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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	

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	

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	

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.

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]:
$= 0.785 * G^2 * Peq$
$= 0.785 * 32.3750^2 * 300.000$
$= 246962.328$ lb.
Contact Load on Gasket Surfaces [Hp]:
$= 2 * b * Pi * G * m * P +$
$= 2 * 0.1875 * 3.1416 * 32.3750 * 0.5000 * 300.00$
$= 5721.135$ lb.
Hydrostatic End Load at Flange ID [Hd]:

= Pi * $Bcor^2$ * P / 4
= 3.1416 * 32.0000^2 *300.0000 / 4
= 241274.328 lb.

Pressure Force on Flange Face [Ht]:
= H - Hd
= 246962 - 241274
= 5688.000 lb.

Operating Bolt Load [Wm1]:
= max(H + Hp + H'p, 0)
= max(246962 + 5721 + 0 , 0)
= 252683.469 lb.

Gasket Seating Bolt Load [Wm2]:
= y * b * Pi * G + yPart * bPart * lp
= 0.00*0.1875*3.141*32.375+0.00*0.0000*0.00
= 0.000 lb.

Required Bolt Area [Am]:
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 252683 / 25000 , 0 / 25000
= 10.107 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]:
= Sa * (Am + Ab) / 2
= 25000.00 * (10.1073 + 15.4280) / 2
= 319191.72 lb.

Gasket Seating Force [HG]:
= Wm1 - H
= 252683 - 246962
= 5721.14 lb.

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (36.0000 - 32.3750) / 2
= 1.8125 in.

Distance to Face Pressure Reaction [ht]:
= (hD + hG) / 2
= (2.0000 + 1.8125) / 2
= 1.9062 in.

Distance to End Pressure Reaction [hd]:
= (C - Bcor)/ 2
= (36.0000 - 32.0000) / 2
= 2.0000 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	

```
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

```
Stress Computation Results:   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 <= 1)        0.935
Flange Rigidity Index Oper.    (should be <= 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 <= 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 <= 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 <= 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 <= 1)

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]:
$= 0.785 * G^2 * Peq$
$= 0.785 * 32.3750^2 * 300.000$
$= 246962.328$ lb.
Contact Load on Gasket Surfaces [Hp]:
$= 2 * b * Pi * G * m * P +$
$= 2 * 0.1875 * 3.1416 * 32.3750 * 0.5000 * 300.00$
$= 5721.135$ lb.
Hydrostatic End Load at Flange ID [Hd]:

= Pi * $Bcor^2$ * P / 4
= 3.1416 * 32.0000^2 *300.0000 / 4
= 241274.328 lb.

Pressure Force on Flange Face [Ht]:
= H - Hd
= 246962 - 241274
= 5688.000 lb.

Operating Bolt Load [Wm1]:
= max(H + Hp + H'p, 0)
= max(246962 + 5721 + 0 , 0)
= 252683.469 lb.

Gasket Seating Bolt Load [Wm2]:
= y * b * Pi * G + yPart * bPart * lp
= 0.00*0.1875*3.141*32.375+0.00*0.0000*0.00
= 0.000 lb.

Required Bolt Area [Am]:
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 252683 / 25000 , 0 / 25000
= 10.107 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]:
= Sa * (Am + Ab) / 2
= 25000.00 * (10.1073 + 15.4280) / 2
= 319191.72 lb.

Gasket Seating Force [HG]:
= Wm1 - H
= 252683 - 246962
= 5721.14 lb.

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (36.0000 - 32.3750) / 2
= 1.8125 in.

Distance to Face Pressure Reaction [ht]:
= (hD + hG) / 2
= (2.0000 + 1.8125) / 2
= 1.9062 in.

Distance to End Pressure Reaction [hd]:
= (C - Bcor)/ 2
= (36.0000 - 32.0000) / 2
= 2.0000 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	

```
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

Stress Computation Results:	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating 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 <= 1)	0.935	
Flange Rigidity Index Oper. (should be <= 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 <= 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 <= 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 <= 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 <= 1)

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 - Di / 2) * ( L + Di / 2 - 2 * r ) )
 = 33.44-sqrt((33.44-32.12/2)*(33.44+32.12/2-2*2.06))
 = 5.361 in.
```

M factor for Torispherical Heads (Corroded):

```
 = (3+sqrt((L+C)/(r+C)))/4 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) 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 in.
```

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

```
 = (2*S*E*t)/(M*L+0.2*t) per Appendix 1-4 (d)
 = (2*15085.00*1.00*0.6250)/(1.7560*33.4375+0.2*0.6250)
```

= 320.460 psig

M factor for Torispherical Heads (New & Cold):
= (3+sqrt(L/r))/4 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) 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)
= (300.000*(1.7560*33.4375+0.2*0.6250))/(2*1.00*0.6250)
= 14121.880 psi

Required Thickness of Straight Flange = 0.386 in.

