BWM-715-18

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Note:

Nozzle Calcs.-Firebox Tall is to obtain UG-37 reinforcement calcs. at obround flange long direction.

Nozzle Calcs.-Firebox Small is to get UG-37 reinforcement calcs. at obround flange short direction.

Y. Z.

AUGUST 02, 2018

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Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd psig	Nominal Thickness in.	Total Corr Allowance in.	Element Diameter in.	Allowable Stress(SE) psi
10	20	79.3378	0.625	0.125	120	20000
20	30	79.2927	0.375	0.125	120	20000
30	40	79.3378	0.5	0.125	120	20000
40	50	75	...	0.125	32	20000
50	60	75	...	0.125	24	20000

Element Required Thickness and MAWP :

From	To	Design Pressure psig	M.A.W.P. Corroded psig	M.A.P. New & Cold psig	Minimum Thickness in.	Required Thickness in.
10	20	75	142.869	189.095	0.5625	0.36151
20	30	75	79.1797	125.313	0.375	0.3625
30	40	75	100.611	146.797	0.4375	0.36151
40	50	75	227.18	261.42	1.88	1.20302
50	60	75	420.168	643.087	0.375	0.1875
Minimum			75.000	125.312		

MAWP: 75.000 psig, limited by: DESIGN (user specified)

Internal Pressure Calculation Results :

ASME Code, Section VIII Division 1, 2017

Elliptical Head From 10 To 20 SA-516 70 , UCS-66 Crv. B at 150 °F

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*Do*Kcor)/(2*S*E+2*P*(Kcor-0.1)) per Appendix 1-4 (c)
= (79.338*120.0*0.997)/(2*20000.0*1.0+2*79.338*(0.997-0.1))
= 0.2365 + 0.1250 = 0.3615 in.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 4.338 psig
= (2*S*E*t)/(Kcor*Do-2*t*(Kcor-0.1)) per Appendix 1-4 (c)
= (2*20000.0*1.0*0.4375)/(0.997*120.0-2*0.4375*(1.-0.1))
= 147.207 - 4.338 = 142.869 psig

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (2*S*E*t)/(K*Do-2*t*(K-0.1)) per Appendix 1-4 (c)
= (2*20000.0*1.0*0.5625)/(1.0*120.0-2*0.5625*(1.0-0.1))
= 189.095 psig

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*Do-2*t*(Kcor-0.1)))/(2*E*t)
= (79.338*(0.997*120.0-2*0.4375*(0.997-0.1)))/(2*1.0*0.4375)
= 10779.086 psi

Straight Flange Required Thickness:
= (P*Ro)/(S*E+0.4*P) + ca per Appendix 1-1 (a)(1)
= (79.338*60.0)/(20000.0*1.0+0.4*79.338)+0.125
= 0.363 in.

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 4.338 psig
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (20000.0 * 1.0 * 0.5)/(60.0 - 0.4 * 0.5)
= 167.224 - 4.338 = 162.886 psig

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))^(2))/6
= (2 + (119.125/(2 * 29.844))^(2))/6
= 0.997211

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 2.287 %

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 0.562, tr = 0.224, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.511, Temp. Reduction = 56 °F

Min Metal Temp. w/o impact per UCS-66, Curve B	0 °F
Min Metal Temp. at Required thickness (UCS 66.1)	-55 °F
Min Metal Temp. w/o impact per UG-20(f)	-20 °F

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 0.625, tr = 0.225, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.449, Temp. Reduction = 72 °F

Min Metal Temp. w/o impact per UCS-66, Curve B	6 °F
Min Metal Temp. at Required thickness (UCS 66.1)	-55 °F
Min Metal Temp. w/o impact per UG-20(f)	-20 °F

Cylindrical Shell From 20 To 30 SA-516 70 , UCS-66 Crv. B at 150 °F

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*Ro) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
= (79.293*60.0)/(20000.0*1.0+0.4*79.293)
= 0.2375 + 0.1250 = 0.3625 in.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 4.293 psig
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (20000.0*1.0*0.25)/(60.0-0.4*0.25)
= 83.472 - 4.293 = 79.180 psig

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (20000.0*1.0*0.375)/(60.0-0.4*0.375)
= 125.313 psig

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

= (P*(Ro-0.4*t))/(E*t)
= (79.293*((60.0-0.4*0.25))/(1.0*0.25)
= 18998.533 psi

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 0.313 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 0.375, tr = 0.225, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.899, Temp. Reduction = 10 °F

Min Metal Temp. w/o impact per UCS-66, Curve B -20 °F
Min Metal Temp. at Required thickness (UCS 66.1) -30 °F

Elliptical Head From 30 To 40 SA-516 70 , UCS-66 Crv. B at 150 °F

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*Do*Kcor)/(2*S*E+2*P*(Kcor-0.1)) per Appendix 1-4 (c)
= (79.338*120.0*0.997)/(2*20000.0*1.0+2*79.338*(0.997-0.1))
= 0.2365 + 0.1250 = 0.3615 in.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 4.338 psig
= (2*S*E*t)/(Kcor*Do-2*t*(Kcor-0.1)) per Appendix 1-4 (c)
= (2*20000.0*1.0*0.3125)/(0.997*120.0-2*0.3125*(1.-0.1))
= 104.949 - 4.338 = 100.611 psig

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (2*S*E*t)/(K*Do-2*t*(K-0.1)) per Appendix 1-4 (c)
= (2*20000.0*1.0*0.4375)/(1.0*120.0-2*0.4375*(1.0-0.1))
= 146.797 psig

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*Do-2*t*(Kcor-0.1)))/(2*E*t)
= (79.338*(0.997*120.0-2*0.3125*(0.997-0.1)))/(2*1.0*0.3125)
= 15119.281 psi

Straight Flange Required Thickness:
= (P*Ro)/(S*E+0.4*P) + ca per Appendix 1-1 (a)(1)
= (79.338*60.0)/(20000.0*1.0+0.4*79.338)+0.125
= 0.363 in.

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 4.338 psig
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (20000.0 * 1.0 * 0.375)/(60.0 - 0.4 * 0.375)
= 125.313 - 4.338 = 120.975 psig

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))^(2))/6
= (2 + (119.375/(2 * 29.906))^(2))/6
= 0.997216

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 1.831 %

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 0.438, tr = 0.224, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.716, Temp. Reduction = 28 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -14 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -42 °F
Min Metal Temp. w/o impact per UG-20(f)                   -20 °F
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 0.5, tr = 0.225, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.599, Temp. Reduction = 41 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B             -6 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -47 °F
Min Metal Temp. w/o impact per UG-20(f)                   -20 °F
```

Elliptical Head From 50 To 60 SA-516 70 , UCS-66 Crv. B at 150 °F

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
 = (P*Do*Kcor)/(2*S*E+2*P*(Kcor-0.1)) per Appendix 1-4 (c)
 = (75.0*24.0*0.986)/(2*20000.0*1.0+2*75.0*(0.986-0.1))
 = 0.0442 + 0.1250 = 0.1692 in.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 0.0625 in. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
 = (2*S*E*t)/(Kcor*Do-2*t*(Kcor-0.1)) per Appendix 1-4 (c)
 = (2*20000.0*1.0*0.25)/(0.986*24.0-2*0.25*(0.99-0.1))
 = 430.628 psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
 = (2*S*E*t)/(K*Do-2*t*(K-0.1)) per Appendix 1-4 (c)
 = (2*20000.0*1.0*0.375)/(1.0*24.0-2*0.375*(1.0-0.1))
 = 643.087 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
 = (P*(Kcor*Do-2*t*(Kcor-0.1)))/(2*E*t)
 = (75.0*(0.986*24.0-2*0.25*(0.986-0.1)))/(2*1.0*0.25)
 = 3483.287 psi
```

Straight Flange Required Thickness:
```
 = (P*Ro)/(S*E+0.4*P) + ca   per Appendix 1-1 (a)(1)
 = (75.0*12.0)/(20000.0*1.0+0.4*75.0)+0.125
 = 0.170 in.
```

Straight Flange Maximum Allowable Working Pressure:
```
 = (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
 = (20000.0 * 1.0 * 0.25)/(12.0 - 0.4 * 0.25 )
 = 420.168 psig
```

Factor K, corroded condition [Kcor]:
```
 = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))^(2))/6
 = ( 2 + ( 23.5/( 2 * 5.938 ))^(2))/6
 = 0.986039
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 6.793 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 0.375, tr = 0.062, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.25, Temp. Reduction = 140 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -20 °F
Min Metal Temp. at Required thickness (UCS 66.1)       -155 °F
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 0.375, tr = 0.045, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.18, Temp. Reduction = 140 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -20 °F
Min Metal Temp. at Required thickness (UCS 66.1)       -155 °F
```

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

Hydrostatic Test Pressure Results:

```
Pressure per UG99b      = 1.30 * M.A.W.P. * Sa/S         97.500  psig
Pressure per UG99b[36]  = 1.30 * Design Pres * Sa/S       97.500  psig
Pressure per UG99c      = 1.30 * M.A.P. - Head(Hyd)     158.573  psig
Pressure per UG100      = 1.10 * M.A.W.P. * Sa/S         82.500  psig
Pressure per PED        = max(1.43*DP, 1.25*DP*ratio)   106.875  psig
Pressure per App 27-4   = 1.30 * M.A.W.P. * Sa/S         97.500  psig
User Defined Hydrostatic Test Pressure at High Point     98.000  psig
```

Horizontal Test performed per: UG-99b

Please note that Nozzle, Shell, Head, Flange, etc MAWPs are all considered when determining the hydrotest pressure for those test types that are based on the MAWP of the vessel.

Stresses on Elements due to Test Pressure (psi & psig):

From	To	Stress	Allowable	Ratio	Pressure
10	20	13903.3	26000.0	0.535	102.33
20	30	24519.1	26000.0	0.943	102.33
30	40	19501.5	26000.0	0.750	102.33
50	60	4779.3	26000.0	0.184	102.90

Stress ratios for Nozzle and Pad Materials (psi):

Description	Pad/Nozzle	Ambient	Operating	Ratio
Firebox Tall	Nozzle	20000.00	20000.00	1.000
Firebox Small	Nozzle	20000.00	20000.00	1.000
N3:6in Outlet	Nozzle	17100.00	17100.00	1.000
M2:24in ShellMW	Nozzle	17100.00	17100.00	1.000
M2:24in ShellMW	Pad	20000.00	20000.00	1.000
N7 6in PSV	Nozzle	20000.00	20000.00	1.000

N8A 4in Drain	Nozzle	17100.00	17100.00	1.000
N9 4in OilDrain	Nozzle	17100.00	17100.00	1.000
N10 4in Anode	Nozzle	17100.00	17100.00	1.000
N10 4in Anode	Pad	20000.00	20000.00	1.000
N13 2in PI	Nozzle	17100.00	17100.00	1.000
N14A 2in T	Nozzle	17100.00	17100.00	1.000
N16 2in LLSD	Nozzle	17100.00	17100.00	1.000
N1 6in Inlet	Nozzle	20000.00	20000.00	1.000
Dome 24in Shell	Nozzle	17100.00	17100.00	1.000
Dome 24in Shell	Pad	20000.00	20000.00	1.000
N8B 4in. DRAIN	Nozzle	17100.00	17100.00	1.000
N22 2in. HLSD	Nozzle	17100.00	17100.00	1.000
N4 6in. OIL OUT	Nozzle	17100.00	17100.00	1.000
N11 4in. ANODE	Nozzle	17100.00	17100.00	1.000
N11 4in. ANODE	Pad	20000.00	20000.00	1.000
N12 4in. ANODE	Nozzle	17100.00	17100.00	1.000
N12 4in. ANODE	Pad	20000.00	20000.00	1.000
N14B 2in. THER	Nozzle	17100.00	17100.00	1.000
N15 2in. THER.	Nozzle	17100.00	17100.00	1.000
N23 2in. T-12	Nozzle	17100.00	17100.00	1.000
N17B 2in Gauge	Nozzle	17100.00	17100.00	1.000
M1:24	Nozzle	17100.00	17100.00	1.000
M1:24	Pad	20000.00	20000.00	1.000
N18A 2 Gauge	Nozzle	17100.00	17100.00	1.000
N5 10in Water	Nozzle	20000.00	20000.00	1.000
N18B 2in Gauge	Nozzle	17100.00	17100.00	1.000
N17A 2in Gauge	Nozzle	17100.00	17100.00	1.000
N19A 2in. GG	Nozzle	17100.00	17100.00	1.000
N19B 2in. GG	Nozzle	17100.00	17100.00	1.000
N20A 2in. GG	Nozzle	17100.00	17100.00	1.000
N20B 2in. GG	Nozzle	17100.00	17100.00	1.000
N6 10in. OIL LL	Nozzle	20000.00	20000.00	1.000
N2 6in. GAS OUT	Nozzle	17100.00	17100.00	1.000

Minimum 1.000

Stress ratios for Pressurized Vessel Elements (psi):

Description	Ambient	Operating	Ratio
	20000.00	20000.00	1.000
	20000.00	20000.00	1.000
	20000.00	20000.00	1.000
	20000.00	20000.00	1.000
	20000.00	20000.00	1.000

Minimum 1.000

Hoop Stress in Nozzle Wall during Pressure Test (psi):

Description	Ambient	Operating	Ratio
Firebox Tall	4011.47	26000.00	0.154
Firebox Small	1923.87	26000.00	0.074
N3:6in Outlet	417.77	22230.00	0.019
M2:24in ShellMW	3233.73	22230.00	0.145
N7 6in PSV	484.97	26000.00	0.019
N8A 4in Drain	378.47	22230.00	0.017
N9 4in OilDrain	378.47	22230.00	0.017

N10 4in Anode	797.86	22230.00	0.036
N13 2in PI	349.81	22230.00	0.016
N14A 2in T	349.81	22230.00	0.016
N16 2in LLSD	349.81	22230.00	0.016
N1 6in Inlet	484.97	26000.00	0.019
Dome 24in Shell	3233.73	22230.00	0.145
N8B 4in. DRAIN	378.47	22230.00	0.017
N22 2in. HLSD	349.81	22230.00	0.016
N4 6in. OIL OUT	417.77	22230.00	0.019
N11 4in. ANODE	797.86	22230.00	0.036
N12 4in. ANODE	797.86	22230.00	0.036
N14B 2in. THER	349.81	22230.00	0.016
N15 2in. THER.	349.81	22230.00	0.016
N23 2in. T-12	349.81	22230.00	0.016
N17B 2in Gauge	349.81	22230.00	0.016
M1:24	3233.73	22230.00	0.145
N18A 2 Gauge	349.81	22230.00	0.016
N5 10in Water	660.78	26000.00	0.025
N18B 2in Gauge	349.81	22230.00	0.016
N17A 2in Gauge	349.81	22230.00	0.016
N19A 2in. GG	349.81	22230.00	0.016
N19B 2in. GG	349.81	22230.00	0.016
N20A 2in. GG	349.81	22230.00	0.016
N20B 2in. GG	349.81	22230.00	0.016
N6 10in. OIL LL	1096.72	26000.00	0.042
N2 6in. GAS OUT	1069.17	22230.00	0.048

Elements Suitable for Internal Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length ft.	Outside Diameter in.	Corroded Thickness in.	Factor A	Factor B psi
10	20	No Calc	120	0.4375	0.00050637	7342.3
20	30	31.9861	120	0.25	0.00004	552.188
30	40	No Calc	120	0.3125	0.00036169	5244.5
40	50	No Calc	...	1.755	No Calc	No Calc
50	60	No Calc	24	0.25	0.0014468	13900.6

