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DESIGN CALCULATION

ASME Code Version : 2015

Analysis Performed by : PRESSURE VESSEL ENGINEERING

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Description: Firetube Arrangement - Before FEA
Drawing: 11110d-1 R0
Author: Ben Vanderloo, P.Eng.
Date: July 19, 2017

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Input Echo, Component 1, Description: Head

Design Internal Pressure	P	125.00	psig
Temperature for Internal Pressure		500.00	F
User Entered Minimum Design Metal Temperature		-20.00	F
Include Hydrostatic Head Components		NO	
Material Specification (Not Normalized)		SA-516 70	
Material UNS Number		K02700	
Material Form used		Plate	
Allowable Stress At Temperature	S	20000.00	psi
Allowable Stress At Ambient	SA	20000.00	psi
Yield Stress At Temperature	Sy	31000.00	psi
Curve Name for Chart UCS 66		B	
Joint efficiency for Head Joint	E	1.00	
Outside Diameter of Elliptical Head	D	72.000	in.
Minimum Thickness of Pipe or Plate	T	0.3900	in.
Nominal Thickness of Pipe or Plate	Tnom	0.3900	in.
Shell/Head Int. Corrosion Allowance	CA	0.0000	in.
Aspect Ratio	AR	2.0000	
Length of Straight Flange	STRTFLG	2.0000	in.
Skip UG-16(b) Min. thickness calculation		NO	
Type of Element:		Elliptical Head	

Internal pressure results, Shell Number 1, Desc.: Head
ASME Code, Section VIII, Division 1, 2015

Thickness Due to Internal Pressure (Tr):
= (P*(D-2.0*CAE)*K) / (2*S*E+2*P*(K-0.1)) per Appendix 1-4 (c)
= (125.00*(72.0000-2*0.000)*1.00)/(2*20000.00*1.00+2*125.00*(1.00-0.1))
= 0.2237 + 0.0000 = 0.2237 in.

Max. All. Working Pressure at Given Thickness (MAWP):
= (2*S*E*(T-CA-CAE)) / (K*(D-2*CAE)-2*(T-CA-CAE)*(K-0.1)) per Appendix 1-4(c)
= (2*20000.00*1.00*(0.3900))/(1.00*72.0000-2*(0.3900)*(1.00-0.1))
= 218.80 psig

Maximum Allowable Pressure, New and Cold (MAPNC):
= (2*SA*E*T) / (K*D-2*T*(K-0.1)) per Appendix 1-4 (c)
= (2*20000.00*1.00*0.3900)/(1.00*72.0000-2*0.3900*(1.00-0.1))
= 218.80 psig

Actual stress at given pressure and thickness (Sact):
= (P*(K*(D-2*CAE)-2*(T-CA-CAE)*(K-0.1))) / (2*E*(T-CA-CAE))
= (125.00*(1.00*72.0000-2*(0.3900)*(1.00-0.1)))/(2*1.00*(0.3900))
= 11425.96 psi

SUMMARY OF INTERNAL PRESSURE RESULTS:

Required Thickness plus Corrosion Allowance, Trca		0.2237	in.
Actual Thickness as Given in Input		0.3900	in.
Maximum Allowable Working Pressure	MAWP	218.800	psig
Maximum Allowable Pressure, NC	MAPNC	218.800	psig

Design Pressure as Given in Input P 125.000 psig

Hydrostatic Test Pressures (Measured at High Point):

Hydrotest per UG-99(b); 1.3 * MAWP * Sa/S	284.44	psig
Hydrotest per UG-99(c); 1.3 * MAPNC	284.44	psig
Pneumatic per UG-100 ; 1.1 * MAWP * Sa/S	240.68	psig

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 2.378 %

Minimum Design Metal Temperature per UCS-66 Curve : B

tg = 0.390 , tg_sr = 0.390 , tr = 0.224 , c = 0.0000 in. , E* = 1.00
Stress Ratio = tr * (E*) / (tg_sr - c) = 0.574 , Temp. Reduction = 45 F

Min. Metal Temp. w/o impact per Fig. UCS-66	-20	F
Min. Metal Temp. at Req'd thk. (UCS 66.1)	-55	F
Min. Metal Temp. w/o impact per UG-20(f)	-20	F

Weight and Volume Results, No C.A. :

Volume of Shell Component	VOLMET	2569.1	in.^3
Weight of Shell Component	WMET	719.3	lb.
Inside Volume of Component	VOLID	47287.3	in.^3
Weight of Water in Component	WWAT	1995.3	lb.
Inside Vol. of 2.00 in. Straight	VOLSCA	7967.5	in.^3
Total Volume for Head + Straight	VOLTOT	55254.8	in.^3

Input Echo, Nozzle Item 1, Description: Neck

Design Internal Pressure (Case 1)	P	125.00	psig
Temperature for Internal Pressure	TEMP	500.00	F
Include Hydrostatic Head Components		NO	
Shell or Head Material (Not Normalized or NA)		SA-516 70	
Material UNS Number		K02700	
Shell/Head Allowable Stress at Temperature	S	20000.00	psi
Shell/Head Allowable Stress At Ambient	SA	20000.00	psi
Shell/Head Yield Stress at Temperature	Sy	31000.00	psi
Outside Diameter of Elliptical Head	D	72.000	in.
Aspect Ratio of Elliptical Head	AR	2.00	
Actual Thickness of Shell or Head	T	0.3900	in.
Corrosion Allowance for Shell or Head	CAS	0.0000	in.
Is this Nozzle a Radial Nozzle		YES	
Is the Nozzle Outside the 80% diameter Limit		YES	
Nozzle Material (Not Normalized or NA)		SA-516 70	
Material UNS Number		K02700	
Nozzle Allowable Stress at Temperature	SN	20000.00	psi
Nozzle Allowable Stress At Ambient	SNA	20000.00	psi
Diameter Basis for Nozzle	BASISN	ID	
Inside Diameter of Nozzle	DIA	32.000	in.
Nozzle Size and Thickness Basis	DBN	Actual	
Actual Thickness of Nozzle	THK	0.5000	in.
Corrosion Allowance for Nozzle	CAN	0.0000	in.
Joint Efficiency of Shell Seam at Nozzle	ES	1.00	
Joint Efficiency of Nozzle Neck	EN	1.00	
Insert or Abutting Nozzle Type	NTYP	Insert	
Outward Projection of Nozzle	HO	2.881	in.
Weld leg size between Nozzle and Pad/Shell	WO	0.5000	in.
Groove weld depth between Nozzle and Vessel	WGNV	0.3900	in.
Inside Projection of Nozzle	H	0.8200	in.
Weld leg size, Inside Nozzle to Shell	WI	0.0000	in.
Method used for checking Nozzle opening		UG-37	
Method used for checking Large Nozzles		App. 1-7	
Is this is Manway/Access/Inspection Opening		No	
Skip Iterative Failure Thickness Calculations		Yes	

Reinforcement CALCULATION, Description: Neck

ASME Code, Section VIII, Div. 1, 2015, UG-37 to UG-45

Actual Inside Diameter Used in Calculation		32.000	in.
Actual Thickness Used in Calculation		0.500	in.

Internal Pressure Results for SHELL/HEAD :

Reqd thk per UG-37(a) of Elliptical Head, Tr Internal Pressure
Thickness Due to Internal Pressure:

= (P*(D-2.0*CAE)*K) / (2*S*E+2*P*(K-0.1)) per Appendix 1-4 (c)
= (125.00*(72.0000-2*0.000)*1.00)/(2*20000.00*1.00+2*125.00*(1.00-0.1))
= 0.2237 + 0.0000 = 0.2237 in.

Internal Pressure Results for NOZZLE :

Reqd thk per UG-37(a) of Nozzle Wall, Trn Internal Pressure
Thickness Due to Internal Pressure:
= (P*(D/2+CA)) / (S*E-0.6*P) per UG-27 (c)(1)
= (125.00*(32.0000/2+0.0000))/(20000.00*1.00-0.6*125.00)
= 0.1004 + 0.0000 = 0.1004 in.

UG-40, Limits of Reinforcement : Internal Pressure

Effective material diameter limit,	DL	64.000	in.
Effective material thickness limit, no pad	TLNP	0.975	in.