Percent Elongation per UHA-44 (75*tnom/Rf)*(1-Rf/Ro) 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) per UG-27 (c)(1)
= (300.000*16.0625)/(15085.00*0.85-0.6*300.000)
= 0.3812 + 0.0625 = 0.4437 in.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (15085.00*0.85*0.6875)/(16.0625+0.6*0.6875)
= 535.071 psig

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (20000.00*0.85*0.7500)/(16.0000+0.6*0.7500)
= 775.076 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 psi

Percent Elongation per UHA-44 (50*tnom/Rf)*(1-Rf/Ro) 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) per UG-27 (c)(1)
= (100.000*16.0625)/(20000.00*0.85-0.6*100.000)
= 0.0948 + 0.0625 = 0.1573 in.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (20000.00*0.85*0.4375)/(16.0625+0.6*0.4375)
= 455.590 psig

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (20000.00*0.85*0.5000)/(16.0000+0.6*0.5000)
= 521.472 psig

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 psi

Percent Elongation per UCS-79 (50*tnom/Rf)*(1-Rf/Ro) 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) per UG-27 (c)(1)
= (300.000*16.0625)/(15085.00*0.85-0.6*300.000)
= 0.3812 + 0.0625 = 0.4437 in.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (15085.00*0.85*0.6875)/(16.0625+0.6*0.6875)
= 535.071 psig

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (20000.00*0.85*0.7500)/(16.0000+0.6*0.7500)
= 775.076 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 psi

Percent Elongation per UHA-44 (50*tnom/Rf)*(1-Rf/Ro) 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 - Di / 2) * (L + Di / 2 - 2 * r))
= 33.44-sqrt((33.44-32.12/2)*(33.44+32.12/2-2*2.06))
= 5.361 in.

M factor for Torispherical Heads (Corroded):
= (3+sqrt((L+C)/(r+C)))/4 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) 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 in.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= (2*S*E*t)/(M*L+0.2*t) per Appendix 1-4 (d)
= (2*20000.00*1.00*0.6250)/(1.7560*33.4375+0.2*0.6250)
= 424.873 psig

M factor for Torispherical Heads (New & Cold):
= (3+sqrt(L/r))/4 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) 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

Elements Suitable for Internal Pressure.

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

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

From	To	Actual Len.	Allow. Len.	Ring Inertia	Ring Inertia

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.

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

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)].