External Pressure Calculations:

From	To	External Actual T. in.	External Required T. in.	External Design Pressure psig	External M.A.W.P. psig
10	20	0.5625	0.1875	...	29.7431
20	30	0.375	No Calc	...	1.53385
30	40	0.4375	0.1875	...	15.1751
40	50	1.88	1.1564	...	No Calc
50	60	0.375	0.1875	...	160.886

Minimum 1.534

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners ft.	Allowable Length Bet. Stiffeners ft.	Ring Inertia Required in**4	Ring Inertia Available in**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	31.9861	No Calc	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	No Calc	No Calc	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

ASME Code, Section VIII Division 1, 2017

Elliptical Head From 10 to 20 Ext. Chart: CS-2 at 150 °F

Elastic Modulus from Chart: CS-2 at 150 °F : 0.290E+08 psi

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
0.438	120.00	274.29	0.0005064	7342.30

EMAP = B/(K0*D/t) = 7342.3042/(0.9 *274.2857) = 29.7431 psig

*Check the requirements of UG-33(a)(1) using P = 1.67 * External Design pressure for this head.*

Material UNS Number: K02700

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
= ((2*20000.0*1.0*0.4375)/(0.997*119.125+0.2*0.4375))/1.67
= 88.148 psig

Maximum Allowable External Pressure [MAEP]:
= min(MAEP, MAWP)
= min(29.74, 88.1479)
= 29.743 psig

Cylindrical Shell From 20 to 30 Ext. Chart: CS-2 at 150 °F

Elastic Modulus from Chart: CS-2 at 150 °F : 0.290E+08 psi

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
0.250	120.00	383.83	480.00	3.1986	0.0000381	552.19

EMAP = (4*B)/(3*(D/t)) = (4*552.1876)/(3*480.0) = 1.5339 psig

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
0.250	120.00	383.83	480.00	3.1986	0.0000381	552.19

EMAP = (4*B)/(3*(D/t)) = (4*552.1876)/(3*480.0) = 1.5339 psig

Elliptical Head From 30 to 40 Ext. Chart: CS-2 at 150 °F

Elastic Modulus from Chart: CS-2 at 150 °F : 0.290E+08 psi

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
0.312	120.00	384.00	0.0003617	5244.50

EMAP = B/(K0*D/t) = 5244.5029/(0.9 *384.0) = 15.1751 psig

*Check the requirements of UG-33(a)(1) using P = 1.67 * External Design pressure for this head.*

Material UNS Number: K02700

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
= ((2*20000.0*1.0*0.3125)/(0.997*119.375+0.2*0.3125))/1.67
= 62.844 psig

Maximum Allowable External Pressure [MAEP]:
= min(MAEP, MAWP)
= min(15.18, 62.8438)
= 15.175 psig

Elliptical Head From 50 to 60 Ext. Chart: CS-2 at 150 °F

Elastic Modulus from Chart: CS-2 at 150 °F : 0.290E+08 psi

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
0.250	24.00	96.00	0.0014468	13900.58

EMAP = B/(K0*D/t) = 13900.5781/(0.9 *96.0) = 160.8863 psig

*Check the requirements of UG-33(a)(1) using P = 1.67 * External Design pressure for this head.*

Material UNS Number: K02700

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
= ((2*20000.0*1.0*0.25)/(0.986*23.5+0.2*0.25))/1.67
= 257.861 psig

Maximum Allowable External Pressure [MAEP]:
= min(MAEP, MAWP)
= min(160.89, 257.8609)
= 160.886 psig

Input Values:

Wind Design Code	NBC-2015	
Design Wind Speed	70	mile/hr
Exposure Category	A, Open Terrain	
Importance Factor	1.0	
Roughness Classification	Moderately smooth	
Base Elevation	0	ft.
Percent Wind for Hydrotest	33.0	
Using User defined Wind Press. Vs Elev.	N	
Damping Factor (Beta) for Wind (Ope)	0.0080	
Damping Factor (Beta) for Wind (Empty)	0.0000	
Damping Factor (Beta) for Wind (Filled)	0.0000	
Height of Hill or Escarpment H or Hh	0	ft.
Distance Upwind of Crest Lh	0	ft.
Distance from Crest to the Vessel x	0	ft.
Type of Terrain (Hill, Escarpment)	Flat	

Calculated Values:

Gust Effect Factor	[Cg]	2.00
Force Coefficient	[Cf]	0.515
External Pressure Coefficient	[Cp]	1.000
Natural Frequency of Vessel (Operating)		33.000 Hz
Natural Frequency of Vessel (Empty)		33.000 Hz
Natural Frequency of Vessel (Test)		33.000 Hz

Equation to determine the Wind Pressure at level h [p(h)]:
= Iw * q * Ce(height,Exp) * Cg * Cp

Intermediate values for each element are shown below, Static Analysis:

Element	Ce	Cg	Iw	q
10 to 20	0.900	2.000	1.000	13.230
20 to 30	0.900	2.000	1.000	13.230
30 to 40	0.900	2.000	1.000	13.230
40 to 50	0.900	2.000	1.000	13.230
50 to 60	0.900	2.000	1.000	13.230

Height to diameter ratio was less than 4 and Fn > 1, therefore Cg = 2.

Wind Pressure on the first element [p]:
= Iw * q * Ce * Cg
= 1.0 * 13.23 * 0.9 * 2.0
= 23.814 psf

Force on the first element [F]:
= p * Wind Area * Cf
= 23.81 * 21.819 * 0.515
= 267.805 lb.

Wind Loads on Masses/Equipment/Piping

ID	Wind Area in²	Elevation ft.	Pressure psf	Force lb.
FIRETUBES	0.00	7.00	23.81	0.00

Wind Load Calculation:

From	To	Wind Height ft.	Wind Diameter ft.	Wind Area in²	Wind Pressure psf	Element Wind Load lb.
10	20	6.5625	12	3141.94	23.814	267.805
20	30	6.5625	12	51840	23.814	4418.62
30	40	6.5625	12	3136.05	23.814	267.303
40	50	5.91167	3.2	72.192	23.814	6.15333
50	60	1.31039	2.4	831.158	23.814	70.8443

Earthquake Load Calculation:

Input Values:

Seismic Design Code		ASCE/SEI 7-16
Seismic Load Reduction Scale Factor		0.700
Importance Factor		1.000
Table Value Fa		1.000
Table Value Fv		1.400
Max. Mapped Res. Acceleration	[SS]	1.000
Max. Eff. Ground Acceleration	[S]	0.400
Force Modification Factor R		3.000
Site Class		C
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	0.000
Force Factor		0.000
Consider Vertical Acceleration		No
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		0.000
User Value of Sd1 (used if > 0)		0.000

Seismic Analysis Results:

Sms = Fa * Ss = 1.0 * 1.0 = 1.0
Sm1 = Fv * S1 = 1.4 * 0.4 = 0.56
Sds = 2/3 * Sms = 2/3 * 1.0 = 0.667
Sd1 = 2/3 * Sm1 = 2/3 * 0.56 = 0.373

Check Approximate Fundamental Period from 12.8-7 [Ta]:
= Ct * hn^(x) where Ct = 0.020, x = 0.75 and hn = Structural Height (ft.)
= 0.020 * (11.5312^(0.75))
= 0.125 seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:
= (1/Natural Frequency) = (1/33.0)
= 0.030

Check the Value of T which is the smaller of Cu*Ta and T:
= Minimum Value of (1.4 * 0.125, 0.03) per 12.8.2
= 0.030

As the time period is < 0.06 second, use section 15.4.2.

Compute the Base Shear per equation 15.4-5, [V]:
= 0.3 * Sds * W * I
= 0.3 * 0.667 * 188602 * 1.0
= 37720.352 lb.

Final Base Shear, V = 26404.25 lb.

Earthquake Load Calculation:

From	To	Earthquake Height ft.	Earthquake Weight lb.	Element Ope	Load lb.

10	20	4.95312	37720.4	5268.66
20	Sadl	4.96875	37720.4	5285.28
Sadl	30	4.96875	37720.4	5285.28
20	30	4.96875	37720.4	5285.28
30	40	4.96354	37720.4	5279.74

Note:
The Earthquake Loads calculated and printed in the Earthquake Load calculation report have been factored by the input scalar/load reduction factor of: 0.700.

ASME Horizontal Vessel Analysis: Stresses for the Left Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Horizontal Vessel Stress Calculations : Operating Case

Input and Calculated Values:

Vessel Mean Radius	Rm	59.88	in.
Stiffened Vessel Length per 4.15.6	L	30.33	ft.
Distance from Saddle to Vessel tangent	a	50.00	in.
Saddle Width	b	18.00	in.
Saddle Bearing Angle	theta	154.00	degrees
Wear Plate Width	b1	25.00	in.
Wear Plate Bearing Angle	theta1	167.00	degrees
Wear Plate Thickness	tr	0.2500	in.
Wear Plate Allowable Stress	Sr	20000.00	psi
Inside Depth of Head	h2	2.49	ft.
Shell Allowable Stress used in Calculation		20000.00	psi
Head Allowable Stress used in Calculation		20000.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		125051.53	lb.

Horizontal Vessel Analysis Results:	Actual psi	Allowable psi
Long. Stress at Top of Midspan	7666.10	20000.00
Long. Stress at Bottom of Midspan	10807.75	20000.00
Long. Stress at Top of Saddles	11283.16	20000.00
Long. Stress at Bottom of Saddles	8052.98	20000.00
Tangential Shear in Shell	4167.00	16000.00
Circ. Stress at Horn of Saddle	24456.20	25000.00
Circ. Compressive Stress in Shell	1383.82	20000.00

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
= Ftr * (Ft/Num of Saddles + Z Force Load) * B / E
= 3.0 * (5030.7/2 + 0) * 78.75/111.0
= 5353.6 lb.

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
= max(Fl, Friction Load, Sum of X Forces) * B / Ls
= max(2244.42, 39452.4, 0) * 78.75/264.0
= 11768.5 lb.

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
= max(Fl, Friction Force, Sum of X Forces) * B / Ls
= max(26404.25, 39452.4, 0) * 78.75/264.0
= 11768.5 lb.

Saddle Reaction Force due to Earthquake Ft [Fst]:
= Ftr * (Ft/Num of Saddles + Z Force Load) * B / E
= 3.0 * (26404/2 + 0) * 78.75/111.0
= 28099.1 lb.

Load Combination Results for Q + Wind or Seismic [Q]:
= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
= 96952 + Max(11768, 5354, 11768, 28099)
= 125051.5 lb.

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	126730.12	lb.
Transverse Shear Load Saddle	13202.12	lb.
Longitudinal Shear Load Saddle	39452.40	lb.

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

K1 = 0.1689	K2 = 0.7629	K3 = 0.4476	K4 = 0.2834
K5 = 0.6649	K6 = 0.0294	K7 = 0.0221	K8 = 0.2958
K9 = 0.2094	K10 = 0.0324	K1* = 0.2919	K6p = 0.0229
K7p = 0.0172			

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -125052*4.17[1-(1-4.17/30.33+(4.99²-2.487²)/
(2*4.17*30.33))/(1+(4*2.49)/(3*30.33))]
= -81098.3 ft.lb.

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/(3L))-4a/L
= 125052*30.3/4(1+2(4.99²-2.487²)/(30.33²))/(1+(4*2.487)/
(3*30.333))-4*4.17/30.33
= 368576.3 ft.lb.

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
= P * Rm/(2t) - M2/(pi*Rm²t)
= 77.135 * 59.875/(2* 0.25) - 4422916/(pi*59.9²* 0.25)
= 7666.10 psi

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 77.135 * 59.875/(2 * 0.25) + 4422916/(pi * 59.9² * 0.25)
= 10807.75 psi

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 77.135*59.875/(2*0.25)--973179.8/(0.1689*pi*59.9²*0.25)
= 11283.16 psi

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 77.135*59.875/(2*0.25)+-973179.8/(0.2919*pi*59.9²*0.25)

= 8052.98 psi

Maximum Shear Force in the Saddle (4.15.5) [T]:
= Q(L-2a)/(L+(4*h2/3))
= 125052(30.33 - 2 * 4.17)/(30.33 + (4 * 2.49/3))
= 81759.0 lb.

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
= K2 * T / (Rm * t)
= 0.7629 * 81759.02/(59.875 * 0.25)
= 4167.00 psi

Decay Length (4.15.22) [x1,x2]:
= 0.78 * sqrt(Rm * t)
= 0.78 * sqrt(59.875 * 0.25)
= 3.018 in.

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
= -K5 * Q * k / (t * (b + X1 + X2))
= - 0.6649 * 125052 * 0.1/(0.25 * (18.0 + 3.02 + 3.02))
= -1383.82 psi

Effective reinforcing plate width (4.15.1) [B1]:
= min(b + 1.56 * sqrt(Rm * t), 2a)
= min(18.0 + 1.56 * sqrt(59.875 * 0.25), 2 * 50.0)
= 24.04 in.

Wear Plate/Shell Stress ratio (4.15.29) [eta]:
= min(Sr/S, 1)
= min(20000.0/20000.0, 1)
= 1.0000

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
= -K5 * Q * k / (B1(t + eta * tr))
= - 0.6649 * 125052 * 0.1/(24.036(0.25 + 1.0 * 0.25))
= -691.91 psi

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:
= -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)²)
= -125052/(4(0.25+ 1.0* 0.25)24.036) -
12*0.022*125052*59.875/(30.33(0.25+1.0*0.25)²)
= -24456.20 psi

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
= Alpha * Ls * (Design Temperature - Ambient Temperature)
= 0.000007 * 264.0 * (150.0 - 70.0)
= 0.139 in.

