 * 0.333 ) ) * ( 12.3750 / 2.000 ) * 113.168 = 1050.34 \text{ psi} \end{aligned}$$

The Allowable Tubesheet Shear Stress [Tau allowed]:

$$= 0.8 * S = 0.8 * 20000.00 = 16000.00 \text{ psi}$$

The Tubesheet Shear Stress - Final Thickness [Tauf]:

$$\begin{aligned} & = ( 1 / (2 * mu) ) * ( ao / h ) * Pe \\ & = ( 1 / (2 * 0.333 ) ) * ( 12.3750 / 0.295 ) * 242.269 = 15230.44 \text{ psi} \end{aligned}$$

Reqd Tubesheet Thickness, for Shear Stress (Including CA) [HreqS]:

$$= H + Cats + Catc = 0.2953 + 0.0000 + 0.0000 = 0.2953 \text{ in.}$$

Reqd Tubesheet Thickness for Given Loadings (Including CA) [Hreqd] :

$$= \text{Max}( HreqB, HreqS ) = \text{Max}( 1.4312 , 0.2953 ) = 1.4312 \text{ in.}$$

UHX-13.5.9 Step 9:

Determine Coefficient [Fq]:

$$\begin{aligned} & = ( Zd + Q3 * Zv ) * Xa^4 / 2 \\ & = ( 0.0311 + -0.5328 * 0.0762 ) * 3.6724^4 / 2 = -0.8572 \end{aligned}$$

The Tube Stress in the outermost Tube row [Sigmat0]

$$\begin{aligned} & = ( ( Ps * xs - Pt * xt ) - Pe * Fq ) / ( xt - xs ) ) \\ & = ( ( 100.00 * 0.6804 - 300.00 * 0.7781 ) - 113.17 * -0.857 ) / \\ & ( 0.7781 - 0.6804 ) ) \\ & = -700.2524 \text{ psi} \end{aligned}$$

The Allowable Tube Stress, [SigmatA]

$$= Sot = 11400.0000 \text{ psi}$$

Check for Buckling because the Tubes are in Compression

Determine the Factor of Safety [Fs]:

$$\begin{aligned} & = \text{Max}( ( 3.25 - 0.5 * Fq ), ( 1.25 ) ) \\ & = \text{Max}( ( 3.25 - 0.5 * -0.8572 ), ( 1.25 ) ) \end{aligned}$$

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$$= 2.0000 \text{ (Should be } \leq 2 \text{ )}$$

Determine the Factor [rt]:

$$= ( ( dt^2 + (dt - 2*tt)^2 )^{.5} )/4$$

$$= ( ( 0.7500^2 + (0.7500 - 2*0.0625)^2 )^{.5} )/4 = 0.2441 \text{ in.}$$

Determine the Factor [Ct]:

$$= ( 2 * PI^2 * Et/Syt )^{0.5}$$

$$= ( 2 * 3.14^2 * .28025E+08/23040 )^{0.5} = 154.9517$$

Determine the Factor [Ft]:

$$= k * L/r = 1.0 * 12.00 / 0.244 = 49.1662$$

The Buckling Allowable Stress [Stb]:

$$= Sy,t/Fs*( 1 - Ft/(2*Ct) )$$

$$= 23040 / 2.00 *( 1 - 49.166 / (2*154.952 ) )$$

$$= 9692.353 \text{ psi (Never greater than Sot)}$$

The Force on the Outermost Tube [TubeForce]:

$$= \text{TubeStress} * \text{Tube Area} = -700.25 * 0.1350 = -94.53 \text{ lb.}$$

Allowable Tube-To-Tubesheet Load per ASME App. A [Lmax]:

$$= (PI/4)*(DT^2-(DT-2*TT)^2)*SOT*fr*fe*fy*ft$$

$$= .785*(0.750^2-(0.750-2*0.0625)^2)*11400*0.70*1.00*1.00*1.00$$

$$= 1077.22 \text{ lb.}$$

UHX-13.5.10 Step 10:

Note: For a given Shell thickness of: 0.500 in.