Results of Nozzle Reinforcement Area Calculations:

Area Available, A1 to A5		Design	External	Mapnc	
Area Required	Ar	7.160	NA	NA	in^2
Area in Shell	A1	5.320	NA	NA	in^2
Area in Nozzle Wall	A2	0.779	NA	NA	in^2
Area in Inward Nozzle	A3	0.820	NA	NA	in^2
Area in Welds	A4	0.250	NA	NA	in^2
Area in Pad	A5	0.000	NA	NA	in^2
Total Area Available	Atot	7.170	NA	NA	in^2

Internal Pressure Case Governs the Analysis

Nozzle Tangent Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Reinforcement Area Required for Nozzle:
Ar = (DLR*TR+2*THK*TR*(1-FFR1)) UG-37(c) or UG-39
Ar = (32.0000*0.2237+2*(0.5000-0.0000)*0.2237*(1.0-1.00))
Ar = 7.160 in^2

Areas per UG-37.1 but with DL = Diameter Limit, DLR = Nozzle Opening size:
Area Available in Shell (A1):
A1 = (DL-DLR)*(ES*(T-CAS)-TR)-2*(THK-CAN)*(ES*(T-CAS)-TR)*(1-FFR1)
A1 = (64.000-32.000)*(1.00*(0.3900-0.000)-0.224)-2*(0.500-0.000)
(1.00(0.3900-0.0000)-0.2237)*(1.0-1.00)
A1 = 5.320 in^2

Area Available in Nozzle Wall, no Pad:
A2np = (2 * MIN(TLNP,HO)) * (THK - CAN - TRN) * FFR2
A2np = (2 * 0.9750) * (0.5000 - 0.0000 - 0.1004) * 1.00)
A2np = 0.779 in^2

Area Available in Nozzle Penetration:
A3 = 2 * (TN-CAN-CAN) * MIN(H-CAN, TL, 2.5*(TN-CAN-CAN)) * FFR2
A3 = 2 * (0.5000) * (0.8200) * 1.00
A3 = 0.820 in^2

Area Available in Welds, no Pad:
A4np = Wo^2*FFR2 + (Wi-Can/0.707)^2*FFR2
A4np = 0.5000^2 * 1.0000 + (0.0000)^2 * 1.0000
A4np = 0.250 in^2

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

```
Wall Thickness for Internal/External pressures      ta = 0.1004 in.
Wall Thickness per UG16(b),   tr16b = 0.0625 in.
Wall Thickness, shell/head, internal pressure     trb1 = 0.2237 in.
Wall Thickness                 tb1 = max(trb1, tr16b) = 0.2237 in.
Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0625 in.
Wall Thickness per table UG-45                   tb3 = 0.3280 in.
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 0.328 , max( 0.224 , 0.063 ) ]
 = 0.2237 in.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
 = max( ta, tb )
 = max( 0.1004 , 0.2237 )
 = 0.2237 in.
```

Available Nozzle Neck Thickness = 0.5000 in. --> OK

```
Weight of Nozzle, Nozzle Neck Only, Uncorroded         58.48  lb.
Weight of Nozzle, Nozzle Neck Only, Corroded           58.48  lb.
```

Minimum Design Metal Temperature (MDMT) Results :

MDMT of Shell, UCS curve : B

tg = 0.390 , tg_sr = 0.390 , tr = 0.224 , c = 0.0000 in. , E* = 1.00
Stress Ratio = tr * (E*) / (tg_sr - c) = 0.574 , Temp. Reduction = 45 F

```
Min. Metal Temp. w/o impact per Fig. UCS-66               -20  F
Min. Metal Temp. at Req'd thk. (UCS 66.1)                 -55  F
Min. Metal Temp. w/o impact per UG-20(f)                  -20  F
```

MDMT of Nozzle Neck to Flange Weld, UCS Curve : B

tg = 0.500 , tg_sr = 0.500 , tr = 0.100 , c = 0.0000 in. , E* = 1.00
Stress Ratio = tr * (E*) / (tg_sr - c) = 0.201 , Temp. Reduction = 140 F

```
Min. Metal Temp. w/o impact per Fig. UCS-66                -6  F
Min. Metal Temp. at Req'd thk. (UCS 66.1)                -146  F
Min. Metal Temp. w/o impact per UG-20(f)                  -20  F
```

MDMT of Nozzle-Shell/Head Weld for the Nozzle (UCS-66(a)1(b)), Curve : B

tg = 0.390 , tg_sr = 0.390 , tr = 0.224 , c = 0.0000 in. , E* = 1.00
Stress Ratio = tr * (E*) / (tg_sr - c) = 0.574 , Temp. Reduction = 45 F

```
Min. Metal Temp. w/o impact per Fig. UCS-66               -20  F
Min. Metal Temp. at Req'd thk. (UCS 66.1)                 -55  F
Min. Metal Temp. w/o impact per UG-20(f)                  -20  F

Governing MDMT of the Head                             :   -55 F
Governing MDMT of all the sub-joints on this junction  :   -55 F
```

Weld Size Calculations, Nozzle Number 1, Desc.: Neck

```
Intermediate Calcs. for nozzle/shell welds          Tmin      0.3900  in.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness	
Nozzle Weld	0.2500 = Min per Code	0.3535 = 0.707 * WO	, in.

Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

Weld Load [W]:
```
 = (AR-A1+2*(THK-Can)*Ffr1*(E1(T-Cas)-Tr))*S
 = (7.1597 - 5.3203 + 2 * ( 0.5000 - 0.0000 ) * 1.0000 *
   (1.00 * ( 0.3900 - 0.0000 ) - 0.2237 ) ) * 20000
 = 40114.25 lb.
```

Weld Load [W1]:
```
 = (A2+A5+A4-(WI-CAN/.707)^2*Ffr2)*S
 = ( 0.7793 + 0.0000 + 0.2500 - 0.0000 * 1.00 ) * 20000
 = 20585.32 lb.
```

Weld Load [W2]:
```
 = (A2+A3+A4+(2*(THK-CAN)*(T-CAS)*Fr1))*S
 = ( 0.7793 + 0.8200 + 0.2500 + 0.3900 ) * 20000
 = 44785.32 lb.
```

Weld Load [W3]:
```
 = (A2+A3+A4+A5+(2*(THK-CAN)*(T-CAS)*Fr1))*S
 = ( 0.7793 + 0.8200 + 0.0000 + 0.2500 + 0.3900 ) * 20000
 = 44785.32 lb.
```

Strength of Connection Elements for Failure Path Analysis :

Shear, Outward Nozzle Weld [Sonw]:
```
 = (PI/2) * Dlo * Wo * 0.49 * Snw
 = ( 3.1416 / 2.0 ) * 33.0000 * 0.5000 * 0.49 * 20000
 = 253998. lb.
```

Shear, Nozzle Wall [Snw]:
```
 = (PI * (DLR+Dlo) /4.0) * (THK-Can) * 0.7 * Sn
 = ( 3.1416 * 16.2500 ) * ( 0.5000 - 0.0000 ) * 0.7 * 20000
 = 357356. lb.
```

Tension, Nozzle Groove Weld [Tngw]:
```
 = (PI/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
 = ( 3.1416 / 2.0 ) * 33.0000 * ( 0.3900 - 0.0000 ) * 0.74 * 20000
 = 299199. lb.
```

Strength of Failure Paths:
```
 PATH11 = ( Sonw + Snw ) = ( 253997 + 357356 ) = 611353 lb.
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
        = ( 253997 + 0 + 299199 + 0 ) = 553196 lb.
 PATH33 = ( Sonw + Tngw + Sinw )
        = ( 253997 + 299199 + 0 ) = 553196 lb.
```

Summary of Failure Path Calculations:
```
Path 1-1 = 611353 lb., must exceed W = 40114 lb. or W1 = 20585 lb.
Path 2-2 = 553196 lb., must exceed W = 40114 lb. or W2 = 44785 lb.
Path 3-3 = 553196 lb., must exceed W = 40114 lb. or W3 = 44785 lb.
```

Percent Elongation Calculations:
```
% Elongation per Table UG-79-1 ( 50 * tnom/Rf * (1-Rf/Ro) ) 1.538 %
```

M.A.W.P. Results Based on Areas, Head and Nozzle neck:

Best M.A.W.P for given geometry	AMAWP	125.000	psig
Best M.A.P.(NC) for given geometry	AMAPnc	125.000	psig

Note: To determine if the nozzle is governing the design, Compare Nozzle MAWP/MAPnc with that of the Head computed from the Shell/Head Module.

Input Echo, COMPONENT 1, Description: Neck App13

Figure Number Analyzed		B2	
Design Internal Pressure	P	125.0000	psig
Design Temperature	Temp	500.0000	F
VESSEL MATERIAL DATA:			
Material Specification		SA-516 70	
Shell Allowable Stress at Design Temp	S	20000.0000	psi
Shell Allowable Stress at Ambient	SA	20000.0000	psi
Shell Yield Stress at Design Temperature	Sy	31000.0000	psi
SHORT-SIDE VESSEL DATA:			
Short-side Length Dimension	2R	16.0000	in.
Minimum Thickness of Short-side Plates	t1	0.5000	in.
Mid-side Joint Efficiency on Short-side	E	1.0000	
Corner Joint Efficiency on Short-side	EC	1.0000	
LONG-SIDE VESSEL DATA:			
Long-side Length Dimension	L2	8.0000	in.
Minimum Thickness of Long-side Plates	t2	0.5000	in.
Mid-side Joint Efficiency on Long-side	E	1.0000	
ADDITIONAL VESSEL DATA:			
Minimum Thickness of End Plate	t5	1.1875	in.
C-Factor for End Plate	Cf_Epl	0.2500	
REINFORCEMENT MATERIAL DATA:			
Reinforcement Material Specification		SA-516 70	
Reinf Allowable Stress at Design Temp	Sr	20000.0000	psi
Reinf Allowable Stress at Ambient	SA	20000.0000	psi
Reinf Yield Stress at Design Temp	Sy	31000.0000	psi
Pitch Distance for Reinforcement	p	5.0000	in.
C-Factor for Reinforcement (from UG-47)		2.1000	
DELTA (Reinforcement Material Parameter)		6000.0000	psi^0.5
SHORT-SIDE RECTANGULAR BEAM DATA:			
Outside Distance from Outside of Vessel		2.1250	in.
Width of Reinforcing Member		1.1875	in.
LONG-SIDE RECTANGULAR BEAM DATA:			
Outside Distance from Outside of Vessel		2.1250	in.
Width of Reinforcing Member		1.1875	in.

Rectangular Vessel Results, Item number 1, Desc: Neck App13
ASME Code, Section VIII, Division 1, 2015 App. 13

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

Short-side 1 Calculations

Membrane Ligament Efficiency [Em]:
= 1.000

Bending Ligament Efficiency [Eb]:
= 1.000

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
= t1 - CA / 2
= 0.500 - 0.000 / 2
= 0.250 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
= -(t1 - CA) / 2
= -(0.500 - 0.000) / 2
= -0.250 in.

Short-side 2 Calculations

Membrane Ligament Efficiency [Em]:
= 1.000

Bending Ligament Efficiency [Eb]:
= 1.000

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
= t1 - CA / 2
= 0.500 - 0.000 / 2
= 0.250 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
= -(t1 - CA) / 2
= -(0.500 - 0.000) / 2
= -0.250 in.

Long-side 1 Calculations

Membrane Ligament Efficiency [Em]:
= 1.000

Bending Ligament Efficiency [Eb]:
= 1.000

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
= t1 - CA / 2
= 0.500 - 0.000 / 2
= 0.250 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
= -(t1 - CA) / 2
= -(0.500 - 0.000) / 2
= -0.250 in.

Long-side 2 Calculations

Membrane Ligament Efficiency [Em]:
= 1.000

Bending Ligament Efficiency [Eb]:
= 1.000

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
= t1 - CA / 2
= 0.500 - 0.000 / 2
= 0.250 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
= -(t1 - CA) / 2
= -(0.500 - 0.000) / 2
= -0.250 in.

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

		Em	Eb	Ci	Co
Short-side	1	1.000	1.000	0.250	-0.250
	2	1.000	1.000	0.250	-0.250
Long-side	1	1.000	1.000	0.250	-0.250
	2	1.000	1.000	0.250	-0.250

REINFORCEMENT CALCULATIONS:

Maximum Distance B/W Reinforcing Members (Eq.(1) of UG-47) [pmax]:
= 9.17 in.

Beta and J Values:

Short-side BETA [Bs]:
= H / pmax
= 16.00 / 9.17
= 1.75

Short-side J from Table 13-8(d) [Js]:
= 2.68

Long-side BETA [Bl]:
= h / pmax
= 16.00 / 9.17
= 1.75

Long-side J from Table 13-8(d) [Jl]:
= 2.68

Max Pitch Values for Long and Short-sides based on Equations (1a)-(1d) from Section 13-8:

Short-side Pitch [p1]:
= t1 * sqrt(S * J / P)
= 0.50 * sqrt(20000.00 * 2.68 / 125.00)
= 10.36 in.

Long-side Pitch [p2]:
= t2 * sqrt(S * J / P)
= 0.50 * sqrt(20000.00 * 2.68 / 125.00)
= 10.36 in.

Maximum Pitch (Minimum of p, p1, and p2)
= Min(pmax, p1, p2)
= Min(9.17 , 10.36 , 10.36)
= 9.17 in.

Effective Width of Shell Plate (Section 13-8, Eq. (2))

In Compression [w]:
= Min(Min(t1, t2) * Delta / sqrt(Sy), p)
= Min(Min(0.50 , 0.50) * 6000.00 / sqrt(31000.00), 5.00)
= 5.00 in.

In Tension [w]:
= 5.00 in.

Moment of Inertia of a Strip of the Vessel Wall:

Thickness t1, I1 = 0.0000 in**4

REINFORCEMENT CALCULATIONS:

Effective Area of Reinforcement on Shell (t * w):

Short-side Ap = 2.5000 in^2
Long-side Ap = 2.5000 in^2

Moment of Inertia of Effective Area of Reinforcement (w * t3 / 12):**

Short-side Is = 0.0521 in**4
Long-side Il = 0.0521 in**4

Moment of Inertia of Combined Reinforcement and Effective Width:

In Compression I11 = 3.1650 in**4
I21 = 3.1650 in**4
In Tension I11 = 3.1650 in**4
I21 = 3.1650 in**4

Distance from Neutral Axis of Cross Section of Composite Section to the Inside Surface of the Vessel (in.):

		Ci	Co
Short-side,	in Compression	0.9093	-1.7157
	in Tension	0.9093	-1.7157
Long-side,	in Compression	0.9093	-1.7157
	in Tension	0.9093	-1.7157

Rectangular Vessel Reinforcement Parameters:

r (Section 13-5) = 9.5625
Gamma1 = L2 / r = 0.8366
C2 (Section 13-5) = 1946.2922
A3 (Section 13-5) = 46.0415

Membrane Stress Calculations per Section 13-11

Membrane Stresses at Long-side 1

Membrane Stress at Long-side 1 at A [SmlA]:
= P * R * p / (A1 + p * t1)
= 125.00 * 8.00 * 5.00 / (2.5234 + 5.00 * 0.50)
= 995.33 psi

Membrane Stress at Long-side 1 at B [SmlB]:
= P * R * p / (A1 + p * t1)
= 125.00 * 8.00 * 5.00 / (2.5234 + 5.00 * 0.50)
= 995.33 psi

Membrane Stresses at Long-side 2

Membrane Stress at Long-side 2 at A [SmlA]:
= P * R * p / (A1 + p * t1)