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	106.0000	in.
Baseplate Thickness	Bpthk	1.2500	in.
Baseplate Width	Bpwid	18.5000	in.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	0.3750	in.
Web Thickness	Webtk	0.3750	in.
Web Location	Webloc	Side	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	31.0293	0.2500	0.1250	7.7573	0.9697	0.1616
Wearplate	25.0000	0.2500	0.3750	6.2500	2.3438	0.9115
Web	0.3750	17.2500	9.1250	6.4688	59.0273	699.0293
BasePlate	18.5000	1.2500	18.3750	23.1250	424.9219	7810.9507
Totals	...	...	...	43.6011	487.2626	8511.0527

```
Value  C1 = Sumof(Ay)/Sumof(A)                =      11.1755  in.
Value   I = Sumof(Io) - C1*Sumof(Ay)          =    3065.6606  in**4
Value  As = Sumof(A) - Ashell                 =      35.8438  in²

K1 = (1+cos(beta)-0.5*sin(beta)² )/(pi-beta+sin(beta)*cos(beta)) = 0.2670

Fh = K1 * Q = 0.267 * 125051.531 = 33394.3906 lb.

Tension Stress, St = ( Fh/As )       =        931.6656  psi
Allowed Stress, Sa = 0.6 * Yield Str =      22800.0000  psi
```

Saddle Splitting Dimension [d]:

```
 = B - R * sin( theta )/ theta
 = 78.8 - 59.75 * sin( 1.3439 )/1.3439
 = 35.429 in.
```

```
Bending Moment, M  = Fh * d          =      98595.4688  ft.lb.

Bending Stress, Sb = ( M * C1 / I  ) =       4313.0068  psi
Allowed Stress, Sa = 2/3 * Yield Str =      25333.3340  psi
```

Minimum Thickness of Baseplate per Moss:

```
 = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))½
 = ( 3(125052 + 1679)18.5/( 2 * 106.0 * 25333.334 ))½
 = 1.144 in.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

```
 = Web Length / ( Nribs - 1 )
 = 117.6552/( 2 - 1 )
 = 117.655 in.
```

Baseplate Pressure Area [Ap]:

```
 = e * Bpwid / 2
 = 117.6552 * 18.5/2
 = 1088.310 in²
```

Axial Load [P]:

```
 = Ap * Bp
 = 1088.3 * 63.77
 = 69400.758 lb.
```

Area of the Rib and Web [Ar]:

```
 = Rib Area + Web Area
 = 6.609 + 22.06
 = 28.670 in²
```

Compressive Stress [Sc]:

```
 = P/Ar
 = 69400.8/28.6697
```

= 2420.699 psi

Check of Outside Ribs:
Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.3750	17.6250	9.1875	6.6094	60.7236	171.0950
Web	58.8276	0.3750	0.1875	22.0603	4.1363	0.2585
Values	...	...	...	28.6697	64.8599	171.3535

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * rl / 2
= 39452.4/(2 * 106.0) * 117.655 * 64.28/2
= 58644.613 ft.lb.

Compressive Allowable, KL/R < Cc (14.2514 < 122.736) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(14.25)²/(2 * 122.74²)) * 38000/
(5/3+3*(14.25)/(8* 122.74)-(14.25³)/(8*122.74³)
= 22072.238 psi

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * Distance Side/I)/Sba
= 2420.7/22072.24 + (703735 * 15.738/583.294)/25333.33
= 0.859

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	25000.00	psi
Bolt Corrosion Allowance	Bca	0.0000	in.
Distance from Bolts to Edge	Edgedis	18.0000	in.
Nominal Bolt Diameter	Bnd	1.2500	in.
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	18600.00	psi
Area Available in a Single Bolt	BltArea	0.9290	in²
Saddle Load QO (Weight)	QO	98631.0	lb.
Saddle Load QL (Wind/Seismic contribution)	QL	11768.5	lb.
Maximum Transverse Force	Ft	13202.1	lb.
Maximum Longitudinal Force	Fl	39452.4	lb.
Saddle Bolted to Steel Foundation		Yes	

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:
= 0.0 (QO > QL --> No Uplift in Longitudinal direction)

Bolt Area due to Shear Load [Bltarears]:
= Fl / (Stba * Nbolts)
= 39452.4/(25000.0 * 2.0)
= 0.7890 in²

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 6.56 * 13202.12 + 0.0

= 86638.93 ft.lb.

Eccentricity (e):
= Rmom / QO
= 1039667/98631.01
= 10.54 in. < Bplen/6 --> No Uplift in Transverse direction

Bolt Area due to Transverse Load [Bltareart]:
= 0 (No Uplift)

Required Area of a Single Bolt [Bltarear]:
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0, 0.789, 0.0]
= 0.7890 in²

ASME Horizontal Vessel Analysis: Stresses for the Right Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Input and Calculated Values:

Vessel Mean Radius	Rm	59.88	in.
Stiffened Vessel Length per 4.15.6	L	30.33	ft.
Distance from Saddle to Vessel tangent	a	50.00	in.
Saddle Width	b	18.00	in.
Saddle Bearing Angle	theta	154.00	degrees
Wear Plate Width	b1	25.00	in.
Wear Plate Bearing Angle	theta1	167.00	degrees
Wear Plate Thickness	tr	0.2500	in.
Wear Plate Allowable Stress	Sr	20000.00	psi
Inside Depth of Head	h2	2.49	ft.
Shell Allowable Stress used in Calculation		20000.00	psi
Head Allowable Stress used in Calculation		20000.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		121986.12	lb.

Horizontal Vessel Analysis Results:	Actual psi	Allowable psi
Long. Stress at Top of Midspan	7705.57	20000.00
Long. Stress at Bottom of Midspan	10768.28	20000.00
Long. Stress at Top of Saddles	11236.42	20000.00
Long. Stress at Bottom of Saddles	8080.02	20000.00
Tangential Shear in Shell	4064.01	16000.00
Circ. Stress at Horn of Saddle	23856.70	25000.00
Circ. Compressive Stress in Shell	1349.90	20000.00

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
= Ftr * (Ft/Num of Saddles + Z Force Load) * B / E

= 3.0 * (5030.7/2 + 0) * 78.75/111.0
= 5353.6 lb.

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
= max(Fl, Friction Load, Sum of X Forces) * B / Ls
= max(2244.42, 38226.24, 0) * 78.75/264.0
= 11402.7 lb.

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
= max(Fl, Friction Force, Sum of X Forces) * B / Ls
= max(26404.25, 38226.24, 0) * 78.75/264.0
= 11402.7 lb.

Saddle Reaction Force due to Earthquake Ft [Fst]:
= Ftr * (Ft/Num of Saddles + Z Force Load) * B / E
= 3.0 * (26404/2 + 0) * 78.75/111.0
= 28099.1 lb.

Load Combination Results for Q + Wind or Seismic [Q]:
= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
= 93887 + Max(11403, 5354, 11403, 28099)
= 121986.1 lb.

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	123664.71	lb.
Transverse Shear Load Saddle	13202.12	lb.
Longitudinal Shear Load Saddle	38226.24	lb.

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

K1 = 0.1689	K2 = 0.7629	K3 = 0.4476	K4 = 0.2834
K5 = 0.6649	K6 = 0.0294	K7 = 0.0221	K8 = 0.2958
K9 = 0.2094	K10 = 0.0324	K1* = 0.2919	K6p = 0.0229
K7p = 0.0172			

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -121986*4.17[1-(1-4.17/30.33+(4.99²-2.492²)/
(2*4.17*30.33))/(1+(4*2.49)/(3*30.33))]
= -79245.9 ft.lb.

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/(3L))-4a/L
= 121986*30.3/4(1+2(4.99²-2.492²)/(30.33²))/(1+(4*2.492)/
(3*30.333))-4*4.17/30.33
= 359315.2 ft.lb.

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
= P * Rm/(2t) - M2/(pi*Rm²t)
= 77.135 * 59.875/(2* 0.25) - 4311783/(pi*59.9²* 0.25)
= 7705.57 psi

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 77.135 * 59.875/(2 * 0.25) + 4311783/(pi * 59.9² * 0.25)
= 10768.28 psi

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 77.135*59.875/(2*0.25)--950950.5/(0.1689*pi*59.9²*0.25)
= 11236.42 psi

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 77.135*59.875/(2*0.25)+-950950.5/(0.2919*pi*59.9²*0.25)
= 8080.02 psi

Maximum Shear Force in the Saddle (4.15.5) [T]:
= Q(L-2a)/(L+(4*h2/3))
= 121986(30.33 - 2 * 4.17)/(30.33 + (4 * 2.49/3))
= 79738.4 lb.

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
= K2 * T / (Rm * t)
= 0.7629 * 79738.38/(59.875 * 0.25)
= 4064.01 psi

Decay Length (4.15.22) [x1,x2]:
= 0.78 * sqrt(Rm * t)
= 0.78 * sqrt(59.875 * 0.25)
= 3.018 in.

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
= -K5 * Q * k / (t * (b + X1 + X2))
= - 0.6649 * 121986 * 0.1/(0.25 * (18.0 + 3.02 + 3.02))
= -1349.90 psi

Effective reinforcing plate width (4.15.1) [B1]:
= min(b + 1.56 * sqrt(Rm * t), 2a)
= min(18.0 + 1.56 * sqrt(59.875 * 0.25), 2 * 50.0)
= 24.04 in.

Wear Plate/Shell Stress ratio (4.15.29) [eta]:
= min(Sr/S, 1)
= min(20000.0/20000.0, 1)
= 1.0000

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
= -K5 * Q * k / (B1(t + eta * tr))
= - 0.6649 * 121986 * 0.1/(24.036(0.25 + 1.0 * 0.25))
= -674.95 psi

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:
= -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)²)
= -121986/(4(0.25+ 1.0* 0.25)24.036) -
12*0.022*121986*59.875/(30.33(0.25+1.0*0.25)²)
= -23856.70 psi

Results for Vessel Ribs, Web and Base

Baseplate Length Bplen 106.0000 in.

Baseplate Thickness	Bpthk	1.2500	in.
Baseplate Width	Bpwid	18.5000	in.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	0.3750	in.
Web Thickness	Webtk	0.3750	in.
Web Location	Webloc	Side	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	31.0293	0.2500	0.1250	7.7573	0.9697	0.1616
Wearplate	25.0000	0.2500	0.3750	6.2500	2.3438	0.9115
Web	0.3750	17.2500	9.1250	6.4688	59.0273	699.0293
BasePlate	18.5000	1.2500	18.3750	23.1250	424.9219	7810.9507
Totals	...	...	...	43.6011	487.2626	8511.0527

Value C1 = Sumof(Ay)/Sumof(A) = 11.1755 in.
Value I = Sumof(Io) - C1*Sumof(Ay) = 3065.6606 in**4
Value As = Sumof(A) - Ashell = 35.8438 in²

K1 = (1+cos(beta)-0.5*sin(beta)²)/(pi-beta+sin(beta)*cos(beta)) = 0.2670

Fh = K1 * Q = 0.267 * 121986.125 = 32575.7871 lb.

Tension Stress, St = (Fh/As) = 908.8275 psi
Allowed Stress, Sa = 0.6 * Yield Str = 22800.0000 psi

Saddle Splitting Dimension [d]:
= B - R * sin(theta)/ theta
= 78.8 - 59.75 * sin(1.3439)/1.3439
= 35.429 in.

Bending Moment, M = Fh * d = 96178.5703 ft.lb.

Bending Stress, Sb = (M * C1 / I) = 4207.2812 psi
Allowed Stress, Sa = 2/3 * Yield Str = 25333.3340 psi

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))½
= (3(121986 + 1679)18.5/(2 * 106.0 * 25333.334))½
= 1.130 in.

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:
= Web Length / (Nribs - 1)
= 117.6552/(2 - 1)
= 117.655 in.

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2
= 117.6552 * 18.5/2
= 1088.310 in²

Axial Load [P]:
= Ap * Bp
= 1088.3 * 62.21
= 67699.523 lb.

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 6.609 + 22.06
= 28.670 in²

Compressive Stress [Sc]:
= P/Ar
= 67699.5/28.6697
= 2361.360 psi

Check of Outside Ribs:
Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.3750	17.6250	9.1875	6.6094	60.7236	171.0950
Web	58.8276	0.3750	0.1875	22.0603	4.1363	0.2585
Values	...	...	...	28.6697	64.8599	171.3535

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * rl / 2
= 38226.2/(2 * 106.0) * 117.655 * 64.28/2
= 56821.973 ft.lb.

Compressive Allowable, KL/R < Cc (14.2514 < 122.736) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(14.25)²/(2 * 122.74²)) * 38000/
(5/3+3*(14.25)/(8* 122.74)-(14.25³)/(8*122.74³)
= 22072.238 psi

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * Distance Side/I)/Sba
= 2361.36/22072.24 + (681864 * 15.738/583.294)/25333.33
= 0.833

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	25000.00	psi
Bolt Corrosion Allowance	Bca	0.0000	in.
Distance from Bolts to Edge	Edgedis	18.0000	in.
Nominal Bolt Diameter	Bnd	1.2500	in.
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	18600.00	psi
Area Available in a Single Bolt	BltArea	0.9290	in²
Saddle Load QO (Weight)	QO	95565.6	lb.
Saddle Load QL (Wind/Seismic contribution)	QL	11402.7	lb.
Maximum Transverse Force	Ft	13202.1	lb.
Maximum Longitudinal Force	Fl	39452.4	lb.
Saddle Bolted to Steel Foundation		Yes	

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:
= 0.0 (QO > QL --> No Uplift in Longitudinal direction)

Bolt Area due to Shear Load [Bltarears]:

= Fl / (Stba * Nbolts)
= 39452.4/(25000.0 * 2.0)
= 0.7890 in²

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 6.56 * 13202.12 + 0.0
= 86638.93 ft.lb.

Eccentricity (e):
= Rmom / QO
= 1039667/95565.6
= 10.88 in. < Bplen/6 --> No Uplift in Transverse direction

Bolt Area due to Transverse Load [Bltareart]:
= 0 (No Uplift)

Required Area of a Single Bolt [Bltarear]:
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0, 0.789, 0.0]
= 0.7890 in²

ASME Horizontal Vessel Analysis: Stresses for the Left Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Horizontal Vessel Stress Calculations : Test Case

Input and Calculated Values:

Vessel Mean Radius	Rm	59.88	in.
Stiffened Vessel Length per 4.15.6	L	30.33	ft.
Distance from Saddle to Vessel tangent	a	50.00	in.
Saddle Width	b	18.00	in.
Saddle Bearing Angle	theta	154.00	degrees
Wear Plate Width	b1	25.00	in.
Wear Plate Bearing Angle	theta1	167.00	degrees
Wear Plate Thickness	tr	0.2500	in.
Wear Plate Allowable Stress	Sr	20000.00	psi
Inside Depth of Head	h2	2.49	ft.
Shell Allowable Stress used in Calculation		36100.00	psi
Head Allowable Stress used in Calculation		36100.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		101632.79	lb.

Horizontal Vessel Analysis Results:	Actual psi	Allowable psi
Long. Stress at Top of Midspan	10717.76	36100.00
Long. Stress at Bottom of Midspan	13271.06	36100.00
Long. Stress at Top of Saddles	13657.44	36100.00
Long. Stress at Bottom of Saddles	11032.18	36100.00
Tangential Shear in Shell	3386.63	28880.00
Circ. Stress at Horn of Saddle	19876.22	54150.00
Circ. Compressive Stress in Shell	1124.67	36100.00

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
= Ftr * (Ft/Num of Saddles + Z Force Load) * B / E
= 3.0 * (1660.1/2 + 0) * 78.75/111.0
= 1766.7 lb.

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
= max(Fl, Friction Load, Sum of X Forces) * B / Ls
= max(740.66, 0.0, 0) * 78.75/264.0
= 220.9 lb.

Load Combination Results for Q + Wind or Seismic [Q]:
= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
= 99866 + Max(221, 1767, 0, 0)
= 101632.8 lb.

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	103311.38	lb.
Transverse Shear Load Saddle	830.07	lb.
Longitudinal Shear Load Saddle	740.66	lb.

Hydrostatic Test Pressure at center of Vessel: 100.162 psig

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

K1 = 0.1689	K2 = 0.7629	K3 = 0.4476	K4 = 0.2834
K5 = 0.6649	K6 = 0.0294	K7 = 0.0221	K8 = 0.2958
K9 = 0.2094	K10 = 0.0324	K1* = 0.2919	K6p = 0.0229
K7p = 0.0172			

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:

```
 = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
 = -101633*4.17[1-(1-4.17/30.33+(4.99²-2.487²)/
   (2*4.17*30.33))/(1+(4*2.49)/(3*30.33))]
 = -65910.8 ft.lb.
```

Moment per Equation 4.15.4 [M2]:

```
 = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
 = 101633*30.3/4(1+2(4.99²-2.487²)/(30.33²))/(1+(4*2.487)/
   (3*30.333))-4*4.17/30.33
 = 299552.0 ft.lb.
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

```
 = P * Rm/(2t) - M2/(pi*Rm²t)
 = 100.162 * 59.875/(2* 0.25) - 3594624/(pi*59.9²* 0.25)
 = 10717.76 psi
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

```
 = P * Rm/(2t) + M2/(pi * Rm² * t)
 = 100.162 * 59.875/(2 * 0.25) + 3594624/(pi * 59.9² * 0.25 )
 = 13271.06 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:

```
 = P * Rm/(2t) - M1/(K1*pi*Rm²t)
 = 100.162*59.875/(2*0.25)--790929.6/(0.1689*pi*59.9²*0.25)
 = 13657.44 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:

```
 = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
 = 100.162*59.875/(2*0.25)+-790929.6/(0.2919*pi*59.9²*0.25)
 = 11032.18 psi
```

Maximum Shear Force in the Saddle (4.15.5) [T]:

```
 = Q(L-2a)/(L+(4*h2/3))
 = 101633( 30.33 - 2 * 4.17)/(30.33 + ( 4 * 2.49/3))
 = 66447.8 lb.
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:

= K2 * T / (Rm * t)
= 0.7629 * 66447.78/(59.875 * 0.25)
= 3386.63 psi

Decay Length (4.15.22) [x1,x2]:
= 0.78 * sqrt(Rm * t)
= 0.78 * sqrt(59.875 * 0.25)
= 3.018 in.