ASME TubeSheet Results per Part UHX, 2007

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 Reqd 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.
```

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]:
= SQRT(1.9 * WM1 * hg / (S * G))
= SQRT(1.9 * 252683.47 * 1.812 / (20000.00 * 32.375))
= 1.159 in.

Required Tubesheet Flanged Extension thk. per UHX-9 (seating) [hr_seat]:
= SQRT(1.9 * W * hg / (Sa * G))
= SQRT(1.9 * 319191.72 * 1.812 / (20000.00 * 32.375))
= 1.303 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]:
= ltx / h (modified for corrosion if present)
= 1.5000 / 2.0000 = 0.7500 (must be 0 <= rho <= 1)

Compute the Effective Tube Hole Diameter [d*]:
= Max(dt - 2tt*(Et/E)(St/S)(rho), dt - 2tt)
= Max(0.7500 -2*0.0625 *(.28025E+08/.28025E+08)*
(11400 /20000)*(0.750), 0.7500 -2*0.0625)
= 0.6966 in.

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt = 2 * 12.000 + 0.750 = 24.750 in.

Determine the Basic Ligament Efficiency for Shear [mu]:
= (p - dt)/p = (1.1250 - 0.7500)/1.1250 = 0.3333

Compute the Equivalent Outer Tube Limit Radius [ao]:
= Do / 2 = 24.7500 / 2 = 12.3750 in.

Compute the Effective Tube Pitch [p*]:
= p / sqrt(1 - 4 * min(AL, 4*Do*p)/(Pi * Do^2))
= 1.1250 / sqrt(1 - 4 * min(0.00 , 4*24.750 *1.125)/(3.141 * 24.750^2))
= 1.1250 in.

Compute the Effective Ligament Efficiency for Bending [mu*]:
= (p* - d*) / p* = (1.1250 - 0.6966) / 1.1250 = 0.3808

Compute the Ratio [Rhos]:
= as / ao = 16.0000 / 12.3750 = 1.292929

Compute the Ratio [Rhoc]:
= ac / ao = 16.1875 / 12.3750 = 1.308081

Compute Parameter [xt]:
$= 1 - Nt * ((dt - 2 * tt)/(2 * ao))^2$
$= 1 - 348 * ((0.7500 - 2 * 0.0625)/(2 * 12.3750))^2 = 0.7781$

Determine Parameter [xs]:
$= 1 - Nt*(dt/(2*ao))^2$
$= 1 - 348 *(0.7500 /(2*12.3750))^2 = 0.6804$

Determine the Value [h'g]:
= Max((hg - CATC), 0) (For pressure only cases)
= Max((0.000 - 0.000), 0) = 0.000 in.

UHX-13.5.2 Step 2:

Determine the Axial Shell Stiffness [Ks]:
= pi * ts(Ds + ts)Es/L
= 3.1416 * 0.5000 (32.0000 + 0.5000).28440E+08/86.000
= 16882408.0000 psi * in.

Determine the Axial Tube Stiffness [Kt]:
= pi * tt(Dt - tt)Et/L
= 3.1416 * 0.0625 (0.7500 - 0.0625).28025E+08/86.000
= 43989.5742 psi * in.

Compute the Stiffness Factor [Kst]:
= Ks / (Nt * Kt) = .16882E+08 / (348 * 43989.574) = 1.10282

Compute Factor [J]:
= 1 / (1 + Ks/Kj)
= 1/(1 + .16882E+08/0.000) = 1.0000000 (= 1 if No Exp. Jt.)

Compute Shell Coefficient [betas]:
$= ((12 * (1-nus^2))^{0.25})/((Ds + ts) * ts)^{0.5}$
$= ((12 * (1 - 0.30^2))^{0.25}) / ((32.0000 + 0.5000) * 0.5000)^{0.5}$
= 0.4510 1/in.

Determine Shell Coefficient [ks]:
$= betas * Es * ts^3/ (6 * (1 - nus^2))$
$= 0.451 * .28440E+08 * 0.500^3 / (6 * (1 - 0.300^2))$
= 293613.4375 psig*in.^2

Determine Shell Coefficient [Lambdas]:
= (6*Ds*ks)/(h^3) * (1 + h*betas + 0.5*(h*betas)^2)
= 6*32.000 *293613.438/(2.000^3) * (1 + 2.000 *0.451 + 0.407)
= 16268163.0000 psig

Determine Shell Coefficient [deltaS]:
$= Ds^2/(4 * Es * Ts) * (1 - nus/2)$
$= 32.000^2/(4 * .28440E+08 * 0.500) * (1 - 0.3 /2)$
= 0.0000153024 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 ; nu* = 0.310175 ; E* = 11123767. psi

Compute the Tube Bundle Stiffness Factor [Xa]:
= ((24 *(1 - nu*^{2})*Nt * Et* tt* (dt - tt)* ao^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
Zd = 0.031149 ; ZV = 0.076156 ; ZM = 0.412984

UHX-13.5.4 Step 4:

Compute the Diameter Ratio [K]:
= A / Do = 38.4000 / 24.7500 = 1.5515

Compute Coefficient [F]:
= (1 - nu*) / (E*) * (Lambdas + Lambdac + 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]:
= (Rhos - 1 - Phi * Zv)/(1 + Phi * Zm)
= (1.2929 - 1 - 2.3219 *0.0762)/(1 + 2.3219 *0.4130)
= 0.059269361

Compute Parameter [Qz1]:
= (Zd + Q1*Zv)/2 *Xa^4
= (0.03115 + 0.05927 *0.07616)/2 *3.67242 ^{4} = 3.2433

Compute Parameter [Qz2]:
= (Zv + Q1*Zm)/2 *Xa^4
= (0.07616 + 0.05927 *0.41298)/2 *3.67242 ^{4} = 9.1521

Compute Parameter [U]:
= (Zv + (Rhos - 1)*Zm)*Xa^4 / (1 + Phi*Zm)
= (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]:
= (Gc - C) / Do (config b)
= (32.3750 - 36.0000) / 24.7500 = -0.14646

Compute Parameter [gamma]:
= (alphatm*(Ttm - AMB_TEMP) - alphasm*(Tsm - AMB_TEMP))* L
= (0.677E-05*(70.0 - 70.0) - 0.582E-05*(70.0 - 70.0))*86.00
= 0.000 in. (For Pressure only cases)

Calculate Parameter [OmegaS]:
= rhos * ks * Betas * deltaS(1 + h * Betas)
= 1.2929 * 293613.44 * 0.4510 * 0.000015 (1 + 2.0000 * 0.4510)
= 4.9823 in.^2

Calculate Parameter [Omega*S]:
= Ao^2* (Rhos^2- 1) * (Rhos - 1) / 4 - OmegaS
= 12.375^2* (1.293^2- 1) * (1.293 - 1) / 4 - 4.982
= 2.5504 in.^2

Calculate Parameter [OmegaC]:

```
 = rhoc * kc * Betac * deltaC( 1 + h * Betac )
 = 1.3081 * 0.00 * 0.0000 * 0.000000 ( 1 + 2.0000 * 0.0000 )
 = 0.0000 in.^2
```

Calculate Parameter [Omega*C]:

```
 = ao^2[( Rhoc^2+1 )*( Rhoc-1 )/4 -(Rhos-1)/2]- OmegaC
 = 12.37500^2[( 1.30808^2+1 )*( 1.30808 -1 )/4 -(1.29293 -1)/2]- 0.00000
 = 9.5472 in.^2
```

Compute the Pressure [P*S]:
= 0.000 psig
= 0 For Pressure only cases or Configurations d,e,f,A,B,C,D

Compute the Pressure [P*C]:
= 0.000 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]:

```
 = Ps * {xs + 2( 1 - xs )nut + [2/Kst(Ds/Do)^2]nus -
   [(rhos^2-1)/(J*Kst)]-[(1-J)/(2J*Kst)][(Dj^2-(2As)^2)/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 psig
```

Compute the Pressure [P't]:

```
 = [ xt + 2(1 - xt)nut + 1/(J * Kst) ]*Pt
 = [ 0.778 + 2(1 - 0.778 )0.300 +
   1/(1.00000 * 1.103 ) ]* 300.000
 = 545.3995 psig
```

Compute the Pressure [Pgama]:

```
 = Nt * Kt * gama / ( pi * ao^2)
 = 348 * 43989.574 * 0.000 / (3.142 * 12.375^2) = 0.000 psig
```

Compute the Pressure [Pw]:

```
 = -gamab * U * W / (2 * pi * ao^2)
 = --0.146 * 18.304 * 319191.72 / (2 * 3.142 * 12.375^2) = 889.330 psig
```

Calculate the Pressure [Prim]:

```
 = -( U/ao^2)(Omega*S * Ps - Omega*C * Pt )
 = -( 18.304 / 12.375^2)(2.550 * 100.000 - 9.547 * 300.000 )
 = 311.8563 psig
```

Calculate the Pressure [POmega]:

```
 = U/ao^2(OmegaS * P*s - OmegaC * P*c )
 = 18.304 /12.3750^2( 4.9823 * 0.0000 - 0.0000 * 0.0000 )
 = 0.0000 psig
```

Determine the Effective Pressure [Pe]:

```
 = J * Kst / (1 + J * Kst *(Qz1 + (Rhos - 1) * Qz2)) *
   (P's - P't + Pgama + Pw + Prim )
 = 0.1000E+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 psig
```

UHX-13.5.7 Step 7:

Determine Factor [Q2]:

```
 = [( (Omega*S * Ps- Omega*C * Pt) - (Omegas * P*s- Omegac * P*c) )* CNV_FAC +
   W * gamab/(2*pi) ] / (1 + Phi*Zm)
 = [ ( ( 2.550 * 100.000 - 9.547 * 300.000 ) -
```