```
  = 125.00 * 8.00 * 5.00 / ( 2.5234 + 5.00 * 0.50 )
  = 995.33 psi
```

Membrane Stress at Long-side 2 at B [SmlB]:

```
  = P * R * p / ( A1 + p * t1 )
  = 125.00 * 8.00 * 5.00 / ( 2.5234 + 5.00 * 0.50 )
  = 995.33 psi
```

Membrane Stresses at Short-side 1

Membrane Stress at Short-side 1 at B [SmsB]:

```
  = P * R * p / ( A1 + p * t1 )
  = 125.00 * 8.00 * 5.00 / ( 2.5234 + 5.00 * 0.50 )
  = 995.33 psi
```

Membrane Stress at Short-side 1 at C [SmsC]:

```
  = P * ( R + L2) * p / ( A1 + p * t1 )
  = 125.00 * ( 8.00 + 8.00 ) * 5.00 / ( 2.5234 +
    5.00 * 0.50 )
  = 1990.67 psi
```

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 at B [SmsB]:

```
  = P * R * p / ( A1 + p * t1 )
  = 125.00 * 8.00 * 5.00 / ( 2.5234 + 5.00 * 0.50 )
  = 995.33 psi
```

Membrane Stress at Short-side 2 at C [SmsC]:

```
  = P * ( R + L2) * p / ( A1 + p * t1 )
  = 125.00 * ( 8.00 + 8.00 ) * 5.00 / ( 2.5234 +
    5.00 * 0.50 )
  = 1990.67 psi
```

MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-11 Equations (1-3). (psi) :

STRESS LOCATIONS		Actual	Allowable
Long-side 1	at A	995.33	20000.00
	at B	995.33	20000.00
Long-side 2	at A	995.33	20000.00
	at B	995.33	20000.00
Short-side 1	at B	995.33	20000.00
	at C	1990.67	20000.00
Short-side 2	at B	995.33	20000.00
	at C	1990.67	20000.00

Bending Stress Calculations per Section 13-11

Bending Stresses at Long-side 1

Bending Stress at Long-side 1 at A Inner[SblAi]:

```
  = ( P * L2 * p * c / 6 * I11 ) *
    ( -C2 / A3 )
  = ( 125.00 * 8.00 * 5.00 * 0.91 / 6 * 3.17 ) *
    ( -1946.29 / 46.04 ))
  = -10120.76 psi
```

Bending Stress at Long-side 1 at A Outer[SblAo]:

```
  = ( P * L2 * p * c / 6 * I11 ) *
    ( -C2 / A3 )
```

```
  = ( 125.00 * 8.00 * 5.00 * -1.72 / 6 * 3.17 ) *
    ( -1946.29 / 46.04 ))
  = 19095.84 psi
```

Bending Stress at Long-side 1 at B Inner[SblBi]:

```
  = ( P * L2 * p * c / 6 * I11 ) * ( 3 *
    L2 - ( C2 / A3 ))
  = ( 125.00 * 8.00 * 5.00 * 0.91 / 6 * 3.17 ) * ( 3 *
    8.00 - ( 1946.29 / 46.04 ))
  = -4374.76 psi
```

Bending Stress at Long-side 1 at B Outer[SblBo]:

```
  = ( P * L2 * p * c / 6 * I11 ) * ( 3 *
    L2 - ( C2 / A3 ))
  = ( 125.00 * 8.00 * 5.00 * -1.72 / 6 * 3.17 ) * ( 3 *
    8.00 - ( 1946.29 / 46.04 ))
  = 8254.29 psi
```

Bending Stresses at Long-side 2

Bending Stress at Long-side 2 at A Inner[SblAi]:

```
  = ( P * L2 * p * c / 6 * I11 ) *
    ( -C2 / A3 )
  = ( 125.00 * 8.00 * 5.00 * 0.91 / 6 * 3.17 ) *
    ( -1946.29 / 46.04 ))
  = -10120.76 psi
```

Bending Stress at Long-side 2 at A Outer[SblAo]:

```
  = ( P * L2 * p * c / 6 * I11 ) *
    ( -C2 / A3 )
  = ( 125.00 * 8.00 * 5.00 * -1.72 / 6 * 3.17 ) *
    ( -1946.29 / 46.04 ))
  = 19095.84 psi
```

Bending Stress at Long-side 2 at B Inner[SblBi]:

```
  = ( P * L2 * p * c / 6 * I11 ) * ( 3 *
    L2 - ( C2 / A3 ))
  = ( 125.00 * 8.00 * 5.00 * 0.91 / 6 * 3.17 ) * ( 3 *
    8.00 - ( 1946.29 / 46.04 ))
  = -4374.76 psi
```

Bending Stress at Long-side 2 at B Outer[SblBo]:

```
  = ( P * L2 * p * c / 6 * I11 ) * ( 3 *
    L2 - ( C2 / A3 ))
  = ( 125.00 * 8.00 * 5.00 * -1.72 / 6 * 3.17 ) * ( 3 *
    8.00 - ( 1946.29 / 46.04 ))
  = 8254.29 psi
```

Bending Stresses at Short-side 1

Bending Stress at Short-side 1 at B Inner[SbsBi]:

```
  = ( P * L2 * p * c / 6 * I11 ) * [ 3 * L2 -
    ( C2 / A3 )]
  = ( 125.00 * 8.00 * 5.00 *0.91 / 6 * 3.17 ) * [ 3 * 8.00 -
    ( 1946.29 / 46.04 )]
  = -4374.76 psi
```

Bending Stress at Short-side 1 at B Outer[SbsBo]:

```
  = ( P * L2 * p * c / 6 * I11 ) * [ 3 * L2 -
    ( C2 / A3 )]
```

```
  = ( 125.00 * 8.00 * 5.00 * -1.72 / 6 * 3.17 ) * [ 3 * 8.00 -
    ( 1946.29 / 46.04 )]
  = 8254.29 psi
```

Bending Stress at Short-side 1 at C Inner[SbsCi]:

```
  = ( P * L2 * p * c / 6 * I1 ) * [ 3 * ( L2 +
    2 * R ) - ( C2 / A3 )]
  = ( 125.00 * 8.00 * 5.00 * 0.91 / 6 * 3.17 ) * [ 3 * ( 8.00 +
    2 * 9.56 ) - ( 1946.29 / 46.04 )]
  = 9361.77 psi
```

Bending Stress at Short-side 1 at C Outer[SbsCo]:

```
  = ( P * L2 * p * c / 6 * I1 ) * [ 3 * ( L2 +
    2 * R ) - ( C2 / A3 )]
  = ( 125.00 * 8.00 * 5.00 * -1.72 / 6 * 3.17 ) * [ 3 * ( 8.00 +
    2 * 9.56 ) - ( 1946.29 / 46.04 )]
  = -17663.78 psi
```

Bending Stresses at Short-side 2

Bending Stress at Short-side 2 at B Inner[SbsBi]:

```
  = ( P * L2 * p * c / 6 * I11 ) * [ 3 * L2 -
    ( C2 / A3 )]
  = ( 125.00 * 8.00 * 5.00 *0.91 / 6 * 3.17 ) * [ 3 * 8.00 -
    ( 1946.29 / 46.04 )]
  = -4374.76 psi
```

Bending Stress at Short-side 2 at B Outer[SbsBo]:

```
  = ( P * L2 * p * c / 6 * I11 ) * [ 3 * L2 -
    ( C2 / A3 )]
  = ( 125.00 * 8.00 * 5.00 * -1.72 / 6 * 3.17 ) * [ 3 * 8.00 -
    ( 1946.29 / 46.04 )]
  = 8254.29 psi
```

Bending Stress at Short-side 2 at C Inner[SbsCi]:

```
  = ( P * L2 * p * c / 6 * I1 ) * [ 3 * ( L2 +
    2 * R ) - ( C2 / A3 )]
  = ( 125.00 * 8.00 * 5.00 * 0.91 / 6 * 3.17 ) * [ 3 * ( 8.00 +
    2 * 9.56 ) - ( 1946.29 / 46.04 )]
  = 9361.77 psi
```

Bending Stress at Short-side 2 at C Outer[SbsCo]:

```
  = ( P * L2 * p * c / 6 * I1 ) * [ 3 * ( L2 +
    2 * R ) - ( C2 / A3 )]
  = ( 125.00 * 8.00 * 5.00 * -1.72 / 6 * 3.17 ) * [ 3 * ( 8.00 +
    2 * 9.56 ) - ( 1946.29 / 46.04 )]
  = -17663.78 psi
```

BENDING STRESSES: Bending Stress Calculations per Section 13-11, Equations (4-7). (psi) :

STRESS LOCATIONS		Inner	Outer	Allowable
Long-side 1	at A	-10120.76	19095.84	20666.67
	at B	-4374.76	8254.29	20666.67
Long-side 2	at A	-10120.76	19095.84	20666.67
	at B	-4374.76	8254.29	20666.67
Short-side 1	at B	-4374.76	8254.29	20666.67
	at C	9361.77	-17663.78	20666.67
Short-side 2	at B	-4374.76	8254.29	20666.67
	at C	9361.77	-17663.78	20666.67

Total Stress Calculations per Section 13-11

Total Stresses at Long-side 1

Total Stress at long side 1 at A inner [STL_Ai]:
= SmlA + SblAi
= 995.33 + -10120.76
= -9125.43 psi

Total Stress at long side 1 at A outer [STL_Ao]:
= SmlA + SblAo
= 995.33 + 19095.84
= 20091.17 psi

Total Stress at long side 1 at B inner [STL_Bi]:
= SmlB + SblBi
= 995.33 + -4374.76
= -3379.43 psi

Total Stress at long side 1 at B outer [STL_Bo]:
= SmlB + SblBo
= 995.33 + 8254.29
= 9249.63 psi

Total Stresses at Long-side 2

Total Stress at long side 2 at A inner [STL_Ai]:
= SmlA + SblAi
= 995.33 + -10120.76
= -9125.43 psi

Total Stress at long side 2 at A outer [STL_Ao]:
= SmlA + SblAo
= 995.33 + 19095.84
= 20091.17 psi

Total Stress at long side 2 at B inner [STL_Bi]:
= SmlB + SblBi
= 995.33 + -4374.76
= -3379.43 psi

Total Stress at long side 2 at B outer [STL_Bo]:
= SmlB + SblBo
= 995.33 + 8254.29
= 9249.63 psi

Total Stresses at Short-side 1

Total Stress at short side 1 at B inner [STS_Bi]:
= SmsB + SbsBi
= 995.33 + -4374.76
= -3379.43 psi

Total Stress at short side 1 at B outer [STS_Bo]:
= SmsB + SbsBo
= 995.33 + 8254.29
= 9249.63 psi

Total Stress at short side 1 at C inner [STS_Ci]:

= SmsC + SbsCi
= 1990.67 + 9361.77
= 11352.44 psi

Total Stress at short side 1 at C outer [STS_Co]:
= SmsC + SbsCo
= 1990.67 + -17663.78
= -15673.11 psi

Total Stresses at Short-side 2

Total Stress at short side 2 at B inner [STS_Bi]:
= SmsB + SbsBi
= 995.33 + -4374.76
= -3379.43 psi

Total Stress at short side 2 at B outer [STS_Bo]:
= SmsB + SbsBo
= 995.33 + 8254.29
= 9249.63 psi

Total Stress at short side 2 at C inner [STS_Ci]:
= SmsC + SbsCi
= 1990.67 + 9361.77
= 11352.44 psi

Total Stress at short side 2 at C outer [STS_Co]:
= SmsC + SbsCo
= 1990.67 + -17663.78
= -15673.11 psi

TOTAL STRESSES: Total Stress Calculations per Section 13-11, Equations (8-11). (psi) :

STRESS LOCATIONS		Inner	Outer	Allowable
Long-side 1	at A	-9125.43	20091.17	20666.67
	at B	-3379.43	9249.63	20666.67
Long-side 2	at A	-9125.43	20091.17	20666.67
	at B	-3379.43	9249.63	20666.67
Short-side 1	at B	-3379.43	9249.63	20666.67
	at C	11352.44	-15673.11	20666.67
Short-side 2	at B	-3379.43	9249.63	20666.67
	at C	11352.44	-15673.11	20666.67

END PLATE STRESSES (psi) :

	Actual	Allowable
End Plate	5673.13	20000.00

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	1990.67	psi
High Stress Percentage	9.95	%
M.A.W.P. for Membrane Stresses	1255.86	psig

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	19095.84	psi
High Stress Percentage	92.40	%
M.A.W.P. for Bending Stresses	135.28	psig

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	20091.17	psi
High Stress Percentage	97.22	%
M.A.W.P. for Total Stresses	128.58	psig

Input Echo, Flange Item 1, Description: Flange

Description of Flange Geometry (Type)		Loose Ring	
Description of Flange Analysis		Analysis Only	
Design Pressure	P	125.00	psig
Design Temperature		500.00	F
Corrosion Allowance	ci	0.0000	in.
Flange Inside Diameter	B	17.000	in.
Flange Outside Diameter	A	21.250	in.
Flange Thickness	t	1.1875	in.
Perform thickness calcs. based on rigidity		Yes	
Flange Material (Not Normalized)		SA-516 70	
Flange Material UNS Number		K02700	
Flange Allowable Stress At Temperature	Sfo	20000.00	psi
Flange Allowable Stress At Ambient	Sfa	20000.00	psi
Bolt Material		SA-193 B7	
Bolt Material UNS Number		G41400	
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	nsp	0	
Diameter of Bolt Circle	C	20.000	in.
Nominal Bolt Diameter	a	0.6250	in.
Type of Thread Series		TEMA Thread Series	
Number of Bolts	n	34	
Compute Full Flange Design Bolt Load (S*ab) ?		No	
Flange Face Outside Diameter	Fod	21.250	in.
Flange Face Inside Diameter	Fid	17.000	in.
Flange Facing Sketch		Code Sketch 1a	
Gasket Outside Diameter	Go	21.250	in.
Gasket Inside Diameter	Gi	17.000	in.
Gasket Factor,	m	1.0000	
Gasket Design Seating Stress	y	200.00	psi
Column for Gasket Seating		2, Code Column II	
Shell Material		SA-516 70	
Shell Material UNS Number		K02700	
Shell Allowable Stress At Temperature	So	20000.00	psi
Shell Allowable Stress At Ambient	Sa	20000.00	psi
Full face Gasket Flange Option		Program Selects	

ASME Code, Section VIII, Division 1, 2015

Flange analysis, Flange number 1, Description: Flange
ASME Code, Section VIII, Div. 1, 2015 App. 2

Distance to Full Face Gasket ID Centroid, hg		0.730	in.

Distance to Full Face Gasket OD Centroid, h'g		0.316	in.
Code R Dimension,	R = (C-B)/2 - g1	1.500	in.
Gasket Contact Width,	N = (Goc-Gicor)/2	2.125	in.
Basic Gasket Width,	b0 = Full Face	1.062	in.
Effective Gasket Width,	b = (C-Gi) / 4.0	0.750	in.
Gasket Reaction Diameter,	G = C - 2.0 * hg	18.541	in.

Note: This gasket extends beyond the Bolt circle diameter, it will be designed per Taylor Forge Bulletin NO. 45.

Basic Flange and Bolt loads:

Hydrostatic End Load due to Pressure[H]:
= 0.785 * G * G * Peq
= 0.785 * 18.5405 *18.5405 *125.0000
= 33747.738 lb.

Contact Load on Gasket Surfaces[Hp]:
= 2 * b * PI * G * m * P
= 2 * 0.7500 * 3.1416 * 18.5405 * 1.0000 * 125.00
= 10921.280 lb.

Full Face ID Gasket Compression[H'p]:
= Hp * hg / h'g
= (10921 * 0.7297 / 0.3157)
= 25247.637 lb.

Full Face ID Pressure Load[H'GY]:
= b * PI * G * y * hg / h'g
= 0.7500 * 3.1416 * 18.5405 * 200 * 0.7297 / 0.3157
= 20198.107 lb.

Hydrostatic End Load at Flange ID[Hd]:
= 0.785 * Bcor * Bcor * P
= 0.785 * 17.0000 * 17.0000 *125.0000
= 28372.512 lb.

Pressure Force on Flange Face[Ht]:
= H - Hd
= 33747 - 28372
= 5375.227 lb.

Operating Bolt Load[Wm1]:
= H + Hp + H'p (cannot be < 0)
= (33747 + 10921 + 25247)
= 69916.656 lb.

Gasket Seating Bolt Load[Wm2]:
= y * b * PI * G + yPart * bPart * lp + H'GY
= 200.00*0.7500*3.141*18.541+0.00*0.0000*0.00+20198.11
= 28935.133 lb.

Required Bolt Area[Am]:
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 69916 / 25000 , 28935 / 25000
= 2.79667 in^2

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
= 2a + 6t/(m + 0.5)

= 2 * 0.625 + 6 * 1.188 /(1.00 + 0.5)
= 6.000 in.

Actual Circumferential Bolt Spacing [Bs]:
= C * sin(pi / n)
= 20.000 * sin(3.142 / 34)
= 1.845 in.

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(1.845 /(2 * 0.625 + 1.188)), 1)
= 1.0000

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

	Minimum	Actual	Maximum
Bolt Area, in^2	2.797	6.868	
Radial distance bet. hub and bolts	0.750	1.500	
Radial distance bet. bolts and the edge	0.750	0.625	
Circumferential spacing between bolts	1.500	1.845	6.000

Flange Design Bolt Load, Gasket Seating[W]:
= Sa * (Am + Ab) / 2.0
= 25000.00 * (2.7967 + 6.8680) / 2.0
= 120808.33 lb.

Gasket Seating Force[Hg]:
= W - H
= 120808 - 33747
= 87060.59 lb.

Moment Arm Calculations:

Distance to Gasket Load Reaction[hg]:
= (C - Gicor) * (2 * Gicor + C) / (6 * (Gicor + C))
= (20.000 - 17.000) * (2 * 17.000 + 20.000) /
(6 * (17.000 + 20.000))
= 0.7297 in.

Reverse Moment arm[h"g]:
= hg * h'g / (hg + h'g)
= 0.7297 * 0.3157 / (0.7297 + 0.3157)
= 0.2203 in.

Distance to Face Pressure Reaction[ht]:
= (R + g1cor + hg) / 2.0
= (1.5000 + 0.0000 + 0.7297) / 2.0
= 1.1149 in.

Distance to End Pressure Reaction[hd]:
= R + g1cor
= 1.5000 + 0.0000
= 1.5000 in.

Summary of Moments for Internal Pressure:

Loading		Force	Distance	Bolt Corr	Moment	
End Pressure,	Md	28373.	1.5000	1.0000	3547.	ft.lb.
Face Pressure,	Mt	5375.	1.1149	1.0000	499.	ft.lb.
Gasket Load,	Mg	0.	0.0000	1.0000	0.	ft.lb.