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
= -K5 * Q * k / (t * (b + X1 + X2))
= - 0.6649 * 101633 * 0.1/(0.25 * (18.0 + 3.02 + 3.02))
= -1124.67 psi

Effective reinforcing plate width (4.15.1) [B1]:
= min(b + 1.56 * sqrt(Rm * t), 2a)
= min(18.0 + 1.56 * sqrt(59.875 * 0.25), 2 * 50.0)
= 24.04 in.

Wear Plate/Shell Stress ratio (4.15.29) [eta]:
= 1.0000 Materials are the same, test case

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
= -K5 * Q * k / (B1(t + eta * tr))
= - 0.6649 * 101633 * 0.1/(24.036(0.25 + 1.0 * 0.25))
= -562.33 psi

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:
= -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)²)
= -101633/(4(0.25+ 1.0* 0.25)24.036) -
12*0.022*101633*59.875/(30.33(0.25+1.0*0.25)²)
= -19876.22 psi

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	106.0000	in.
Baseplate Thickness	Bpthk	1.2500	in.
Baseplate Width	Bpwid	18.5000	in.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	0.3750	in.
Web Thickness	Webtk	0.3750	in.
Web Location	Webloc	Side	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	31.0293	0.2500	0.1250	7.7573	0.9697	0.1616
Wearplate	25.0000	0.2500	0.3750	6.2500	2.3438	0.9115
Web	0.3750	17.2500	9.1250	6.4688	59.0273	699.0293
BasePlate	18.5000	1.2500	18.3750	23.1250	424.9219	7810.9507
Totals	...	...	...	43.6011	487.2626	8511.0527

Value C1 = Sumof(Ay)/Sumof(A) = 11.1755 in.
Value I = Sumof(Io) - C1*Sumof(Ay) = 3065.6606 in**4
Value As = Sumof(A) - Ashell = 35.8438 in²

K1 = (1+cos(beta)-0.5*sin(beta)²)/(pi-beta+sin(beta)*cos(beta)) = 0.2670

Fh = K1 * Q = 0.267 * 101632.789 = 27140.5312 lb.

Tension Stress, St = (Fh/As) = 757.1901 psi
Allowed Stress, Sa = 0.6 * Yield Str = 22800.0000 psi

Saddle Splitting Dimension [d]:
= B - R * sin(theta)/ theta
= 78.8 - 59.75 * sin(1.3439)/1.3439
= 35.429 in.

Bending Moment, M = Fh * d = 80131.2188 ft.lb.

Bending Stress, Sb = (M * C1 / I) = 3505.2979 psi
Allowed Stress, Sa = 2/3 * Yield Str = 25333.3340 psi

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))½
= (3(101633 + 1679)18.5/(2 * 106.0 * 25333.334))½
= 1.033 in.

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:
= Web Length / (Nribs - 1)
= 117.6552/(2 - 1)
= 117.655 in.

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2
= 117.6552 * 18.5/2
= 1088.310 in²

Axial Load [P]:
= Ap * Bp
= 1088.3 * 51.83
= 56403.891 lb.

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 6.609 + 22.06
= 28.670 in²

Compressive Stress [Sc]:
= P/Ar
= 56403.9/28.6697
= 1967.368 psi

Check of Outside Ribs:
Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.3750	17.6250	9.1875	6.6094	60.7236	171.0950
Web	58.8276	0.3750	0.1875	22.0603	4.1363	0.2585
Values	...	...	...	28.6697	64.8599	171.3535

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * rl / 2
= 740.7/(2 * 106.0) * 117.655 * 64.28/2
= 1100.962 ft.lb.

Compressive Allowable, KL/R < Cc (14.2514 < 122.736) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(14.25)²/(2 * 122.74²)) * 38000/
(5/3+3*(14.25)/(8* 122.74)-(14.25³)/(8*122.74³)
= 22072.238 psi

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * Distance Side/I)/Sba
= 1967.37/22072.24 + (13211.54 * 15.738/583.294)/25333.33
= 0.103

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	25000.00	psi
Bolt Corrosion Allowance	Bca	0.0000	in.
Distance from Bolts to Edge	Edgedis	18.0000	in.
Nominal Bolt Diameter	Bnd	1.2500	in.
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	18600.00	psi
Area Available in a Single Bolt	BltArea	0.9290	in²
Saddle Load QO (Weight)	QO	101544.7	lb.
Saddle Load QL (Wind/Seismic contribution)	QL	220.9	lb.
Maximum Transverse Force	Ft	830.1	lb.
Maximum Longitudinal Force	Fl	740.7	lb.
Saddle Bolted to Steel Foundation		Yes	

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:
= 0.0 (QO > QL --> No Uplift in Longitudinal direction)

Bolt Area due to Shear Load [Bltarears]:
= Fl / (Stba * Nbolts)
= 740.66/(25000.0 * 2.0)
= 0.0148 in²

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 6.56 * 830.07 + 0.0
= 5447.33 ft.lb.

Eccentricity (e):
= Rmom / QO
= 65367.95/101544.67
= 0.64 in. < Bplen/6 --> No Uplift in Transverse direction

Bolt Area due to Transverse Load [Bltareart]:
= 0 (No Uplift)

Required Area of a Single Bolt [Bltarear]:
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0, 0.0148, 0.0]
= 0.0148 in²

ASME Horizontal Vessel Analysis: Stresses for the Right Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Input and Calculated Values:

Vessel Mean Radius	Rm	59.88	in.
Stiffened Vessel Length per 4.15.6	L	30.33	ft.
Distance from Saddle to Vessel tangent	a	50.00	in.
Saddle Width	b	18.00	in.
Saddle Bearing Angle	theta	154.00	degrees
Wear Plate Width	b1	25.00	in.
Wear Plate Bearing Angle	theta1	167.00	degrees
Wear Plate Thickness	tr	0.2500	in.
Wear Plate Allowable Stress	Sr	20000.00	psi
Inside Depth of Head	h2	2.49	ft.
Shell Allowable Stress used in Calculation		36100.00	psi
Head Allowable Stress used in Calculation		36100.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		99299.38	lb.

Horizontal Vessel Analysis Results:	Actual psi	Allowable psi
Long. Stress at Top of Midspan	10747.85	36100.00
Long. Stress at Bottom of Midspan	13240.97	36100.00
Long. Stress at Top of Saddles	13622.04	36100.00
Long. Stress at Bottom of Saddles	11052.67	36100.00
Tangential Shear in Shell	3308.20	28880.00
Circ. Stress at Horn of Saddle	19419.88	54150.00
Circ. Compressive Stress in Shell	1098.85	36100.00

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
= Ftr * (Ft/Num of Saddles + Z Force Load) * B / E
= 3.0 * (1660.1/2 + 0) * 78.75/111.0
= 1766.7 lb.

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
= max(Fl, Friction Load, Sum of X Forces) * B / Ls
= max(740.66, 0.0, 0) * 78.75/264.0
= 220.9 lb.

Load Combination Results for Q + Wind or Seismic [Q]:
= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
= 97533 + Max(221, 1767, 0, 0)
= 99299.4 lb.

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	100977.97	lb.

Transverse Shear Load Saddle 830.07 lb.
Longitudinal Shear Load Saddle 740.66 lb.

Hydrostatic Test Pressure at center of Vessel: 100.162 psig

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

K1 = 0.1689 K2 = 0.7629 K3 = 0.4476 K4 = 0.2834
K5 = 0.6649 K6 = 0.0294 K7 = 0.0221 K8 = 0.2958
K9 = 0.2094 K10 = 0.0324 K1* = 0.2919 K6p = 0.0229
K7p = 0.0172

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -99299*4.17[1-(1-4.17/30.33+(4.99²-2.492²)/
(2*4.17*30.33))/(1+(4*2.49)/(3*30.33))]
= -64507.9 ft.lb.

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/(3L))-4a/L
= 99299*30.3/4(1+2(4.99²-2.492²)/(30.33²))/(1+(4*2.492)/
(3*30.333))-4*4.17/30.33
= 292490.5 ft.lb.

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
= P * Rm/(2t) - M2/(pi*Rm²t)
= 100.162 * 59.875/(2* 0.25) - 3509886/(pi*59.9²* 0.25)
= 10747.85 psi

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 100.162 * 59.875/(2 * 0.25) + 3509886/(pi * 59.9² * 0.25)
= 13240.97 psi

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 100.162*59.875/(2*0.25)--774094.6/(0.1689*pi*59.9²*0.25)
= 13622.04 psi

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 100.162*59.875/(2*0.25)+-774094.6/(0.2919*pi*59.9²*0.25)
= 11052.67 psi

Maximum Shear Force in the Saddle (4.15.5) [T]:
= Q(L-2a)/(L+(4*h2/3))
= 99299(30.33 - 2 * 4.17)/(30.33 + (4 * 2.49/3))
= 64908.8 lb.

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
= K2 * T / (Rm * t)
= 0.7629 * 64908.79/(59.875 * 0.25)

= 3308.20 psi

Decay Length (4.15.22) [x1,x2]:
= 0.78 * sqrt(Rm * t)
= 0.78 * sqrt(59.875 * 0.25)
= 3.018 in.

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
= -K5 * Q * k / (t * (b + X1 + X2))
= - 0.6649 * 99299 * 0.1/(0.25 * (18.0 + 3.02 + 3.02))
= -1098.85 psi

Effective reinforcing plate width (4.15.1) [B1]:
= min(b + 1.56 * sqrt(Rm * t), 2a)
= min(18.0 + 1.56 * sqrt(59.875 * 0.25), 2 * 50.0)
= 24.04 in.

Wear Plate/Shell Stress ratio (4.15.29) [eta]:
= 1.0000 Materials are the same, test case

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
= -K5 * Q * k / (B1(t + eta * tr))
= - 0.6649 * 99299 * 0.1/(24.036(0.25 + 1.0 * 0.25))
= -549.42 psi

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:
= -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)²)
= -99299/(4(0.25+ 1.0* 0.25)24.036) -
12*0.022*99299*59.875/(30.33(0.25+1.0*0.25)²)
= -19419.88 psi

Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	106.0000	in.
Baseplate Thickness	Bpthk	1.2500	in.
Baseplate Width	Bpwid	18.5000	in.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	0.3750	in.
Web Thickness	Webtk	0.3750	in.
Web Location	Webloc	Side	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	31.0293	0.2500	0.1250	7.7573	0.9697	0.1616
Wearplate	25.0000	0.2500	0.3750	6.2500	2.3438	0.9115
Web	0.3750	17.2500	9.1250	6.4688	59.0273	699.0293
BasePlate	18.5000	1.2500	18.3750	23.1250	424.9219	7810.9507
Totals	...	...	...	43.6011	487.2626	8511.0527

Value C1 = Sumof(Ay)/Sumof(A)	=	11.1755	in.
Value I = Sumof(Io) - C1*Sumof(Ay)	=	3065.6606	in**4
Value As = Sumof(A) - Ashell	=	35.8438	in²

K1 = (1+cos(beta)-0.5*sin(beta)²)/(pi-beta+sin(beta)*cos(beta)) = 0.2670

Fh = K1 * Q = 0.267 * 99299.383 = 26517.4062 lb.

```
Tension Stress, St = ( Fh/As )       =        739.8056  psi
Allowed Stress, Sa = 0.6 * Yield Str =      22800.0000  psi
```

Saddle Splitting Dimension [d]:

```
 = B - R * sin( theta )/ theta
 = 78.8 - 59.75 * sin( 1.3439 )/1.3439
 = 35.429 in.
```

```
Bending Moment, M  = Fh * d          =      78291.4688  ft.lb.

Bending Stress, Sb = ( M * C1 / I  ) =       3424.8191  psi
Allowed Stress, Sa = 2/3 * Yield Str =      25333.3340  psi
```

Minimum Thickness of Baseplate per Moss:

```
 = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))½
 = ( 3(99299 + 1679)18.5/( 2 * 106.0 * 25333.334 ))½
 = 1.022 in.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

```
 = Web Length / ( Nribs - 1 )
 = 117.6552/( 2 - 1 )
 = 117.655 in.
```

Baseplate Pressure Area [Ap]:

```
 = e * Bpwid / 2
 = 117.6552 * 18.5/2
 = 1088.310 in²
```

Axial Load [P]:

```
 = Ap * Bp
 = 1088.3 * 50.64
 = 55108.902 lb.
```

Area of the Rib and Web [Ar]:

```
 = Rib Area + Web Area
 = 6.609 + 22.06
 = 28.670 in²
```

Compressive Stress [Sc]:

```
 = P/Ar
 = 55108.9/28.6697
 = 1922.199 psi
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.3750	17.6250	9.1875	6.6094	60.7236	171.0950
Web	58.8276	0.3750	0.1875	22.0603	4.1363	0.2585
Values	...	...	...	28.6697	64.8599	171.3535

Bending Moment [Rm]:

```
 = Fl /( 2 * Bplen ) * e * rl / 2
 = 740.7/( 2 * 106.0 ) * 117.655 * 64.28/2
 = 1100.962 ft.lb.
```

Compressive Allowable, KL/R < Cc (14.2514 < 122.736) per AISC E2-1 [Sca]:

= (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(14.25)²/(2 * 122.74²)) * 38000/
(5/3+3*(14.25)/(8* 122.74)-(14.25³)/(8*122.74³)
= 22072.238 psi

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * Distance Side/I)/Sba
= 1922.2/22072.24 + (13211.54 * 15.738/583.294)/25333.33
= 0.101

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	25000.00	psi
Bolt Corrosion Allowance	Bca	0.0000	in.
Distance from Bolts to Edge	Edgedis	18.0000	in.
Nominal Bolt Diameter	Bnd	1.2500	in.
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	18600.00	psi
Area Available in a Single Bolt	BltArea	0.9290	in²
Saddle Load QO (Weight)	QO	99211.3	lb.
Saddle Load QL (Wind/Seismic contribution)	QL	220.9	lb.
Maximum Transverse Force	Ft	830.1	lb.
Maximum Longitudinal Force	Fl	740.7	lb.
Saddle Bolted to Steel Foundation		Yes	

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:
= 0.0 (QO > QL --> No Uplift in Longitudinal direction)

Bolt Area due to Shear Load [Bltarears]:
= Fl / (Stba * Nbolts)
= 740.66/(25000.0 * 2.0)
= 0.0148 in²

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 6.56 * 830.07 + 0.0
= 5447.33 ft.lb.