```
   ( 4.982 * 0.000 - 0.000 * 0.000 ) ) * 1.000 +
   319191.7 * -0.146 /(2*3.14159) ] / (1 + 2.32190 * 0.41298 )
 = -5130.250976562 lb.
```

Calculate Factor [Q3]:
$= Q1 + 2 * Q2 / (Pe * ao^2$
$= 0.059 + 2 * -5130.251 / (113.168 * 12.375^2 = -0.532774$

Fm Value from Table UHX-13.1 = 0.266387

The Tubesheet Bending Stress - Original Thickness [Sigma]:
$= (1.5 * Fm / mu*) * (2 * ao/(H - h'g)^2 * Pe$
$= (1.5 * 0.2664 /0.3808) * (2 * 12.3750 /(2.000 - 0.000))^2 * 113.17$
$= 18183.7910$ psi

The Allowable Tubesheet Bending Stress [Sigma allowed]:
$= 1.5 * S = 1.5 * 20000.00 = 30000.00$ psi

The Tubesheet Bending Stress - Final Thickness [Sigmaf]:
$= (1.5 * Fm/mu*) * (2 * ao/(h - h'g)^2* Pe$
$= (1.5 * 0.1570 /0.3808) * (2 * 12.3750 /(1.431 - 0.000))^2* 162.21$
$= 29999.5137$ psi

Reqd Tubesheet Thickness, for Bending Stress (Including CA) [HReqB]:
$= h + Cats + Catc = 1.4312 + 0.0000 + 0.0000 = 1.4312$ in.

UHX-13.5.8 Step 8:

The Tubesheet Average Shear Stress - Original Thickness [Tau]:
$= (1/(2*mu)) * (ao/h) * Pe$
$= (1/(2*0.333)) * (12.3750 /2.000) * 113.168 = 1050.34$ psi

The Allowable Tubesheet Shear Stress [Tau allowed]:
$= 0.8 * S = 0.8 * 20000.00 = 16000.00$ psi

The Tubesheet Shear Stress - Final Thickness [Tauf]:
$= (1/(2*mu)) * (ao/h) * Pe$
$= (1/(2*0.333)) * (12.3750 /0.295) * 242.269 = 15230.44$ psi

Reqd Tubesheet Thickness, for Shear Stress (Including CA) [HreqS]:
$= H + Cats + Catc = 0.2953 + 0.0000 + 0.0000 = 0.2953$ in.

Reqd Tubesheet Thickness for Given Loadings (Including CA) [Hreqd] :
$= Max(HreqB, HreqS) = Max(1.4312 , 0.2953) = 1.4312$ in.

UHX-13.5.9 Step 9:

Determine Coefficient [Fq]:
$= (Zd + Q3*Zv)*Xa^4/2$
$= (0.0311 +-0.5328 *0.0762)*3.6724^4/2 = -0.8572$

The Tube Stress in the outermost Tube row [Sigmato]
$= ((Ps*xs - Pt*xt) - Pe*Fq)/(xt - xs))$
$= ((100.00 *0.6804 - 300.00 *0.7781) - 113.17 *-0.857)/$
$(0.7781 - 0.6804))$
$= -700.2524$ psi

The Allowable Tube Stress, [SigmatA]
$= Sot = 11400.0000$ psi

Check for Buckling because the Tubes are in Compression

Determine the Factor of Safety [Fs]:
$= Max((3.25 - 0.5*Fq), (1.25))$
$= Max((3.25 - 0.5*-0.8572), (1.25))$

= 2.0000 (Should be <= 2)

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 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 psi (Never greater than Sot)

The Force on the Outermost Tube [TubeForce]:
= TubeStress * Tube Area = -700.25 * 0.1350 = -94.53 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 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 psi

The Shell Bending Stress due to Joint Interaction [Sigmasb]
= 6*ks/ts^2* {betas[deltaS*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 psi

Shell Stress Summation vs. Allowable
|Sigmasm| + |Sigmasb| =< 1.5 * Ss
|4526.7 | + |-16789.4 | =< 30000.00 psi
21316.11 must be < or = 30000.00 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

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 Stresses Bend	Allwd	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 Ten	Allwd	Cmp	Allwd	Tube Loads Ld	Allwd	Shell Stress	Allwd	Channel Stress	Allwd	Pass 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

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) MAWP	Tubeside (0 shellside) Stress Rat.	Shellside (0 tubeside) MAWP	Shellside (0 tubeside) 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) MAPnc	Tubeside (0 shellside) Stress Rat.	Shellside (0 tubeside) MAPnc	Shellside (0 tubeside) 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	

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.	R e q d T h k Int.	Ext.	Joint Eff Long	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