```
Gasket Seating, Ma      120808.    0.7297    1.0000       7346. ft.lb.
Full Face Load, Mr       87061.    0.2203    1.0000       1599. ft.lb.

Total Moment for Operation,       Mo                      4046. ft.lb.
Total Moment for Gasket Seating,  Ma                      7346. ft.lb.

Effective Hub Length, ho =                                0.000  in.
Hub Ratio,          h/ho = Defined as 0.0                 0.000
Thickness Ratio,   g1/g0 = Defined as 0.0                 0.000

Factors from Figure 2-7.1                      K =        1.250
                   T =      1.818              U =        9.703
                   Y =      8.830              Z =        4.556
```

Tangential Flange Stress, Operating[Sto]:

```
 = ( Y * Mo ) / ( t^2* Bcor )
 = ( 8.8296 * 48551 ) / ( 1.1875^2* 17.0000 )
 = 17882.5 psi
```

Bolt Stress, Operating[Bso]:

```
 = ( Wm1 / Ab )
 = ( 69916 / 6.8680 )
 = 10180.1 psi
```

Bolt Stress, Seating[Bsa]:

```
 = ( Wm2 / Ab )
 = ( 28935 / 6.8680 )
 = 4213.0 psi
```

Radial Stress at Bolt Circle, Full Face Gaskets, Operating[Srfo]:

```
 = 6 * Mr / (t^2* (PI*C - n * dB))
 = 6 * 1598 /
   ( 1.1875^2* ( 3.1416 * 20.0000 - 34 * 0.6250 ) )
 = 1962.9 psi
```

Stress Computation Results:

	Operating		Gasket Seating		
	Actual	Allowed	Actual	Allowed	
Tangential Flange	17883.	20000.	0.	20000.	psi
Bolting	10180.	25000.	4213.	25000.	psi
Full Faced Gasket	1963.	20000.	0.	20000.	psi