Eccentricity (e):
= Rmom / QO
= 65367.95/99211.27
= 0.66 in. < Bplen/6 --> No Uplift in Transverse direction

Bolt Area due to Transverse Load [Bltareart]:
= 0 (No Uplift)

Required Area of a Single Bolt [Bltarear]:
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0, 0.0148, 0.0]
= 0.0148 in²

INPUT VALUES, Nozzle Description: Firebox Tall From : 10

Pressure for Reinforcement Calculations	P	77.187	psig
Temperature for Internal Pressure	Temp	150	°F
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	20000.00	psi
Shell Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Elliptical Head	D	118.8750	in.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	0.5625	in.
Head Internal Corrosion Allowance	c	0.1250	in.
Head External Corrosion Allowance	co	0.0000	in.

Note : User defined Limit(s) of Reinforcement specified below:

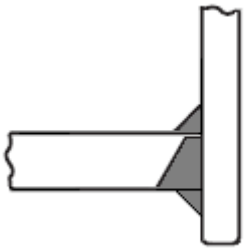
Physical Maximum for Diameter Limit	Dmax	90.5000	in.
Distance from Head Centerline	L1	24.0000	in.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material		SA-516 70	
Material UNS Number		K02700	
Material Specification/Type		Plate	
Allowable Stress at Temperature	Sn	20000.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		49.5000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.7500	in.
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	3.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.3750	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.5625	in.
Inside Projection	h	1.2300	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, with Inside projection

Note : Checking Nozzle in the Meridional direction.

Reinforcement CALCULATION, Description: Firebox Tall

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation          49.500  in.
Actual Thickness Used in Calculation                  0.750  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Elliptical Head, Tr [Int. Press]
```
 = (P*D*K)/(2*Sv*E-0.2*P) Appendix 1-4(c)
 = (77.19*119.125*0.997)/( 2*20000.0*1.0-0.2*77.19)
 = 0.2293 in.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
 = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
 = (77.19*24.75)/(20000*1.0+0.4*77.19)
 = 0.0954 in.
```

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    94.6521  in.
Parallel to Vessel Wall, opening length              d    47.3261  in.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.0938  in.
Normal to Vessel Wall, Inward                             1.0938  in.
```

Weld Strength Reduction Factor [fr1]:
```
 = min( 1, Sn/Sv )
 = min( 1, 20000.0/20000.0 )
 = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
 = min( 1, Sn/Sv )
 = min( 1, 20000.0/20000.0 )
 = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
 = min( fr2, fr4 )
 = min( 1.0, 1.0 )
 = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5	Design	External	Mapnc

Area Required	Ar	11.572	NA	NA
Area in Shell	A1	9.199	NA	NA
Area in Nozzle Wall	A2	1.159	NA	NA
Area in Inward Nozzle	A3	1.094	NA	NA
Area in Welds	A41+A42+A43	0.141	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	11.592	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 72.97 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (50.4637*0.2293*1.0+2*0.625*0.2293*1.0*(1-1.0))
= 11.572 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 44.188(1.0 * 0.4375 - 1.0 * 0.229) - 2 * 0.625
(1.0 * 0.4375 - 1.0 * 0.2293) * (1 - 1.0)
= 9.199 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 1.094)(0.625 - 0.0954)1.0
= 1.159 in²

Area Available in Inward Nozzle [A3]:
= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.5 * (1.0938) * 1.0
= 1.094 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.375² * 1.0 + (0.0)² * 1.0
= 0.141 in²

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.562, tr = 0.229, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.524, Temp. Reduction = 53 °F

Min Metal Temp. w/o impact per UCS-66, Curve B 0 °F
Min Metal Temp. at Required thickness (UCS 66.1) -53 °F
Min Metal Temp. w/o impact per UG-20(f) -20 °F

Governing MDMT of all the sub-joints of this Junction : -53 °F

Weld Size Calculations, Description: Firebox Tall

Intermediate Calc. for nozzle/shell Welds Tmin 0.5000 in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.2500 = Min per Code	0.2651 = 0.7 * Wo in.

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

Weld Load [W]:
```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, (11.5723 - 9.1992 + 2 * 0.625 * 1.0 *
   (1.0 * 0.4375 - 0.2293 ) )20000)
 = 52667.83 lb.
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 1.1586 + 0.0 + 0.1406 - 0.0 * 1.0 ) * 20000
 = 25983.74 lb.
```

Weld Load [W2]:
```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 1.1586 + 1.0938 + 0.1406 + ( 0.5469 ) ) * 20000
 = 58796.24 lb.
```

Weld Load [W3]:
```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = ( 1.1586 + 1.0938 + 0.1406 + 0.0 + ( 0.5469 ) ) * 20000
 = 58796.24 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 ) * 51.7711 * 0.375 * 0.49 * 20000
 = 298858. lb.
```

Shear, Nozzle Wall [Snw]:
```
 = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
 = (3.1416 * 25.5587) * ( 0.75 - 0.125 ) * 0.7 * 20000
 = 702581. lb.
```

Tension, Shell Groove Weld [Tngw]:
```
 = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
 = ( 3.1416/2.0 ) * 51.7711 * ( 0.5625 - 0.125 ) * 0.74 * 20000
 = 526559. lb.
```

Strength of Failure Paths:

```
 PATH11 = ( SONW + SNW ) = ( 298858 + 702581 ) = 1001439 lb.
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
        = ( 298858 + 0 + 526559 + 0 ) = 825416 lb.
 PATH33 = ( Sonw + Tngw + Sinw )
        = ( 298858 + 526559 + 0 ) = 825416 lb.
```

Summary of Failure Path Calculations:
```
Path 1-1 = 1001438 lb., must exceed W = 52667 lb. or W1 = 25983 lb.
Path 2-2 = 825416 lb., must exceed W = 52667 lb. or W2 = 58796 lb.
Path 3-3 = 825416 lb., must exceed W = 52667 lb. or W3 = 58796 lb.
```

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 77.187 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: Firebox Tall

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation 49.500 in.
Actual Thickness Used in Calculation 0.750 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Elliptical Head, Tr [Int. Press]
= (P*D*K)/(2*Sv*E-0.2*P) Appendix 1-4(c)
= (77.19*119.125*0.997)/(2*20000.0*1.0-0.2*77.19)
= 0.2293 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= (77.19*24.75)/(20000*1.0+0.4*77.19)
= 0.0954 in.

UG-40, Limits of Reinforcement : [Internal Pressure]
Parallel to Vessel Wall (Diameter Limit) Dl 90.5000 in.
Parallel to Vessel Wall, opening length d 45.2500 in.
Normal to Vessel Wall (Thickness Limit), no pad Tlnp 1.0938 in.
Normal to Vessel Wall, Inward 1.0938 in.

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	11.065	NA	NA
Area in Shell	A1	8.796	NA	NA
Area in Nozzle Wall	A2	1.159	NA	NA
Area in Inward Nozzle	A3	1.094	NA	NA
Area in Welds	A41+A42+A43	0.141	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	11.189	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (48.25*0.2293*1.0+2*0.625*0.2293*1.0*(1-1.0))
= 11.065 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)

= 42.25(1.0 * 0.4375 - 1.0 * 0.229) - 2 * 0.625
(1.0 * 0.4375 - 1.0 * 0.2293) * (1 - 1.0)
= 8.796 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 1.094)(0.625 - 0.0954)1.0
= 1.159 in²

Area Available in Inward Nozzle [A3]:
= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.5 * (1.0938) * 1.0
= 1.094 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.375² * 1.0 + (0.0)² * 1.0
= 0.141 in²

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

Wall Thickness for Internal/External pressures ta = 0.2204 in.
Wall Thickness per UG16(b), tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure trb1 = 0.3543 in.
Wall Thickness tb1 = max(trb1, tr16b) = 0.3543 in.
Wall Thickness tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45 tb3 = 0.4530 in.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[0.453, max(0.3543, 0.1875)]
= 0.3543 in.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(0.2204, 0.3543)
= 0.3543 in.

Available Nozzle Neck Thickness = 0.7500 in. --> OK

Weld Size Calculations, Description: Firebox Tall

Intermediate Calc. for nozzle/shell Welds Tmin 0.5000 in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.2500 = Min per Code	0.2651 = 0.7 * Wo in.

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (11.0647 - 8.7956 + 2 * 0.625 * 1.0 *
(1.0 * 0.4375 - 0.2293))20000)
= 50585.77 lb.

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv

= (1.1586 + 0.0 + 0.1406 - 0.0 * 1.0) * 20000
= 25983.74 lb.

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (1.1586 + 1.0938 + 0.1406 + (0.5469)) * 20000
= 58796.24 lb.

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (1.1586 + 1.0938 + 0.1406 + 0.0 + (0.5469)) * 20000
= 58796.24 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) * 49.5 * 0.375 * 0.49 * 20000
= 285747. lb.

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 24.4375) * (0.75 - 0.125) * 0.7 * 20000
= 671761. lb.

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 49.5 * (0.5625 - 0.125) * 0.74 * 20000
= 503460. lb.

Strength of Failure Paths:

PATH11 = (SONW + SNW) = (285747 + 671761) = 957508 lb.
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (285747 + 0 + 503460 + 0) = 789207 lb.
PATH33 = (Sonw + Tngw + Sinw)
= (285747 + 503460 + 0) = 789207 lb.

Summary of Failure Path Calculations:
Path 1-1 = 957508 lb., must exceed W = 50585 lb. or W1 = 25983 lb.
Path 2-2 = 789207 lb., must exceed W = 50585 lb. or W2 = 58796 lb.
Path 3-3 = 789207 lb., must exceed W = 50585 lb. or W3 = 58796 lb.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 77.187 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 8.9820 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 12.5590 in.

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

INPUT VALUES, Nozzle Description: Firebox Small From : 10

Pressure for Reinforcement Calculations	P	77.187	psig
Temperature for Internal Pressure	Temp	150	°F
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	20000.00	psi
Shell Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Elliptical Head	D	118.8750	in.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	0.5625	in.
Head Internal Corrosion Allowance	c	0.1250	in.
Head External Corrosion Allowance	co	0.0000	in.

Note : User defined Limit(s) of Reinforcement specified below:

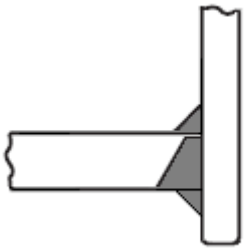
Physical Maximum for Diameter Limit	Dmax	33.8750	in.
Distance from Head Centerline	L1	24.0000	in.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material		SA-516 70	
Material UNS Number		K02700	
Material Specification/Type		Plate	
Allowable Stress at Temperature	Sn	20000.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		24.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.7500	in.
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	10.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.3750	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.5625	in.
Inside Projection	h	1.0000	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, with Inside projection

Note : Checking Nozzle in the Meridional direction.

Reinforcement CALCULATION, Description: Firebox Small

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	24.000	in.
Actual Thickness Used in Calculation	0.750	in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Elliptical Head, Tr [Int. Press]
= (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
= (77.19*0.898*119.125)/(2 *20000.0*1.0-0.2*77.19)
= 0.2066 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= (77.19*12.0)/(20000*1.0+0.4*77.19)
= 0.0462 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

Parallel to Vessel Wall (Diameter Limit)	Dl	34.8161	in.
Parallel to Vessel Wall, opening length	d	17.4081	in.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	1.0938	in.
Normal to Vessel Wall, Inward		0.8750	in.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 20000.0/20000.0)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 20000.0/20000.0)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5	Design	External	Mapnc

Area Required	Ar	4.830	NA	NA
Area in Shell	A1	2.641	NA	NA
Area in Nozzle Wall	A2	1.273	NA	NA
Area in Inward Nozzle	A3	0.875	NA	NA
Area in Welds	A41+A42+A43	0.141	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	4.930	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 76.65 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (23.3821*0.2066*1.0+2*0.625*0.2066*1.0*(1-1.0))
= 4.830 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 11.434(1.0 * 0.4375 - 1.0 * 0.207) - 2 * 0.625
(1.0 * 0.4375 - 1.0 * 0.2066) * (1 - 1.0)
= 2.641 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 1.094)(0.625 - 0.0462)1.0/sin(83.9)
= 1.273 in²

Note: See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Inward Nozzle [A3]:
= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.5 * (0.875) * 1.0
= 0.875 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.375² * 1.0 + (0.0)² * 1.0
= 0.141 in²

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.562, tr = 0.207, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.472, Temp. Reduction = 65 °F

Min Metal Temp. w/o impact per UCS-66, Curve B 0 °F
Min Metal Temp. at Required thickness (UCS 66.1) -55 °F
Min Metal Temp. w/o impact per UG-20(f) -20 °F

Governing MDMT of all the sub-joints of this Junction : -55 °F

Weld Size Calculations, Description: Firebox Small

Intermediate Calc. for nozzle/shell Welds Tmin 0.5000 in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.2500 = Min per Code	0.2651 = 0.7 * Wo in.

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (4.8296 - 2.6407 + 2 * 0.625 * 1.0 *
(1.0 * 0.4375 - 0.2066))20000)
= 49551.70 lb.

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (1.2733 + 0.0 + 0.1406 - 0.0 * 1.0) * 20000
= 28279.42 lb.

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (1.2733 + 0.875 + 0.1406 + (0.5469)) * 20000
= 56716.92 lb.

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (1.2733 + 0.875 + 0.1406 + 0.0 + (0.5469)) * 20000
= 56716.92 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) * 24.6668 * 0.375 * 0.49 * 20000
= 142393. lb.

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 12.0122) * (0.75 - 0.125) * 0.7 * 20000
= 330203. lb.

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 24.6668 * (0.5625 - 0.125) * 0.74 * 20000
= 250884. lb.

Strength of Failure Paths:

PATH11 = (SONW + SNW) = (142393 + 330203) = 472596 lb.
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (142393 + 0 + 250884 + 0) = 393277 lb.
PATH33 = (Sonw + Tngw + Sinw)
= (142393 + 250884 + 0) = 393277 lb.

Summary of Failure Path Calculations:
Path 1-1 = 472596 lb., must exceed W = 49551 lb. or W1 = 28279 lb.
Path 2-2 = 393276 lb., must exceed W = 49551 lb. or W2 = 56716 lb.

Path 3-3 = 393276 lb., must exceed W = 49551 lb. or W3 = 56716 lb.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 77.187 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: Firebox Small

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation 24.000 in.
Actual Thickness Used in Calculation 0.750 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Elliptical Head, Tr [Int. Press]
= (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
= (77.19*0.898*119.125)/(2 *20000.0*1.0-0.2*77.19)
= 0.2066 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= (77.19*12.0)/(20000*1.0+0.4*77.19)
= 0.0462 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

Parallel to Vessel Wall (Diameter Limit)	Dl	33.8750	in.
Parallel to Vessel Wall, opening length	d	16.9375	in.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	1.0938	in.
Normal to Vessel Wall, Inward		0.8750	in.