Min. Shell len. adjacent to the tubesheet should be: 7.200 in.

The Shell Membrane Stress due to Joint Interaction [Sigmasm]:

$$= ao^2/((2*as+ts)*ts) * [Pe + (Rhos^2-1)(Ps-Pt)] + as^2*Pt/((2*as+ts)*ts)$$

$$= 12.375^2/((2*16.000 + 0.5000) * 0.5000) * [113.17 + (1.293^2-1)$$

$$(100.00 - 300.00)] + 16.000^2*300.00 / ((2*16.00 + 0.5000)$$

$$* 0.50)$$

$$= 4526.6943 \text{ psi}$$

The Shell Bending Stress due to Joint Interaction [Sigmasb]

$$= 6*ks/ts^2 * \{betas[\delta s*Ps + as^2*PstarS/(Es*ts) - nus*as*Sigmasm/Es] +$$

$$6(1 - nu^2)/(E*(ao/h)^3(1 + h*betas/2) * [Pe(Zv + Zm*Q1) +$$

$$2/ao^2 * Zm * Q2 ]\}$$

$$= 6 * 293613.438/0.5000^2 * \{0.451 [ 0.000 * 100.000 + 16.0000^2$$

$$* 0.0000 / (.14220E+08) - 0.30 * 16.00 * 4526.7 / .28440E+08 ] +$$

$$6(1 - 0.31^2)/(.11124E+08)(12.38 / 2.00)^3 (1 + 2.00 * 0.45$$

$$/ 2) * [ 113.2 ( 0.076 + 0.413 * 0.059 ) + 2/12.38^2 * 0.413 * -5130.251 ] \}$$

$$= -16789.4180 \text{ psi}$$

Shell Stress Summation vs. Allowable

$$|Sigmasm| + |Sigmasb| \leq 1.5 * Ss$$

$$|4526.7| + |-16789.4| \leq 30000.00 \text{ psi}$$

$$21316.11 \text{ must be } < \text{ or } = 30000.00 \text{ psi}$$

Computations Completed for ASME Tubesheet Configuration b

Summary of Stress/Force Comparisons

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet Bend. Stress	18183.8	<=	30000.0 psi	Ok
Tubesheet Shear Stress	1050.3	<=	16000.0 psi	Ok
Stress in Outermost Tube	700.3	<=	11400.0 psi	Ok
Tube Stress (Buckling)	-700.3	<=	-9692.4 psi	Ok
Force on the Outermost Tube	94.5	<=	1077.2 lb.	Ok

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ASMETube Analysis : Tubesheet

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Shell Stress (jt. inter.) 21316.1 <= 30000.0 psi Ok

Summary of Thickness Comparisons

Thickness (in.)	Required	Actual	P/F
Tubesheet Thickness :	1.4312	2.0000	Ok

Fixed Tubesheet results per ASME UHX-13 2007

Results for 14 Load Cases:

Case#	--Reqd. Thk. + CA Tbsht Extnsn	----- Tubesheet Bend Allwd	Stresses Shear Allwd	Case Type	Pass/ Fail
1uc	1.475 1.303	18924 30000	932 16000	Fvs+Pt-Th	Ok
2uc	1.076 1.303	11894 30000	1326 16000	Ps+Fvt-Th	Ok
3uc	1.431 1.303	18184 30000	1050 16000	Ps+Pt-Th	Ok
4uc	0.658 1.303	10392 67320	3479 16000	Fvs+Fvt+Th	Ok
5uc	0.813 1.303	16682 67320	3203 16000	Fvs+Pt+Th	Ok
6uc	0.637 1.303	10395 67320	3597 16000	Ps+Fvt+Th	Ok
7uc	0.791 1.303	15942 67320	3321 16000	Ps+Pt+Th	Ok
1c	1.638 1.303	21709 30000	1114 16000	Fvs+Pt-Th-Ca	Ok
2c	1.212 1.303	13274 30000	1435 16000	Ps+Fvt-Th-Ca	Ok
3c	1.584 1.303	20627 30000	1204 16000	Ps+Pt-Th-Ca	Ok
4c	0.761 1.303	10507 67320	3422 16000	Fvs+Fvt+Th-Ca	Ok
5c	0.925 1.303	17860 67320	3190 16000	Fvs+Pt+Th-Ca	Ok
6c	0.733 1.303	10143 67320	3511 16000	Ps+Fvt+Th-Ca	Ok
7c	0.896 1.303	16778 67320	3279 16000	Ps+Pt+Th-Ca	Ok
Max:	1.6384 1.303 in.	0.724	0.225	(Str. Ratio)	