```
Estimated M.A.W.P. ( Operating )                        139.80  psig
Estimated M.A.W.P. ( Gasket Seating )                  1405.77  psig
Estimated Finished Weight of Flange                      42.5  lb.
Estimated Unfinished Weight of Forging                   42.5  lb.
```

Input Echo, Component 3, Description: Firetube

Design Internal Pressure	P	15.00	psig
Temperature for Internal Pressure		500.00	F
User Entered Minimum Design Metal Temperature		-20.00	F
Design External Pressure	PEXT	125.00	psig
Temperature for External Pressure		500.00	F
External Pressure Chart Name		CS-2	
Include Hydrostatic Head Components		NO	
Material Specification (Not Normalized)		SA-106 B	
Material UNS Number		K03006	
Material Form used		Smls. pipe	
Allowable Stress At Temperature	S	17100.00	psi
Allowable Stress At Ambient	SA	17100.00	psi
Yield Stress At Temperature	Sy	28500.00	psi
Curve Name for Chart UCS 66		B	
Joint efficiency for Shell Joint	E	1.00	
Design Length of Section	L	120.000	in.
Length of Cylinder for Volume Calcs.	CYLLEN	120.000	in.
Outside Diameter of Cylindrical Shell	D	14.000	in.
Minimum Thickness of Pipe or Plate	T	0.3281	in.
Nominal Thickness of Pipe or Plate	Tnom	0.3750	in.
Shell/Head Int. Corrosion Allowance	CA	0.0000	in.
Skip UG-16(b) Min. thickness calculation		NO	
Type of Element:		Cylindrical Shell	

Internal pressure results, Shell Number 3, Desc.: Firetube
ASME Code, Section VIII, Division 1, 2015

Thickness Due to Internal Pressure (Tr):
= (P*(D/2-CAE)) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
= (15.00*(14.0000/2-0.000)/(17100.00*1.00+0.4*15.00)
= 0.0061 + 0.0000 = 0.0061 in.
= 0.0625 in. (Per Ug 16b)

Max. All. Working Pressure at Given Thickness (MAWP):
= (S*E*(T-CA-CAE)) / ((D/2-CAE)-0.4*(T-CA-CAE)) per Appendix 1-1 (a)(1)
= (17100.00*1.00*(0.3281))/(14.0000/2-0.000-0.4*0.3281)
= 816.88 psig

Maximum Allowable Pressure, New and Cold (MAPNC):
= (SA*E*T) / (D/2-0.4*T) per Appendix 1-1 (a)(1)
= (17100.00*1.00*0.3281)/(14.0000/2-0.4*0.3281)
= 816.88 psig

Actual stress at given pressure and thickness (Sact):
= (P*((D/2-CAE)-0.4*(T-CA-CAE))) / (E*(T-CA-CAE))
= (15.00*(((14.0000/2-0.000)-0.4*(0.3281)))/(1.00*(0.3281))
= 314.00 psi

SUMMARY OF INTERNAL PRESSURE RESULTS:

Required Thickness plus Corrosion Allowance, Trca		0.0625	in.

Actual Thickness as Given in Input		0.3281	in.
Maximum Allowable Working Pressure	MAWP	816.879	psig
Maximum Allowable Pressure, NC	MAPNC	816.879	psig
Design Pressure as Given in Input	P	15.000	psig

Hydrostatic Test Pressures (Measured at High Point):

Hydrotest per UG-99(b); 1.3 * MAWP * Sa/S	1061.94	psig
Hydrotest per UG-99(c); 1.3 * MAPNC	1061.94	psig
Pneumatic per UG-100 ; 1.1 * MAWP * Sa/S	898.57	psig

Minimum Design Metal Temperature per UCS-66 Curve : B
tg = 0.328 , tg_sr = 0.328 , tr = 0.063 , c = 0.0000 in. , E* = 1.00
Stress Ratio = tr * (E*) / (tg_sr - c) = 0.190 , Temp. Reduction = 140 F

Min. Metal Temp. w/o impact per Fig. UCS-66	-20	F
Min. Metal Temp. at Req'd thk. (UCS 66.1)	-155	F
Min. Metal Temp. w/o impact per UG-20(f)	-20	F

External Pressure Results, Shell Number 3, Desc.: Firetube
ASME Code, Section VIII, Division 1, 2015

External Pressure Chart	CS-2	at 500.00	F
Elastic Modulus for Material		27000000.00	psi

Results for Max. Allowable External Pressure (Emawp):

Corroded Thickness of Shell	TCA	0.3281	in.
Outside Diameter of Shell	ODCA	14.000	in.
Design Length of Cylinder or Cone	SLEN	120.000	in.
Diameter / Thickness Ratio	(D/T)	42.6667	
Length / Diameter Ratio	LD	8.5714	
Geometry Factor, A f(DT,LD)	A	0.0006042	
Materials Factor, B, f(A, Chart)	B	8157.3491	psi
Maximum Allowable Working Pressure		254.92	psig

EMAWP = (4*B)/(3*(D/T)) = (4 *8157.3491)/(3 *42.6667) = 254.9172

Results for Reqd Thickness for Ext. Pressure (Tca):

Corroded Thickness of Shell	TCA	0.2566	in.
Outside Diameter of Shell	ODCA	14.000	in.
Design Length of Cylinder or Cone	SLEN	120.000	in.
Diameter / Thickness Ratio	(D/T)	54.5671	
Length / Diameter Ratio	LD	8.5714	
Geometry Factor, A f(DT,LD)	A	0.0003790	
Materials Factor, B, f(A, Chart)	B	5115.9312	psi
Maximum Allowable Working Pressure		125.01	psig

EMAWP = (4*B)/(3*(D/T)) = (4 *5115.9312)/(3 *54.5671) = 125.0064

Results for Maximum Length Calculation: No Conversion

Corroded Thickness of Shell	TCA	0.3281	in.
Outside Diameter of Shell	ODCA	14.000	in.
Design Length of Cylinder or Cone	SLEN	0.957E+15	in.
Diameter / Thickness Ratio	(D/T)	42.6667	
Length / Diameter Ratio	LD	50.0000	
Geometry Factor, A f(DT,LD)	A	0.0006042	
Materials Factor, B, f(A, Chart)	B	8157.3491	psi
Maximum Allowable Working Pressure		254.92	psig

EMAWP = (4*B)/(3*(D/T)) = (4 *8157.3491)/(3 *42.6667) = 254.9172

Summary of External Pressure Results:

Allowable Pressure at Corroded thickness	254.92	psig

Required Pressure as entered by User		125.00	psig
Required Thickness including Corrosion all.		0.2566	in.
Actual Thickness as entered by User		0.3281	in.
Maximum Length for Thickness and Pressure		0.9571E+15	in.
Actual Length as entered by User		120.00	in.

Weight and Volume Results, No C.A. :

Volume of Shell Component	VOLMET	1932.8	in.^3
Weight of Shell Component	WMET	541.2	lb.
Inside Volume of Component	VOLID	16781.4	in.^3
Weight of Water in Component	WWAT	606.0	lb.

Input Echo, Component 2, Description: Cover

Design Internal Pressure	P	125.00	psig
Temperature for Internal Pressure		500.00	F
User Entered Minimum Design Metal Temperature		-20.00	F
Include Hydrostatic Head Components		NO	
Material Specification (Not Normalized)		SA-516 70	
Material UNS Number		K02700	
Material Form used		Plate	
Allowable Stress At Temperature	S	20000.00	psi
Allowable Stress At Ambient	SA	20000.00	psi
Yield Stress At Temperature	Sy	31000.00	psi
Curve Name for Chart UCS 66		B	
Joint efficiency for Head Joint	E	1.00	
Diameter of Flat Head	D	20.000	in.
Minimum Thickness of Pipe or Plate	T	1.1875	in.
Nominal Thickness of Pipe or Plate	Tnom	1.1875	in.
Shell/Head Int. Corrosion Allowance	CA	0.0000	in.
Attachment Factor	CF	0.2500	
Large Diameter of Flat Head	DL	36.000	in.
Skip UG-16(b) Min. thickness calculation		NO	
Type of Element:		Flat Head	

Internal pressure results, Shell Number 2, Desc.: Cover

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Thickness Due to Internal Pressure (Tr):
= (D) * SQRT(Z*CF*P/(S*E)) per UG-34 (c) (3)
= (20.0000)*SQRT(2.07*0.25*125.00/(20000.00*1.00))
= 1.1365 + 0.0000 = 1.1365 in.

Max. All. Working Pressure at Given Thickness (MAWP):
= ((T-CA-CAE)/D)^2 * ((S*E)/(CF*Z)) per UG-34 (c) (3)
= ((1.1875)/20.0000)**2*((20000.00*1.00)/(0.25*2.07))
= 136.47 psig

Maximum Allowable Pressure, New and Cold (MAPNC):
= (T/D)^2*((S*E) / (CF*Z)) per UG-34 (c) (3)
= (1.1875/20.0000)**2*((20000.00*1.00)/(0.25*2.07))
= 136.47 psig

Actual stress at given pressure and thickness (Sact):
= (Z*CF*P) / ((((T-CA-CAE)/D)^2)*E)
= (2.07*0.25*125.00)/((((1.1875)/20.0000)**2)*1.00)
= 18319.48 psi

SUMMARY OF INTERNAL PRESSURE RESULTS:

Required Thickness plus Corrosion Allowance, Trca		1.1365	in.
Actual Thickness as Given in Input		1.1875	in.
Maximum Allowable Working Pressure	MAWP	136.467	psig
Maximum Allowable Pressure, NC	MAPNC	136.467	psig

Design Pressure as Given in Input	P	125.000	psig