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	4.699	NA	NA
Area in Shell	A1	2.569	NA	NA
Area in Nozzle Wall	A2	1.266	NA	NA
Area in Inward Nozzle	A3	0.875	NA	NA
Area in Welds	A41+A42+A43	0.141	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	4.851	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (22.75*0.2066*1.0+2*0.625*0.2066*1.0*(1-1.0))
= 4.699 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
 = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
 = 11.125( 1.0 * 0.4375 - 1.0 * 0.207 ) - 2 * 0.625
   ( 1.0 * 0.4375 - 1.0 * 0.2066 ) * ( 1 - 1.0 )
 = 2.569 in²
```

Area Available in Nozzle Projecting Outward [A2]:
```
 = ( 2 * tlnp )( tn - trn )fr2
 = ( 2 * 1.094 )( 0.625 - 0.0462 )1.0
 = 1.266 in²
```

Area Available in Inward Nozzle [A3]:
```
 = 2 * ti * min( h, Tl, 2.5 * ti) * fr2
 = 2 * 0.5 * ( 0.875 ) * 1.0
 = 0.875 in²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
 = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
 =  0.375² * 1.0 + ( 0.0 )² * 1.0
 = 0.141 in²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 0.1712 in.
Wall Thickness per UG16(b),                      tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure     trb1 = 0.3543 in.
Wall Thickness                tb1 = max(trb1, tr16b) = 0.3543 in.
Wall Thickness                tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45                   tb3 = 0.4530 in.
```

Determine Nozzle Thickness candidate [tb]:
```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 0.453, max( 0.3543, 0.1875 ) ]
 = 0.3543 in.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
 = max( ta, tb )
 = max( 0.1712, 0.3543 )
 = 0.3543 in.
```

Available Nozzle Neck Thickness = 0.7500 in. --> OK

Weld Size Calculations, Description: Firebox Small

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.5000  in.
```

Results Per UW-16.1:
```
                     Required Thickness    Actual Thickness
Nozzle Weld          0.2500 = Min per Code 0.2651 = 0.7 * Wo in.
```

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

Weld Load [W]:
```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, (4.699 - 2.5693 + 2 * 0.625 * 1.0 *
   (1.0 * 0.4375 - 0.2066 ) )20000)
 = 48368.30 lb.
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (1.266 + 0.0 + 0.1406 - 0.0 * 1.0) * 20000
= 28133.22 lb.

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (1.266 + 0.875 + 0.1406 + (0.5469)) * 20000
= 56570.71 lb.

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (1.266 + 0.875 + 0.1406 + 0.0 + (0.5469)) * 20000
= 56570.71 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) * 24.0 * 0.375 * 0.49 * 20000
= 138544. lb.

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 11.6875) * (0.75 - 0.125) * 0.7 * 20000
= 321277. lb.

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 24.0 * (0.5625 - 0.125) * 0.74 * 20000
= 244102. lb.

Strength of Failure Paths:

PATH11 = (SONW + SNW) = (138544 + 321277) = 459821 lb.
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (138544 + 0 + 244102 + 0) = 382646 lb.
PATH33 = (Sonw + Tngw + Sinw)
= (138544 + 244102 + 0) = 382646 lb.

Summary of Failure Path Calculations:
Path 1-1 = 459821 lb., must exceed W = 48368 lb. or W1 = 28133 lb.
Path 2-2 = 382646 lb., must exceed W = 48368 lb. or W2 = 56570 lb.
Path 3-3 = 382646 lb., must exceed W = 48368 lb. or W3 = 56570 lb.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 77.187 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 3.4960 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 14.0730 in.

Percent Elongation Calculations:
% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 3.226 %

INPUT VALUES, Nozzle Description: N3:6in Outlet From : 20

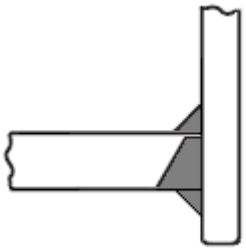
Pressure for Reinforcement Calculations	P	79.080	psig
Temperature for Internal Pressure	Temp	150	°F
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	20000.00	psi
Shell Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	119.2500	in.
Shell Finished (Minimum) Thickness	t	0.3750	in.
Shell Internal Corrosion Allowance	c	0.1250	in.
Shell External Corrosion Allowance	co	0.0000	in.
Distance from Cylinder/Cone Centerline	L1	25.7500	in.
Distance from Bottom/Left Tangent		0.75	ft.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	17100.00	psi
Allowable Stress At Ambient	Sna	17100.00	psi
Diameter Basis (for tr calc only)		ID	
Layout Angle		154.59	deg
Diameter		6.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness	tn	XXS	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	5.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.4685	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.3750	in.
Inside Projection	h	0.3750	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, with Inside projection

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: N3:6in Outlet

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          4.897  in.
Actual Thickness Used in Calculation                0.864  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
```
 = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
 = (79.08*59.75)/(20000*1.0-0.6*79.08)
 = 0.2368 in.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
 = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
 = (79.08*2.57)/(17100*1.0-0.6*79.08)
 = 0.0119 in.
```

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)          Dl    11.4099  in.
Parallel to Vessel Wall, opening length            d     5.7049  in.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    0.6250  in.
Normal to Vessel Wall, Inward                            0.2500  in.
```

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.701	NA	NA
Area in Shell	A1	0.723	NA	NA
Area in Nozzle Wall	A2	0.844	NA	NA
Area in Inward Nozzle	A3	0.262	NA	NA
Area in Welds	A41+A42+A43	0.188	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	2.017	NA	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations              64.45  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (5.7049*0.2368*0.5+2*0.739*0.2368*0.5*(1-0.86))
= 0.701 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 5.705(1.0 * 0.25 - 0.5 * 0.237) - 2 * 0.739
(1.0 * 0.25 - 0.5 * 0.2368) * (1 - 0.855)
= 0.723 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 0.625)(0.739 - 0.0119) 0.855/sin(67.0)
= 0.844 in²

Note: See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Inward Nozzle [A3]:
= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.614 * (0.25) * 0.855
= 0.262 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.4685² * 0.855 + (0.0)² * 0.855
= 0.188 in²

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.375, tr = 0.237, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.947, Temp. Reduction = 5 °F

Min Metal Temp. w/o impact per UCS-66, Curve B	-20 °F
Min Metal Temp. at Required thickness (UCS 66.1)	-25 °F
Governing MDMT of all the sub-joints of this Junction :	-25 °F

Weld Size Calculations, Description: N3:6in Outlet

Intermediate Calc. for nozzle/shell Welds Tmin 0.2500 in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.1750 = 0.7 * tmin.	0.3312 = 0.7 * Wo in.

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (0.7009 - 0.7225 + 2 * 0.739 * 0.855 *
(1.0 * 0.25 - 0.1184))20000)
= 2892.78 lb.

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (0.844 + 0.0 + 0.1877 - 0.0 * 0.86) * 20000
= 20634.22 lb.

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (0.844 + 0.2625 + 0.1877 + (0.3159)) * 20000
= 32202.37 lb.

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (0.844 + 0.2625 + 0.1877 + 0.0 + (0.3159)) * 20000
= 32202.37 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) * 7.3431 * 0.4685 * 0.49 * 17100
= 45280. lb.

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 3.262) * (0.864 - 0.125) * 0.7 * 17100
= 90651. lb.

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 7.3431 * (0.375 - 0.125) * 0.74 * 20000
= 42678. lb.

Strength of Failure Paths:

PATH11 = (SONW + SNW) = (45280 + 90651) = 135931 lb.
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (45280 + 0 + 42678 + 0) = 87958 lb.
PATH33 = (Sonw + Tngw + Sinw)
= (45280 + 42678 + 0) = 87958 lb.

Summary of Failure Path Calculations:
Path 1-1 = 135931 lb., must exceed W = 2892 lb. or W1 = 20634 lb.
Path 2-2 = 87957 lb., must exceed W = 2892 lb. or W2 = 32202 lb.
Path 3-3 = 87957 lb., must exceed W = 2892 lb. or W3 = 32202 lb.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 83.159 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

Note : Checking Nozzle in plane parallel to the vessel axis.

Reinforcement CALCULATION, Description: N3:6in Outlet

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation 4.897 in.
Actual Thickness Used in Calculation 0.864 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (79.08*59.75)/(20000*1.0-0.6*79.08)
= 0.2368 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
= (79.08*2.57)/(17100*1.0-0.6*79.08)
= 0.0119 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

Parallel to Vessel Wall (Diameter Limit)	Dl	10.2940	in.
Parallel to Vessel Wall, opening length	d	5.1470	in.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	0.6250	in.
Normal to Vessel Wall, Inward		0.2500	in.

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.270	NA	NA
Area in Shell	A1	0.065	NA	NA
Area in Nozzle Wall	A2	0.777	NA	NA
Area in Inward Nozzle	A3	0.262	NA	NA
Area in Welds	A41+A42+A43	0.188	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	1.292	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (5.147*0.2368*1.0+2*0.739*0.2368*1.0*(1-0.86))
= 1.270 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 5.147(1.0 * 0.25 - 1.0 * 0.237) - 2 * 0.739
(1.0 * 0.25 - 1.0 * 0.2368) * (1 - 0.855)
= 0.065 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 0.625)(0.739 - 0.0119) 0.855
= 0.777 in²

Area Available in Inward Nozzle [A3]:
= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.614 * (0.25) * 0.855
= 0.262 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.4685² * 0.855 + (0.0)² * 0.855
= 0.188 in²

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

```
Wall Thickness for Internal/External pressures      ta = 0.1369 in.
Wall Thickness per UG16(b),                      tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure     trb1 = 0.3618 in.
Wall Thickness                tb1 = max(trb1, tr16b) = 0.3618 in.
Wall Thickness                tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45                   tb3 = 0.3699 in.
```

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[0.37, max(0.3618, 0.1875)]
= 0.3618 in.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(0.1369, 0.3618)
= 0.3618 in.

Available Nozzle Neck Thickness = 0.875 * 0.864 = 0.756 in. --> OK

Weld Size Calculations, Description: N3:6in Outlet

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.2500  in.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.1750 = 0.7 * tmin.	0.3312 = 0.7 * Wo in.

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (1.2696 - 0.065 + 2 * 0.739 * 0.855 *
(1.0 * 0.25 - 0.2368))20000)
= 24424.86 lb.

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (0.7771 + 0.0 + 0.1877 - 0.0 * 0.86) * 20000
= 19294.35 lb.

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (0.7771 + 0.2625 + 0.1877 + (0.3159)) * 20000
= 30862.50 lb.

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (0.7771 + 0.2625 + 0.1877 + 0.0 + (0.3159)) * 20000
= 30862.50 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) * 6.625 * 0.4685 * 0.49 * 17100
= 40851. lb.

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 2.943) * (0.864 - 0.125) * 0.7 * 17100
= 81786. lb.

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 6.625 * (0.375 - 0.125) * 0.74 * 20000
= 38504. lb.

Strength of Failure Paths:

PATH11 = (SONW + SNW) = (40851 + 81786) = 122637 lb.
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (40851 + 0 + 38504 + 0) = 79356 lb.
PATH33 = (Sonw + Tngw + Sinw)
= (40851 + 38504 + 0) = 79356 lb.

Summary of Failure Path Calculations:
Path 1-1 = 122637 lb., must exceed W = 24424 lb. or W1 = 19294 lb.
Path 2-2 = 79355 lb., must exceed W = 24424 lb. or W2 = 30862 lb.
Path 3-3 = 79355 lb., must exceed W = 24424 lb. or W3 = 30862 lb.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 83.159 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 1.7155 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.1309 in.

INPUT VALUES, Nozzle Description: M2:24in ShellMW From : 20

Pressure for Reinforcement Calculations	P	77.996	psig
Temperature for Internal Pressure	Temp	150	°F
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	20000.00	psi
Shell Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	119.2500	in.
Shell Finished (Minimum) Thickness	t	0.3750	in.
Shell Internal Corrosion Allowance	c	0.1250	in.
Shell External Corrosion Allowance	co	0.0000	in.
Distance from Cylinder/Cone Centerline	L1	24.0000	in.
Distance from Bottom/Left Tangent		13.67	ft.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

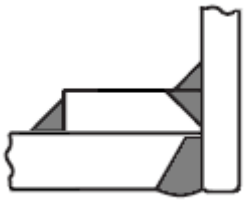
Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	17100.00	psi
Allowable Stress At Ambient	Sna	17100.00	psi
Diameter Basis (for tr calc only)		OD	
Layout Angle		113.58	deg
Diameter		24.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness	tn	XS	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	10.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.2500	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.3750	in.
Inside Projection	h	0.0000	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	20000.00	psi
Pad Allowable Stress At Ambient	Spa	20000.00	psi
Diameter of Pad along vessel surface	Dp	45.5000	in.
Thickness of Pad	te	0.2500	in.
Weld leg size between Pad and Shell	Wp	0.1875	in.
Groove weld depth between Pad and Nozzle	Wgpn	0.2500	in.
Reinforcing Pad Width		10.7500	in.

This is a Manway or Access Opening.

Class of attached Flange	150
Grade of attached Flange	GR 1.1

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle With Pad, no Inside projection

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: M2:24in ShellMW

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation		24.000	in.
Actual Thickness Used in Calculation		0.500	in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (78.0*59.75)/(20000*1.0-0.6*78.0)
= 0.2336 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= (78.0*12.0)/(17100*1.0+0.4*78.0)
= 0.0546 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

Parallel to Vessel Wall (Diameter Limit)	Dl	51.3830	in.
Parallel to Vessel Wall, opening length	d	25.6915	in.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	0.6250	in.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 17100.0/20000.0)
= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 17100.0/20000.0)
= 0.855

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 20000.0/20000.0)

= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(0.855, 1.0)
= 0.855

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	6.026	NA	NA
Area in Shell	A1	0.421	NA	NA
Area in Nozzle Wall	A2	0.350	NA	NA
Area in Inward Nozzle	A3	0.000	NA	NA
Area in Welds	A41+A42+A43	0.089	NA	NA
Area in Element	A5	5.375	NA	NA
TOTAL AREA AVAILABLE	Atot	6.234	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 64.82 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	44.6875	0.2500	in.
Based on given Pad Diameter:	45.5000	0.2500	in.
Based on Shell or Nozzle Thickness:	40.3125	0.3750	in.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (25.6915*0.2336*1.0+2*0.375*0.2336*1.0*(1-0.86))
= 6.026 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 25.691(1.0 * 0.25 - 1.0 * 0.234) - 2 * 0.375
(1.0 * 0.25 - 1.0 * 0.2336) * (1 - 0.855)
= 0.421 in²

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2/sin(alpha3)
= (2 * 0.625) * (0.375 - 0.0546) * 0.855/sin(78.3)
= 0.350 in²

Note: See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 0.25² * 0.86 + (0.0)² * 0.86 + 0.1875² * 1.0
= 0.089 in²

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (48.0202 - 26.5202) * 0.25 * 1.0

= 5.375 in²

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 0.438, tr = 0.055, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.175, Temp. Reduction = 140 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -14 °F
Min Metal Temp. at Required thickness (UCS 66.1)         -155 °F
Min Metal Temp. w/o impact per UG-20(f)                   -20 °F
```

Nozzle Neck to Pad Weld for the Nozzle, Curve: B

Govrn. thk, tg = 0.25, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.934, Temp. Reduction = 7 °F
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -20 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -27 °F
```

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: B

Govrn. thk, tg = 0.25, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.934, Temp. Reduction = 7 °F
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -20 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -27 °F
```

Shell to Pad Weld Junction at Pad OD, Curve: B

Govrn. thk, tg = 0.25, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.934, Temp. Reduction = 7 °F
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -20 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -27 °F
```

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

Govrn. thk, tg = 0.375, tr = 0.234, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.934, Temp. Reduction = 7 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -20 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -27 °F

Governing MDMT of the Nozzle                        :     -27 °F
Governing MDMT of the Reinforcement Pad             :     -27 °F
Governing MDMT of all the sub-joints of this Junction  :  -27 °F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)    -20 °F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)     -155 °F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-c)     -155 °F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

Design Pressure/Ambient Rating = 78.00/285.00 = 0.274

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: M2:24in ShellMW

Intermediate Calc. for nozzle/shell Welds Tmin 0.2500 in.
Intermediate Calc. for pad/shell Welds TminPad 0.2500 in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.1750 = 0.7 * tmin.	0.1768 = 0.7 * Wo in.
Pad Weld	0.1250 = 0.5*TminPad	0.1326 = 0.7 * Wp in.