Load Case Definitions:

Fvs,Fvt - User-defined Shell-side and Tube-side vacuum pressures or 0.0.

Ps, Pt - Shell-side and Tube-side Design Pressures.

(+/-)Th - With or Without Thermal Expansion.

Ca - With or Without Corrosion Allowance.

Tube, Shell and Channel Stress Summary:

Case#	----- Tube Stresses		Tube Loads		Shell Stress		Channel Stress		Pass		
Ten	Allwd	Cmp	Allwd	Ld	Allwd	Stress	Allwd	Stress	Allwd	Fail	
1uc	855	11400	-855	-9692	115	1077	27361	30000	-	0	Ok
2uc	651	11400	-651	-9692	88	1077	4560	30000	-	0	Ok
3uc	700	11400	-700	-9692	95	1077	21316	30000	-	0	Ok
4uc	8430	22800	-8430	-9692	1138	2154	30711	69312	-	0	Ok
5uc	8479	22800	-8479	-9692	1145	2154	19048	69312	-	0	Ok
6uc	8276	22800	-8276	-9692	1117	2154	38261	69312	-	0	Ok
7uc	8325	22800	-8325	-9692	1124	2154	26599	69312	-	0	Ok
1c	883	11400	-883	-9692	119	1077	29373	30000	-	0	Ok
2c	699	11400	-699	-9692	94	1077	4681	30000	-	0	Ok
3c	707	11400	-707	-9692	95	1077	22584	30000	-	0	Ok
4c	8131	22800	-8131	-9692	1098	2154	29943	69312	-	0	Ok
5c	8139	22800	-8139	-9692	1099	2154	17986	69312	-	0	Ok
6c	7955	22800	-7955	-9692	1074	2154	38397	69312	-	0	Ok
7c	7963	22800	-7963	-9692	1075	2154	26441	69312	-	0	Ok
Max RATIO	0.372		0.875		0.531		0.979		-		

Summary of Thickness Comparisons

Thickness (in.)	Required	Actual	P/F
-----------------	----------	--------	-----

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ASMETube Analysis : Tubesheet Case: 1 12:55p May 27,2008

```
-----
Tubesheet Thickness :                1.6384      2.0000      Ok
Tubesheet Thickness Flanged Extension : 1.3029      2.0000      Ok
Tube Thickness :                    0.0126      0.0625      Ok
-----
```

Min Shell length of thk, (0.500) adj. to tubesheet: 7.200 in.

**Maximum Axial Differential Thermal Expansion between Shell and Tubes:**

Tube has higher Thermal growth (Exp. Jt. Extension) : +0.0486 in.

**Tubesheet MAWP used to Compute Hydrotest Pressure:**

Stress / Force Condition	Tubeside (0 shellside)		Shellside (0 tubeside)	
	MAWP	Stress Rat.	MAWP	Stress Rat.
Tubesheet Bending Stress	488.40	1.000	2686.79	1.000
Tubesheet Shear Stress	13057.04	1.000	11025.24	1.000
Tube Tensile Stress	----	----	6769.28	1.000
Tube Compressive Stress	1290.05	1.000	----	----
Tube-Tubesheet Joint load	6113.50	1.000	4828.52	1.000
Tubesheet-Shell Junction	488.40	1.000	425.63	1.000
Tube Pressure Stress	2035.70	1.000	1543.96	1.000
Tubesheet Extension Stress	457.91	0.000	----	----
Minimum MAWP	457.91		425.63	