Hydrostatic Test Pressures (Measured at High Point):

Hydrotest per UG-99(b); 1.3 * MAWP * Sa/S	177.41	psig
Hydrotest per UG-99(c); 1.3 * MAPNC	177.41	psig
Pneumatic per UG-100 ; 1.1 * MAWP * Sa/S	150.11	psig

Minimum Design Metal Temperature per UCS-66 Curve : B

tg = 0.297 , tg_sr = 1.188 , tr = 1.137 , c = 0.0000 in. , E* = 1.00
Stress Ratio = tr * (E*) / (tg_sr - c) = 0.957 , Temp. Reduction = 4 F

Min. Metal Temp. w/o impact per Fig. UCS-66	-20	F
Min. Metal Temp. at Req'd thk. (UCS 66.1)	-24	F
Min. Metal Temp. w/o impact per UG-20(f)	-20	F

Weight and Volume Results, No C.A. :

Volume of Shell Component	VOLMET	753.1	in.^3
Weight of Shell Component	WMET	210.9	lb.

Input Echo, Flange Item 2, Description: Cover/Tube

Description of Flange Geometry (Type)		Integral Weld Neck	
Description of Flange Analysis		Analysis Only	
Design Pressure	P	125.00	psig
Design Temperature		500.00	F
Corrosion Allowance	ci	0.0000	in.
Flange Inside Diameter	B	13.500	in.
Flange Outside Diameter	A	21.250	in.
Flange Thickness	t	1.1875	in.
Thickness of Hub at Small End	g0	0.3281	in.
Thickness of Hub at Large End	g1	0.8821	in.
Length of Hub	h	0.5000	in.
Perform thickness calcs. based on rigidity		Yes	
Flange Material (Not Normalized)		SA-516 70	
Flange Material UNS Number		K02700	
Flange Allowable Stress At Temperature	Sfo	20000.00	psi
Flange Allowable Stress At Ambient	Sfa	20000.00	psi
Bolt Material		SA-193 B7	
Bolt Material UNS Number		G41400	
Bolt Allowable Stress At Temperature	Sb	25000.00	psi
Bolt Allowable Stress At Ambient	Sa	25000.00	psi
Diameter of Bolt Circle	C	20.000	in.
Nominal Bolt Diameter	a	0.6250	in.
Type of Thread Series		TEMA Thread Series	
Number of Bolts	n	34	
Compute Full Flange Design Bolt Load (S*ab) ?		No	
Flange Face Outside Diameter	Fod	21.250	in.
Flange Face Inside Diameter	Fid	16.000	in.
Flange Facing Sketch		Code Sketch 1a	
Gasket Outside Diameter	Go	21.250	in.
Gasket Inside Diameter	Gi	16.000	in.
Gasket Factor,	m	1.0000	
Gasket Design Seating Stress	y	200.00	psi
Column for Gasket Seating		2, Code Column II	
Shell Material		SA-106 B	
Shell Material UNS Number		K03006	
Shell Allowable Stress At Temperature	So	17100.00	psi
Shell Allowable Stress At Ambient	Sa	17100.00	psi
Full face Gasket Flange Option		Program Selects	

Error/Warning Messages for Flange Number 2

Warning - Flange Hub taper 1.108 exceeds 0.33. Check Fig. 2-4(6) of App. 2.
This warning should not be considered for Standard Flanges
as permitted by ASME VIII in Table U-3 or for non-Code vessels.

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Hub Small End Required Thickness due to Internal Pressure:
= (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
= (125.00*(13.5000/2+0.0000))/(20000.00*1.00-0.6*125.00)+Ca
= 0.0423 in.

Flange analysis, Flange number 2, Description: Cover/Tube
ASME Code, Section VIII, Div. 1, 2015 App. 2

Distance to Full Face Gasket ID Centroid, hg		0.963	in.
Distance to Full Face Gasket OD Centroid, h'g		0.316	in.
Corroded Flange ID,	Bcor = B+2.0*ci	13.500	in.
Corroded Large Hub,	g1cor = g1-ci	0.882	in.
Corroded Small Hub,	g0cor = g0-ci	0.328	in.
Code R Dimension,	R = (C-B)/2 - g1	2.368	in.
Gasket Contact Width,	N = (Goc-Gic) / 2	2.625	in.
Basic Gasket Width,	b0 = Full Face	1.312	in.
Effective Gasket Width,	b = (C-Gicor)/4.0	1.000	in.
Gasket Reaction Diameter,	G = C - 2.0 * hg	18.074	in.

Note: This gasket extends beyond the Bolt circle diameter, it will be designed per Taylor Forge Bulletin NO. 45.

Basic Flange and Bolt loads:
Hydrostatic End Load due to Pressure[H]:
= 0.785 * G * G * Peq
= 0.785 * 18.0741 *18.0741 *125.0000
= 32070.965 lb.

Contact Load on Gasket Surfaces[Hp]:
= 2 * b * PI * G * m * P
= 2 * 1.0000 * 3.1416 * 18.0741 * 1.0000 * 125.00
= 14195.345 lb.

Full Face ID Gasket Compression[H'p]:
= Hp * hg / h'g
= (14195 * 0.9630 / 0.3157)
= 43305.266 lb.

Full Face ID Pressure Load[H'GY]:
= b * PI * G * y * hg / h'g
= 1.0000 * 3.1416 * 18.0741 * 200 * 0.9630 / 0.3157
= 34644.215 lb.

Hydrostatic End Load at Flange ID[Hd]:
= 0.785 * Bcor * Bcor * P
= 0.785 * 13.5000 * 13.5000 *125.0000
= 17892.354 lb.

Pressure Force on Flange Face[Ht]:
= H - Hd
= 32070 - 17892
= 14178.611 lb.

Operating Bolt Load[Wm1]:
= H + Hp + H'p (cannot be < 0)

= (32070 + 14195 + 43305)
= 89571.578 lb.

Gasket Seating Bolt Load[Wm2]:
= y * b * PI * G + yPart * bPart * lp + H'GY
= 200.00*1.0000*3.141*18.074+0.00*0.0000*0.00+34644.21
= 46000.492 lb.

Required Bolt Area[Am]:
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 89571 / 25000 , 46000 / 25000
= 3.58286 in^2

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
= 2a + 6t/(m + 0.5)
= 2 * 0.625 + 6 * 1.188 /(1.00 + 0.5)
= 6.000 in.

Actual Circumferential Bolt Spacing [Bs]:
= C * sin(pi / n)
= 20.000 * sin(3.142 / 34)
= 1.845 in.

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(1.845 /(2 * 0.625 + 1.188)), 1)
= 1.0000

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

	Minimum	Actual	Maximum
Bolt Area, in^2	3.583	6.868	
Radial distance bet. hub and bolts	0.938	2.368	
Radial distance bet. bolts and the edge	0.750	0.625	
Circumferential spacing between bolts	1.500	1.845	6.000

Flange Design Bolt Load, Gasket Seating[W]:
= Sa * (Am + Ab) / 2.0
= 25000.00 * (3.5829 + 6.8680) / 2.0
= 130635.79 lb.

Gasket Seating Force[Hg]:
= W - H
= 130635 - 32070
= 98564.83 lb.

Moment Arm Calculations:

Distance to Hub Large End[R]:
= (C - Bcor) / 2 - g1cor
= (20.000 - 13.500) / 2 - 0.882
= 2.3679 in.

Distance to Gasket Load Reaction[hg]:
= (C - Gi) * (2 * Gi + C) / (6 * (Gi + C))
= (20.000 - 16.000) * (2 * 16.000 + 20.000) /
(6 * (16.000 + 20.000))
= 0.9630 in.

Reverse Moment arm[h"g]:
= hg * h'g / (hg + h'g)
= 0.9630 * 0.3157 / (0.9630 + 0.3157)
= 0.2377 in.

Distance to Face Pressure Reaction[ht]:
= (R + g1cor + hg) / 2.0
= (2.3679 + 0.8821 + 0.9630) / 2.0
= 2.1065 in.

Distance to End Pressure Reaction[hd]:
= R + g1cor
= 2.3679 + 0.8821
= 3.2500 in.

Summary of Moments for Internal Pressure:

Loading		Force	Distance	Bolt Corr	Moment	
End Pressure,	Md	17892.	3.2500	1.0000	4846.	ft.lb.
Face Pressure,	Mt	14179.	2.1065	1.0000	2489.	ft.lb.
Gasket Load,	Mg	0.	0.0000	1.0000	0.	ft.lb.
Gasket Seating,	Ma	130636.	0.9630	1.0000	10483.	ft.lb.
Full Face Load,	Mr	98565.	0.2377	1.0000	1953.	ft.lb.

Total Moment for Operation, Mo 7335. ft.lb.
Total Moment for Gasket Seating, Ma 10483. ft.lb.

Effective Hub Length, ho = SQRT(Bcor*g0cor) 2.105 in.
Hub Ratio, h/ho = h / ho 0.238
Thickness Ratio, g1/g0 = (g1cor/g0cor) 2.689

Flange Factors for Integral Flange:
Factor F per 2-7.2 0.884
Factor V per 2-7.3 0.299
Factor f per 2-7.6 4.381
Factors from Figure 2-7.1 K = 1.574
T = 1.679 U = 4.895
Y = 4.454 Z = 2.353
d = 3.714 in.^3 e = 0.4200 in.^-1
Stress Factors Alpha = 1.499
Beta = 1.665 Gamma = 0.893
Delta = 0.451 Lambda = 1.344

Longitudinal Hub Stress, Operating[Sho]:
= (f * Mo / Bcor) / (Rlambda * g1cor^2)
= (4.3813 *88017 / 13.5000) / (1.3437 *0.8821^2)
= 27320.5 psi

Radial Flange Stress, Operating[Sro]:
= (Beta * Mo / Bcor) / (Rlambda * t^2)
= (1.6651 *88017 / 13.5000) / (1.3437 *1.1875^2)
= 5729.1 psi

Tangential Flange Stress, Operating[Sto]:
= (Y* Mo / (t^2* Bcor)) - Z * Sro
= (4.4542 *88017 / (1.1875^2*13.5000)) - 2.3534 *5729
= 7111.0 psi