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (6.0259 - 0.4206 + 2 * 0.375 * 0.855 *
(1.0 * 0.25 - 0.2336))20000)
= 112317.79 lb.

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (0.3496 + 5.375 + 0.0886 - 0.0 * 0.86) * 20000
= 116263.95 lb.

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (0.3496 + 0.0 + 0.0534 + (0.1603)) * 20000
= 11267.07 lb.

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (0.3496 + 0.0 + 0.0886 + 5.375 + (0.1603)) * 20000
= 119470.20 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) * 26.5202 * 0.25 * 0.49 * 17100
= 87263. lb.

Shear, Pad Element Weld [Spew]:
= (pi/2) * DP * WP * 0.49 * SEW
= (3.1416/2.0) * 45.5 * 0.1875 * 0.49 * 20000
= 131328. lb.

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 13.0529) * (0.5 - 0.125) * 0.7 * 17100
= 184070. lb.

Tension, Pad Groove Weld [Tpgw]:
= (pi/2) * Dlo * Wgpn * 0.74 * Seg

= (3.1416/2) * 26.5202 * 0.25 * 0.74 * 20000
= 154134. lb.

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 26.5202 * (0.375 - 0.125) * 0.74 * 20000
= 154134. lb.

Strength of Failure Paths:

PATH11 = (SPEW + SNW) = (131328 + 184070) = 315399 lb.
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (87263 + 154134 + 154134 + 0) = 395531 lb.
PATH33 = (Spew + Tngw + Sinw)
= (131328 + 154134 + 0) = 285463 lb.

Summary of Failure Path Calculations:
Path 1-1 = 315398 lb., must exceed W = 112317 lb. or W1 = 116263 lb.
Path 2-2 = 395531 lb., must exceed W = 112317 lb. or W2 = 11267 lb.
Path 3-3 = 285462 lb., must exceed W = 112317 lb. or W3 = 119470 lb.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 80.992 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

Note : Checking Nozzle in plane parallel to the vessel axis.

Reinforcement CALCULATION, Description: M2:24in ShellMW

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation 24.000 in.
Actual Thickness Used in Calculation 0.500 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (78.0*59.75)/(20000*1.0-0.6*78.0)
= 0.2336 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= (78.0*12.0)/(17100*1.0+0.4*78.0)
= 0.0546 in.

UG-40, Limits of Reinforcement : [Internal Pressure]
Parallel to Vessel Wall (Diameter Limit) Dl 46.5000 in.
Parallel to Vessel Wall, opening length d 23.2500 in.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp 0.6250 in.

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	5.456	NA	NA
Area in Shell	A1	0.380	NA	NA
Area in Nozzle Wall	A2	0.342	NA	NA

Area in Inward Nozzle	A3	0.000	NA	NA
Area in Welds	A41+A42+A43	0.089	NA	NA
Area in Element	A5	5.375	NA	NA
TOTAL AREA AVAILABLE	Atot	6.186	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	42.6250	0.2500	in.
Based on given Pad Diameter:	45.5000	0.2500	in.
Based on Shell or Nozzle Thickness:	36.4375	0.3750	in.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (23.25*0.2336*1.0+2*0.375*0.2336*1.0*(1-0.86))
= 5.456 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 23.25(1.0 * 0.25 - 1.0 * 0.234) - 2 * 0.375
(1.0 * 0.25 - 1.0 * 0.2336) * (1 - 0.855)
= 0.380 in²

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 0.625) * (0.375 - 0.0546) * 0.855
= 0.342 in²

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 0.25² * 0.86 + (0.0)² * 0.86 + 0.1875² * 1.0
= 0.089 in²

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (45.5 - 24.0) * 0.25 * 1.0
= 5.375 in²

Weld Size Calculations, Description: M2:24in ShellMW

Intermediate Calc. for nozzle/shell Welds	Tmin	0.2500	in.
Intermediate Calc. for pad/shell Welds	TminPad	0.2500	in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.1750 = 0.7 * tmin.	0.1768 = 0.7 * Wo in.
Pad Weld	0.1250 = 0.5*TminPad	0.1326 = 0.7 * Wp in.

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)

= max(0, (5.4557 - 0.3804 + 2 * 0.375 * 0.855 *
(1.0 * 0.25 - 0.2336))20000)
= 101715.84 lb.

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (0.3424 + 5.375 + 0.0886 - 0.0 * 0.86) * 20000
= 116119.69 lb.

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (0.3424 + 0.0 + 0.0534 + (0.1603)) * 20000
= 11122.81 lb.

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (0.3424 + 0.0 + 0.0886 + 5.375 + (0.1603)) * 20000
= 119325.95 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) * 24.0 * 0.25 * 0.49 * 17100
= 78970. lb.

Shear, Pad Element Weld [Spew]:
= (pi/2) * DP * WP * 0.49 * SEW
= (3.1416/2.0) * 45.5 * 0.1875 * 0.49 * 20000
= 131328. lb.

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 11.8125) * (0.5 - 0.125) * 0.7 * 17100
= 166578. lb.

Tension, Pad Groove Weld [Tpgw]:
= (pi/2) * Dlo * Wgpn * 0.74 * Seg
= (3.1416/2) * 24.0 * 0.25 * 0.74 * 20000
= 139487. lb.

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 24.0 * (0.375 - 0.125) * 0.74 * 20000
= 139487. lb.

Strength of Failure Paths:

PATH11 = (SPEW + SNW) = (131328 + 166578) = 297906 lb.
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (78970 + 139487 + 139487 + 0) = 357944 lb.
PATH33 = (Spew + Tngw + Sinw)
= (131328 + 139487 + 0) = 270815 lb.

Summary of Failure Path Calculations:
Path 1-1 = 297906 lb., must exceed W = 101715 lb. or W1 = 116119 lb.
Path 2-2 = 357943 lb., must exceed W = 101715 lb. or W2 = 11122 lb.

Path 3-3 = 270815 lb., must exceed W = 101715 lb. or W3 = 119325 lb.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 75.000 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 7.0511 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 17.4605 in.

INPUT VALUES, Nozzle Description: N8A 4in Drain From : 20

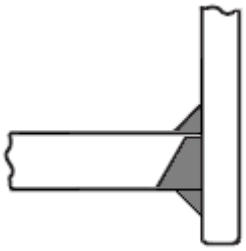
Pressure for Reinforcement Calculations	P	79.288	psig
Temperature for Internal Pressure	Temp	150	°F
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	20000.00	psi
Shell Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	119.2500	in.
Shell Finished (Minimum) Thickness	t	0.3750	in.
Shell Internal Corrosion Allowance	c	0.1250	in.
Shell External Corrosion Allowance	co	0.0000	in.
Distance from Bottom/Left Tangent		16.67	ft.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	17100.00	psi
Allowable Stress At Ambient	Sna	17100.00	psi
Diameter Basis (for tr calc only)		ID	
Layout Angle		180.00	deg
Diameter		4.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness	tn	XXS	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	3.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.4375	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.3750	in.
Inside Projection	h	0.2500	in.
Weld leg size, Inside Element to Shell	Wi	0.2500	in.
ASME Code Weld Type		UW-16.1(c)	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, with Inside projection

Reinforcement CALCULATION, Description: N8A 4in Drain

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              3.152  in.
Actual Thickness Used in Calculation                    0.674  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (79.29*59.75)/(20000*1.0-0.6*79.29)
= 0.2374 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
= (79.29*1.7)/(17100*1.0-0.6*79.29)
= 0.0079 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)            Dl     6.8040  in.
Parallel to Vessel Wall, opening length              d     3.4020  in.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.6250  in.
Normal to Vessel Wall, Inward                             0.1250  in.
```

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 17100.0/20000.0)
= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 17100.0/20000.0)
= 0.855

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(0.855, 1.0)
= 0.855

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.846	NA	NA
Area in Shell	A1	0.041	NA	NA

Area in Nozzle Wall	A2	0.578	NA	NA
Area in Inward Nozzle	A3	0.091	NA	NA
Area in Welds	A41+A42+A43	0.168	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	0.878	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (3.402*0.2374*1.0+2*0.549*0.2374*1.0*(1-0.86))
= 0.846 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 3.402(1.0 * 0.25 - 1.0 * 0.237) - 2 * 0.549
(1.0 * 0.25 - 1.0 * 0.2374) * (1 - 0.855)
= 0.041 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 0.625)(0.549 - 0.0079) 0.855
= 0.578 in²

Area Available in Inward Nozzle [A3]:
= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.424 * (0.125) * 0.855
= 0.091 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.4375² * 0.855 + (0.0732)² * 0.855
= 0.168 in²

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

Wall Thickness for Internal/External pressures ta = 0.1329 in.
Wall Thickness per UG16(b), tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure trb1 = 0.3624 in.
Wall Thickness tb1 = max(trb1, tr16b) = 0.3624 in.
Wall Thickness tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45 tb3 = 0.3320 in.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[0.332, max(0.3624, 0.1875)]
= 0.3320 in.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(0.1329, 0.332)
= 0.3320 in.

Available Nozzle Neck Thickness = 0.875 * 0.674 = 0.590 in. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.375, tr = 0.237, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.95, Temp. Reduction = 5 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -20 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -25 °F

Governing MDMT of all the sub-joints of this Junction  :  -25 °F
```

Weld Size Calculations, Description: N8A 4in Drain

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.2500  in.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.1750 = 0.7 * tmin.	0.3093 = 0.7 * Wo in.

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case       83.575  psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.0425 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 3.6250 in.

INPUT VALUES, Nozzle Description: N9 4in OilDrain From : 20

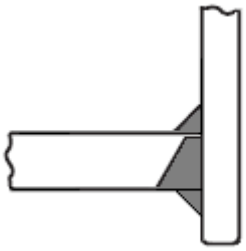
Pressure for Reinforcement Calculations	P	79.277	psig
Temperature for Internal Pressure	Temp	150	°F
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	20000.00	psi
Shell Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	119.2500	in.
Shell Finished (Minimum) Thickness	t	0.3750	in.
Shell Internal Corrosion Allowance	c	0.1250	in.
Shell External Corrosion Allowance	co	0.0000	in.
Distance from Cylinder/Cone Centerline	L1	6.0000	in.
Distance from Bottom/Left Tangent		29.58	ft.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	17100.00	psi
Allowable Stress At Ambient	Sna	17100.00	psi
Diameter Basis (for tr calc only)		ID	
Layout Angle		185.74	deg
Diameter		4.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness	tn	XXS	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	3.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.2500	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.3750	in.
Inside Projection	h	0.3750	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
ASME Code Weld Type		UW-16.1(c)	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, with Inside projection

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: N9 4in OilDrain

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          3.152  in.
Actual Thickness Used in Calculation                0.674  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
```
 = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
 = (79.28*59.75)/(20000*1.0-0.6*79.28)
 = 0.2374 in.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
 = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
 = (79.28*1.7)/(17100*1.0-0.6*79.28)
 = 0.0079 in.
```

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)          Dl     6.8394  in.
Parallel to Vessel Wall, opening length            d     3.4197  in.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    0.6250  in.
Normal to Vessel Wall, Inward                            0.2500  in.
```

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.425	NA	NA
Area in Shell	A1	0.428	NA	NA
Area in Nozzle Wall	A2	0.580	NA	NA
Area in Inward Nozzle	A3	0.181	NA	NA
Area in Welds	A41+A42+A43	0.053	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	1.243	NA	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations              84.17  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (3.4197*0.2374*0.5+2*0.549*0.2374*0.5*(1-0.86))
= 0.425 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 3.42(1.0 * 0.25 - 0.5 * 0.237) - 2 * 0.549
(1.0 * 0.25 - 0.5 * 0.2374) * (1 - 0.855)
= 0.428 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 0.625)(0.549 - 0.0079) 0.855/sin(85.7)
= 0.580 in²

Note: See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Inward Nozzle [A3]:
= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.424 * (0.25) * 0.855
= 0.181 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.25² * 0.855 + (0.0)² * 0.855
= 0.053 in²

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.375, tr = 0.237, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.95, Temp. Reduction = 5 °F

Min Metal Temp. w/o impact per UCS-66, Curve B	-20 °F
Min Metal Temp. at Required thickness (UCS 66.1)	-25 °F
Governing MDMT of all the sub-joints of this Junction :	-25 °F

Weld Size Calculations, Description: N9 4in OilDrain

Intermediate Calc. for nozzle/shell Welds Tmin 0.2500 in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.1750 = 0.7 * tmin.	0.1768 = 0.7 * Wo in.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 83.554 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

Note : Checking Nozzle in plane parallel to the vessel axis.

Reinforcement CALCULATION, Description: N9 4in OilDrain

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation 3.152 in.
Actual Thickness Used in Calculation 0.674 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (79.28*59.75)/(20000*1.0-0.6*79.28)
= 0.2374 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
= (79.28*1.7)/(17100*1.0-0.6*79.28)
= 0.0079 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

Parallel to Vessel Wall (Diameter Limit)	Dl	6.8040	in.
Parallel to Vessel Wall, opening length	d	3.4020	in.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	0.6250	in.
Normal to Vessel Wall, Inward		0.2500	in.

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.845	NA	NA
Area in Shell	A1	0.041	NA	NA
Area in Nozzle Wall	A2	0.578	NA	NA
Area in Inward Nozzle	A3	0.181	NA	NA
Area in Welds	A41+A42+A43	0.053	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	0.854	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (3.402*0.2374*1.0+2*0.549*0.2374*1.0*(1-0.86))
= 0.845 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 3.402(1.0 * 0.25 - 1.0 * 0.237) - 2 * 0.549
(1.0 * 0.25 - 1.0 * 0.2374) * (1 - 0.855)
= 0.041 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 0.625)(0.549 - 0.0079) 0.855
= 0.578 in²

Area Available in Inward Nozzle [A3]:

= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.424 * (0.25) * 0.855
= 0.181 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.25² * 0.855 + (0.0)² * 0.855
= 0.053 in²

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