**Tubesheet MAPnc used to Compute Hydrotest Pressure:**

Stress / Force Condition	Tubeside (0 shellside)		Shellside (0 tubeside)	
	MAPnc	Stress Rat.	MAPnc	Stress Rat.
Tubesheet Bending Stress	587.81	1.000	3073.69	1.000
Tubesheet Shear Stress	22923.09	1.000	12962.62	1.000
Tube Tensile Stress	----	----	7752.16	1.000
Tube Compressive Stress	8910.51	1.000	----	----
Tube-Tubesheet Joint load	6446.21	1.000	5520.93	1.000
Tubesheet-Shell Junction	587.81	1.000	1074.84	1.000
Tube Pressure Stress	2035.70	1.000	1543.96	1.000
Tubesheet Extension Stress	457.91	0.000	----	----
Minimum MAPnc	457.91		1074.84	

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Vessel Design Summary Step: 8 12:55p May 27,2008

Design Code: ASME Code Section VIII Division 1, 2007

Diameter Spec : 32.000 in. ID  
 Vessel Design Length, Tangent to Tangent 11.00 ft.  
 Specified Datum Line Distance 0.00 ft.  
 Shell/Head Matl SA-240 304  
 Shell/Head Matl SA-516 70  
 Shell Side Design Temperature 212 F  
 Channel Side Design Temperature 295 F  
 Shell Side Design Pressure 100.00 psig  
 Channel Side Design Pressure 300.00 psig  
 Shell Side Hydrostatic Test Pressure 130.00 psig  
 Channel Side Hydrostatic Test Pressure 130.00 psig  
 Required Minimum Design Metal Temperature -20 F  
 Warmest Computed Minimum Design Metal Temperature -129 F  
 Wind Design Code ASCE-93  
 Earthquake Design Code UBC-94

Element Pressures and MAWP: psig

Element Desc	Internal	External	M. A. W. P	Corr. All.
Lft Head	300.000	15.000	320.460	0.0625
Channel	300.000	15.000	535.071	0.0625
Flange 1	300.000	15.000	352.520	0.0625
Shell	100.000	15.000	455.590	0.0625
Flange 2	300.000	15.000	352.520	0.0625
RT Channel	300.000	15.000	535.071	0.0625
RT Head	100.000	15.000	424.873	0.0625

Element Type	"To" Elev ft.	Length ft.	Element Thk in.	Reqd Int.	Thk Ext.	Joint Eff Long	Eff Circ
Torisph	0.17	0.167	0.750	0.648	0.165	1.00	0.85
Cylinder	1.17	1.000	0.750	0.444	0.144	0.85	0.85
Body Flg	1.50	0.333	4.000	3.912	3.307	0.85	0.85
Cylinder	9.50	8.000	0.500	0.157	0.226	0.85	0.85
Body Flg	9.83	0.333	4.000	3.912	3.307	0.85	0.85
Cylinder	10.83	1.000	0.750	0.444	0.144	0.85	0.85
Torisph	11.00	0.167	0.750	0.209	0.160	1.00	0.85

Element thicknesses are shown as Nominal if specified, otherwise are Minimum

**Weights:**

Fabricated - Bare W/O Removable Internals 5609.0 lbm  
 Shop Test - Fabricated + Water ( Full ) 9632.5 lbm  
 Shipping - Fab. + Rem. Intls.+ Shipping App. 5609.0 lbm  
 Erected - Fab. + Rem. Intls.+ Insul. (etc) 5609.0 lbm  
 Empty - Fab. + Intls. + Details + Wghts. 5609.0 lbm  
 Operating - Empty + Operating Liquid (No CA) 5609.0 lbm  
 Field Test - Empty Weight + Water (Full) 9632.5 lbm