Average Flange Stress, Operating[Sao]:
= (Sho + MAX(Sro, Sto)) / 2

= (27320 + MAX(5729 , 7110))/ 2
= 17215.7 psi

Bolt Stress, Operating[Bso]:
= (Wm1 / Ab)
= (89571 / 6.8680)
= 13041.9 psi

Bolt Stress, Seating[Bsa]:
= (Wm2 / Ab)
= (46000 / 6.8680)
= 6697.8 psi

Radial Stress at Bolt Circle, Full Face Gaskets, Operating[Srfo]:
= 6 * Mr / (t^2* (PI*C - n * dB))
= 6 * 1952 /
(1.1875^2* (3.1416 * 20.0000 - 34 * 0.6250))
= 2397.6 psi

Stress Computation Results:

	Operating		Gasket Seating		
	Actual	Allowed	Actual	Allowed	
Longitudinal Hub	27321.	30000.	0.	30000.	psi
Radial Flange	5729.	20000.	0.	20000.	psi
Tangential Flange	7111.	20000.	0.	20000.	psi
Maximum Average	17216.	20000.	0.	20000.	psi
Bolting	13042.	25000.	6698.	25000.	psi
Full Faced Gasket	2398.	20000.	0.	20000.	psi

Estimated M.A.W.P. (Operating)	137.25	psig
Estimated M.A.W.P. (Gasket Seating)	136.76	psig
Estimated Finished Weight of Flange	74.1	lb.
Estimated Unfinished Weight of Forging	99.9	lb.

Minimum Design Metal Temperature Results, UCS Curve : B
Stress Ratio = 0.911 , Temperature Reduction per Fig. UCS 66.1 = 9 F

Min. Metal Temp. w/o impact per Fig. UCS-66	-20	F
Min. Metal Temp. at Req'd thk. (UCS 66.1)	-29	F
Min. Metal Temp. w/o impact per UG-20(f)	-20	F

Flange Results Summary for Item 1 : Flange

Flange Type: Loose Ring Analyze Option: Analysis Only

Design Pressure : 125.00 psig

Flange Diameters	id: 17.000	od: 21.250 in.
Gasket Diameters	id: 17.000	od: 21.250 in.
Gasket Factors	m: 1.000	y: 200.000 psi

Flange has 34 Bolts 0.625 in. at BCD 20.000 in.

	Operating	Seating
MAWP	139.800	1405.770

Note: The Flange passed, for the Internal Pressure.

The finished weight of the flange	42.452 lb.
The unfinished weight of the flange	42.452 lb.

Flange Results Summary for Item 2 : Cover/Tube

Flange Type: Integral Weld Neck Analyze Option: Analysis Only

Design Pressure : 125.00 psig

Flange Diameters	id: 13.500	od: 21.250 in.
Gasket Diameters	id: 16.000	od: 21.250 in.
Gasket Factors	m: 1.000	y: 200.000 psi

Flange has 34 Bolts 0.625 in. at BCD 20.000 in.

	Operating	Seating
MAWP	137.250	136.760

Note: The Flange passed, for the Internal Pressure.

Flange MDMT	-28.93 F
The finished weight of the flange	74.083 lb.
The unfinished weight of the flange	99.942 lb.

Summary for Nozzles :

Description	MAWP psig	FLG. MAWP	EXT. P CHECK	MAWPNC	UG-45 CHECK	WLD CHECK	MDMT F	Angle
Neck	125.00	...	...	125.00	OK	OK	-55	90
Min. Press.	125.00	---		125.00				

Rectangular Vessel Results For Item 1 : B2

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	1990.67	psi
High Stress Percentage	9.95	%
M.A.W.P. for Membrane Stresses	1255.86	psig

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	19095.84	psi
High Stress Percentage	92.40	%
M.A.W.P. for Bending Stresses	135.28	psig

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	20091.17	psi
High Stress Percentage	97.22	%
M.A.W.P. for Total Stresses	128.58	psig

Summary for shell/head, Div 1:

Description	MAPNC psig	MAWP psig	Min. T in.	Tr-int in.	Tr-ext in.	EMAWP psig
Head	218.800	218.800	0.390	0.224	---	---
Cover	136.467	136.467	1.188	1.137	---	---
Firetube	816.879	816.879	0.328	0.063	0.257	254.917
Minimum MAWP	136.467	136.467				254.917

Note: Reqd. thk. reported above includes Corrosion Allowance.

Total Shell/Head weight is (New-Cold)	1471.4 lb.
Total Shell/Head weight is (Corroded)	1471.4 lb.
Total Shell/Head weight, filled with Water (New)	4072.7 lb.
Total Shell/Head volume is (New-Cold)	72036.2 in.**3
Total Shell/Head volume is (Corroded)	72036.2 in.**3

Least MAWP and Overall Weight Results :
The Least MAWP (N C) for Cover was 136.47 psig .
The Least MAWP (Cor) for Neck was 125.00 psig .

The total sum of the Weights (N C) was 1613.78 lb. .
The total sum of the Weights (Cor) was 1587.93 lb. .

BSI Obround Flange ver 6.00

Obround Flange Calc **Description**

Design Inputs:

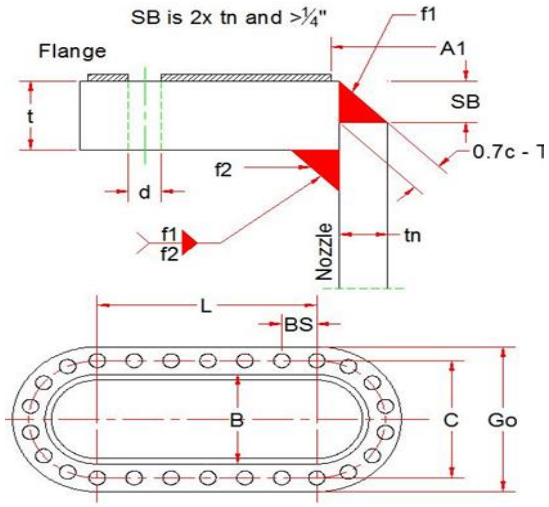
125	**p** [psi] - Design pressure
0.000	**Corr** [in] - Corrosion

Nozzle Inputs:

0.500	**tn** [in] - Nozzle thickness
0.500	**tr** [in] - Thickness required

Flange Inputs:

	SA-516 70 **Material**
20,000	**SFO** [psi] - Allowable stress
21.250	**Go** [in] - Outside diameter on short side
17.000	**B** [in] - Inside diameter on short side
1.188	**t** [in] - Thickness
27,300,000	**E** [in] - Modulus of elasticity



Bolting Inputs:

25,000	**Sa** [psi] - Stress at operating temp
25,000	**Sb** [psi] - Allowable stress at seating
20.000	**C** [in] - Bolt circle diameter on short side
52	**n** - Number of bolts
0.625-11 UNC 2A	**db** [in] - Bolt diameter
16.000	**L** [in] - Long distance bolt centers
1.778	**BS** [in] - Bolt center to center on long side

Gasket Inputs:

17.000	**A1** [in] - Gasket ID
1.0	**m**
200	**y** [psi]

Weld Inputs:

0.500	**f1** [in] - Inside Fillet
0.500	**f2** [in] - Outside Fillet
0.500	**SB** [in] - Flange set back

Variables:

Ra [sq. in] =	PVELookup("BoltData","Lookup","Root Ar",db)		0.208
Size [in] =	PVELookup("BoltData","Lookup","Size",db)		0.625
Rb [in] =	PVELookup("TEMATableD5","Lookup","Rb",db)		0.000
E1 [in] =	PVELookup("TEMATableD5","Lookup","E",db)		0.000
b'' =	0.1	0.1 =	0.1
2b'' =	2*b''	2*0.1 =	0.2
g1 [in] =	f2 + tn	0.5 + 0.5 =	1.000
g0 [in] =	tn	0.5 =	0.500
d [in] =	Size +0.125	0.625 +0.125 =	0.750
Bn =	B+2*Corr	17+2*0 =	17.000
b'o [in] =	Min((Go-C), (C-A1))	MIN((21.25-20), (20-17)) =	1.250
b' [in] =	0.79*(SQRT(b'o))	0.79*(SQRT(1.25)) =	0.883
G [in] =	C-d-2b''	20-0.75-0.2 =	19.050

Loads:

H =	(0.785*(C-d)^2 + (C-d)*L)*p	(0.785*(20-0.75)^2 + (20-0.75)*16)*125 =	74,861
HD =	(0.785*B^2 +B*L)*p	(0.785*17^2 +17*16)*125 =	62,358
HG =	(6.28*b''*G + 0.4*L) *m*p	(6.28*0.1*19.05 + 0.4*16) *1*125 =	2,295
HT =	H-HD	74861-62358 =	12,503
hD =	(C-B-g1)/2	(20-17-1)/2 =	1.000
hG =	(d+2b'')/2	(0.75+0.2)/2 =	0.475
hT =	(C+d+2b''-B)/4	(20+0.75+0.2-17)/4 =	0.988

M =	HD*hD + HG*hG +HT*hT			
		62358*1 + 2295*0.475 +12503*0.988 =		75,795
hR =	(Go-C-d)/4 + d/2	(21.25-20-0.75)/4 + 0.75/2 =		0.500
HR =	M/hR	75795/0.5 =		151,591
Wm1 =	HG+H+HR	2295+74861+151591 =		228,748
Wm2 =	3.14*C*b'*y	3.14*20*0.883*200 =		11,094
Am1 =	Wm1/Sb	228748/25000 =		9.150
Am2 =	Wm2/Sa	11094/25000 =		0.444
Am =	max(Am1,Am2)	MAX(9.15,0.444) =		9.150
Ab =	n*Ra	52*0.208 =		10.840
W =	(Am1+Ab)*Sa/2	(9.15+10.84)*25000/2 =		249,879
TG [lb] =	(HT + HG + W)	(12503 + 2295 + 249879) =		264,678
Preload [lb] =	TG /n	264678 /52 =		5,090
tmin [in] =	SQRT((6*M)/(SFO*(3.14*C-n*d)))			
		SQRT((6*75795)/(20000*(3.14*20-52*0.75))) =		0.977
Checkt =	t>tmin	1.188>0.977		**Acceptable**
tBS =	((BS-2*Size) * (m+0.5))/(6*(E/200000)^0.25)			
		((1.778-2*0.625) * (1+0.5))/(6*(27300000/200000)^0.25) =		0.039
ChecktBS =	t>tBS	1.188>0.039		**Acceptable**

Geometry Contraints:

tx =	max(tr *2,0.25)	MAX(0.5 *2,0.25) =		1.000
c =	min(tn,tx)	MIN(0.5,1) =		0.500
mtc =	0.7*c *minimum throat*	0.7*0.5 =		0.350
f1Chk	0.7*f1 >= mtc	0.7*0.5 >= 0.35		**Acceptable**
f2Chk	0.7*f2 >= mtc	0.7*0.5 >= 0.35		**Acceptable**
ChkWlds1 =	tn <= f1	0.5 <= 0.5		**Acceptable**
ChkWlds2 =	tr <= f1	0.5 <= 0.5		**Acceptable**
MinSB =	c *Min. Set Back*	0.5 =		0.500
MaxSB =	c+ 0.25 *Max Set Back*	0.5+ 0.25 =		0.750
SBChk1	SB>=MinSB	0.5>=0.5		**Acceptable**
SBChk2	SB<=MaxSB	0.5<=0.75		**Acceptable**