```
Wall Thickness for Internal/External pressures      ta = 0.1329 in.
Wall Thickness per UG16(b),                      tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure     trb1 = 0.3624 in.
Wall Thickness                tb1 = max(trb1, tr16b) = 0.3624 in.
Wall Thickness                tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45                   tb3 = 0.3320 in.
```

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[0.332, max(0.3624, 0.1875)]
= 0.3320 in.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(0.1329, 0.332)
= 0.3320 in.

Available Nozzle Neck Thickness = 0.875 * 0.674 = 0.590 in. --> OK

Weld Size Calculations, Description: N9 4in OilDrain

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.2500  in.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.1750 = 0.7 * tmin.	0.1768 = 0.7 * Wo in.

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case       83.554  psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.2709 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 3.7519 in.

INPUT VALUES, Nozzle Description: N10 4in Anode From : 20

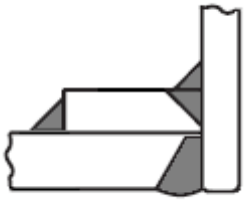
Pressure for Reinforcement Calculations	P	78.714	psig
Temperature for Internal Pressure	Temp	150	°F
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	20000.00	psi
Shell Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	119.2500	in.
Shell Finished (Minimum) Thickness	t	0.3750	in.
Shell Internal Corrosion Allowance	c	0.1250	in.
Shell External Corrosion Allowance	co	0.0000	in.
Distance from Cylinder/Cone Centerline	L1	44.0000	in.
Distance from Bottom/Left Tangent		7.67	ft.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	17100.00	psi
Allowable Stress At Ambient	Sna	17100.00	psi
Diameter Basis (for tr calc only)		ID	
Layout Angle		137.17	deg
Diameter		4.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness	tn	XS	
Corrosion Allowance	can	0.0625	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	5.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.2500	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.3750	in.
Inside Projection	h	0.0000	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	20000.00	psi
Pad Allowable Stress At Ambient	Spa	20000.00	psi
Diameter of Pad along vessel surface	Dp	8.5000	in.
Thickness of Pad	te	0.2500	in.
Weld leg size between Pad and Shell	Wp	0.1875	in.
Groove weld depth between Pad and Nozzle	Wgpn	0.2500	in.
Reinforcing Pad Width		2.0000	in.
ASME Code Weld Type		UW-16.1(c)	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle With Pad, no Inside projection

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: N10 4in Anode

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation		3.826	in.
Actual Thickness Used in Calculation		0.337	in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (78.71*59.75)/(20000*1.0-0.6*78.71)
= 0.2357 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
= (78.71*1.98)/(17100*1.0-0.6*78.71)
= 0.0091 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

Parallel to Vessel Wall (Diameter Limit)	Dl	11.6738	in.
Parallel to Vessel Wall, opening length	d	5.8369	in.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	0.6250	in.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 17100.0/20000.0)
= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 17100.0/20000.0)
= 0.855

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 20000.0/20000.0)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(0.855, 1.0)

= 0.855

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.395	NA	NA
Area in Shell	A1	0.082	NA	NA
Area in Nozzle Wall	A2	0.399	NA	NA
Area in Inward Nozzle	A3	0.000	NA	NA
Area in Welds	A41+A42+A43	0.089	NA	NA
Area in Element	A5	1.000	NA	NA
TOTAL AREA AVAILABLE	Atot	1.569	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 42.60 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	7.8125	0.2500	in.
Based on given Pad Diameter:	8.5000	0.2500	in.
Based on Shell or Nozzle Thickness:	8.8750	0.3750	in.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (5.8369*0.2357*1.0+2*0.2745*0.2357*1.0*(1-0.86))
= 1.395 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 5.837(1.0 * 0.25 - 1.0 * 0.236) - 2 * 0.275
(1.0 * 0.25 - 1.0 * 0.2357) * (1 - 0.855)
= 0.082 in²

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2/sin(alpha3)
= (2 * 0.625) * (0.2745 - 0.0091) * 0.855/sin(45.4)
= 0.399 in²

Note: See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 0.25² * 0.86 + (0.0)² * 0.86 + 0.1875² * 1.0
= 0.089 in²

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (10.6479 - 6.6479) * 0.25 * 1.0
= 1.000 in²

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Pad Weld for the Nozzle, Curve: B

Govrn. thk, tg = 0.25, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.943, Temp. Reduction = 6 °F
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B -20 °F
Min Metal Temp. at Required thickness (UCS 66.1) -26 °F

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: B

Govrn. thk, tg = 0.25, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.943, Temp. Reduction = 6 °F
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B -20 °F
Min Metal Temp. at Required thickness (UCS 66.1) -26 °F

Shell to Pad Weld Junction at Pad OD, Curve: B

Govrn. thk, tg = 0.25, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.943, Temp. Reduction = 6 °F
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B -20 °F
Min Metal Temp. at Required thickness (UCS 66.1) -26 °F

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

Govrn. thk, tg = 0.295, tr = 0.009, c = 0.0625 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 140 °F

Min Metal Temp. w/o impact per UCS-66, Curve B -20 °F
Min Metal Temp. at Required thickness (UCS 66.1) -155 °F

Governing MDMT of the Nozzle : -26 °F
Governing MDMT of the Reinforcement Pad : -26 °F
Governing MDMT of all the sub-joints of this Junction : -26 °F

Weld Size Calculations, Description: N10 4in Anode

Intermediate Calc. for nozzle/shell Welds Tmin 0.2500 in.
Intermediate Calc. for pad/shell Welds TminPad 0.2500 in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.1750 = 0.7 * tmin.	0.1768 = 0.7 * Wo in.
Pad Weld	0.1250 = 0.5*TminPad	0.1326 = 0.7 * Wp in.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 82.427 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

Note : Checking Nozzle in plane parallel to the vessel axis.

Reinforcement CALCULATION, Description: N10 4in Anode

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation 3.826 in.
Actual Thickness Used in Calculation 0.337 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (78.71*59.75)/(20000*1.0-0.6*78.71)
= 0.2357 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
= (78.71*1.98)/(17100*1.0-0.6*78.71)
= 0.0091 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

Parallel to Vessel Wall (Diameter Limit) Dl 7.9020 in.
Parallel to Vessel Wall, opening length d 3.9510 in.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp 0.6250 in.

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.950	NA	NA
Area in Shell	A1	0.055	NA	NA
Area in Nozzle Wall	A2	0.284	NA	NA
Area in Inward Nozzle	A3	0.000	NA	NA
Area in Welds	A41+A42+A43	0.053	NA	NA
Area in Element	A5	0.850	NA	NA
TOTAL AREA AVAILABLE	Atot	1.243	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	6.7500	0.2500	in.
Based on given Pad Diameter:	8.5000	0.1875	in.
Based on Shell or Nozzle Thickness:	6.0000	0.3750	in.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (3.951*0.2357*1.0+2*0.2745*0.2357*1.0*(1-0.86))
= 0.950 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 3.951(1.0 * 0.25 - 1.0 * 0.236) - 2 * 0.275
(1.0 * 0.25 - 1.0 * 0.2357) * (1 - 0.855)
= 0.055 in²

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 0.625) * (0.2745 - 0.0091) * 0.855
= 0.284 in²

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 0.25² * 0.86 + (0.0)² * 0.86 + 0.0² * 1.0
= 0.053 in²

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (7.902 - 4.5) * 0.25 * 1.0
= 0.850 in²

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

```
Wall Thickness for Internal/External pressures      ta = 0.0716 in.
Wall Thickness per UG16(b),                      tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure     trb1 = 0.3607 in.
Wall Thickness                tb1 = max(trb1, tr16b) = 0.3607 in.
Wall Thickness                tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45                   tb3 = 0.2695 in.
```

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[0.27, max(0.3607, 0.1875)]
= 0.2695 in.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(0.0716, 0.2695)
= 0.2695 in.

Available Nozzle Neck Thickness = 0.875 * 0.337 = 0.295 in. --> OK

Weld Size Calculations, Description: N10 4in Anode

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.2500  in.
Intermediate Calc. for pad/shell Welds   TminPad      0.2500  in.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.1750 = 0.7 * tmin.	0.1768 = 0.7 * Wo in.
Pad Weld	0.1250 = 0.5*TminPad	0.1326 = 0.7 * Wp in.

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case       82.427  psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 2.6077 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 8.1613 in.

INPUT VALUES, Nozzle Description: N14A 2in T From : 20

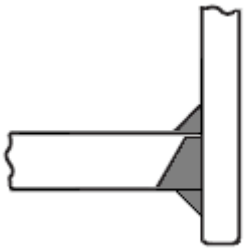
Pressure for Reinforcement Calculations	P	76.704	psig
Temperature for Internal Pressure	Temp	150	°F
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	20000.00	psi
Shell Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	119.2500	in.
Shell Finished (Minimum) Thickness	t	0.3750	in.
Shell Internal Corrosion Allowance	c	0.1250	in.
Shell External Corrosion Allowance	co	0.0000	in.
Distance from Cylinder/Cone Centerline	L1	12.0000	in.
Distance from Bottom/Left Tangent		28.17	ft.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	17100.00	psi
Allowable Stress At Ambient	Sna	17100.00	psi
Diameter Basis (for tr calc only)		ID	
Layout Angle		78.46	deg
Diameter		2.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness	tn	XXS	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	3.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.2500	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.3750	in.
Inside Projection	h	0.2500	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
ASME Code Weld Type		UW-16.1(c)	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, with Inside projection

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: N14A 2in T

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          1.503  in.
Actual Thickness Used in Calculation                0.436  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
```
 = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
 = (76.7*59.75)/(20000*1.0-0.6*76.7)
 = 0.2297 in.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
 = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
 = (76.7*0.88)/(17100*1.0-0.6*76.7)
 = 0.0039 in.
```

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)          Dl     3.5788  in.
Parallel to Vessel Wall, opening length            d     1.7894  in.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    0.6250  in.
Normal to Vessel Wall, Inward                            0.1250  in.
```

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.216	NA	NA
Area in Shell	A1	0.230	NA	NA
Area in Nozzle Wall	A2	0.334	NA	NA
Area in Inward Nozzle	A3	0.040	NA	NA
Area in Welds	A41+A42+A43	0.053	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	0.657	NA	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations              78.42  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (1.7894*0.2297*0.5+2*0.311*0.2297*0.5*(1-0.86))
= 0.216 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 1.789(1.0 * 0.25 - 0.5 * 0.23) - 2 * 0.311
(1.0 * 0.25 - 0.5 * 0.2297) * (1 - 0.855)
= 0.230 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 0.625)(0.311 - 0.0039) 0.855/sin(79.1)
= 0.334 in²

Note: See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Inward Nozzle [A3]:
= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.186 * (0.125) * 0.855
= 0.040 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.25² * 0.855 + (0.0)² * 0.855
= 0.053 in²

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.375, tr = 0.23, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.919, Temp. Reduction = 8 °F

Min Metal Temp. w/o impact per UCS-66, Curve B -20 °F
Min Metal Temp. at Required thickness (UCS 66.1) -28 °F

Governing MDMT of all the sub-joints of this Junction : -28 °F

Weld Size Calculations, Description: N14A 2in T

Intermediate Calc. for nozzle/shell Welds Tmin 0.2500 in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.1750 = 0.7 * tmin.	0.1768 = 0.7 * Wo in.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 78.408 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

Note : Checking Nozzle in plane parallel to the vessel axis.

Reinforcement CALCULATION, Description: N14A 2in T

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation 1.503 in.
Actual Thickness Used in Calculation 0.436 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (76.7*59.75)/(20000*1.0-0.6*76.7)
= 0.2297 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
= (76.7*0.88)/(17100*1.0-0.6*76.7)
= 0.0039 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

Parallel to Vessel Wall (Diameter Limit)	Dl	3.5060	in.
Parallel to Vessel Wall, opening length	d	1.7530	in.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	0.6250	in.
Normal to Vessel Wall, Inward		0.1250	in.

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.423	NA	NA
Area in Shell	A1	0.034	NA	NA
Area in Nozzle Wall	A2	0.328	NA	NA
Area in Inward Nozzle	A3	0.040	NA	NA
Area in Welds	A41+A42+A43	0.053	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	0.455	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (1.753*0.2297*1.0+2*0.311*0.2297*1.0*(1-0.86))
= 0.423 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 1.753(1.0 * 0.25 - 1.0 * 0.23) - 2 * 0.311
(1.0 * 0.25 - 1.0 * 0.2297) * (1 - 0.855)
= 0.034 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 0.625)(0.311 - 0.0039) 0.855
= 0.328 in²

Area Available in Inward Nozzle [A3]:

= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.186 * (0.125) * 0.855
= 0.040 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.25² * 0.855 + (0.0)² * 0.855
= 0.053 in²

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

Wall Thickness for Internal/External pressures ta = 0.1289 in.
Wall Thickness per UG16(b), tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure trb1 = 0.3547 in.
Wall Thickness tb1 = max(trb1, tr16b) = 0.3547 in.
Wall Thickness tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45 tb3 = 0.2596 in.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[0.26, max(0.3547, 0.1875)]
= 0.2596 in.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(0.1289, 0.2596)
= 0.2596 in.

Available Nozzle Neck Thickness = 0.875 * 0.436 = 0.382 in. --> OK

Weld Size Calculations, Description: N14A 2in T

Intermediate Calc. for nozzle/shell Welds Tmin 0.2500 in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.1750 = 0.7 * tmin.	0.1768 = 0.7 * Wo in.

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 78.408 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.2566 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 3.6394 in.

INPUT VALUES, Nozzle Description: N1 6in Inlet From : 20

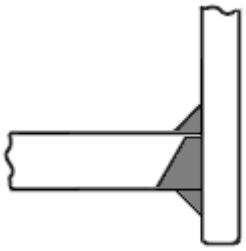
Pressure for Reinforcement Calculations	P	75.000	psig
Temperature for Internal Pressure	Temp	150	°F
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	20000.00	psi
Shell Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	119.2500	in.
Shell Finished (Minimum) Thickness	t	0.3750	in.
Shell Internal Corrosion Allowance	c	0.1250	in.
Shell External Corrosion Allowance	co	0.0000	in.
Distance from Bottom/Left Tangent		28.17	ft.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	20000.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		ID	
Layout Angle		0.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.8800	in.
Flange Material [Normalized]		SA-106 B	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	6.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.2500	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.3750	in.
Inside Projection	h	0.3750	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
ASME Code Weld Type		UW-16.1(c)	
Class of attached Flange		150	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, with Inside projection

Reinforcement CALCULATION, Description: N1 6in Inlet

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation		6.000	in.
Actual Thickness Used in Calculation		0.880	in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (75.0*59.75)/(20000*1.0-0.6*75.0)
= 0.2246 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
= (75.0*3.12)/(20000*1.0-0.6*75.0)
= 0.0117 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

Parallel to Vessel Wall (Diameter Limit)	Dl	12.5000	in.
Parallel to Vessel Wall, opening length	d	6.2500	in.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	0.6250	in.
Normal to Vessel Wall, Inward		0.2500	in.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 20000.0/20000.0)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 20000.0/20000.0)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.404	NA	NA
Area in Shell	A1	0.159	NA	NA

Area in Nozzle Wall	A2	0.929	NA	NA
Area in Inward Nozzle	A3	0.315	NA	NA
Area in Welds	A41+A42+A43	0.062	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	1.466	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (6.25*0.2246*1.0+2*0.755*0.2246*1.0*(1-1.0))
= 1.404 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 6.25(1.0 * 0.25 - 1.0 * 0.225) - 2 * 0.755
(1.0 * 0.25 - 1.0 * 0.2246) * (1 - 1.0)
= 0.159 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 0.625)(0.755 - 0.0117)1.0
= 0.929 in²

Area Available in Inward Nozzle [A3]:
= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.63 * (0.25) * 1.0
= 0.315 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.25² * 1.0 + (0.0)² * 1.0
= 0.062 in²

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

Wall Thickness for Internal/External pressures ta = 0.1367 in.
Wall Thickness per UG16(b), tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure trb1 = 0.3496 in.
Wall Thickness tb1 = max(trb1, tr16b) = 0.3496 in.
Wall Thickness tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45 tb3 = 0.4069 in.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[0.407, max(0.3496, 0.1875)]
= 0.3496 in.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(0.1367, 0.3496)
= 0.3496 in.

Available Nozzle Neck Thickness = 0.8800 in. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.375, tr = 0.225, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.898, Temp. Reduction = 10 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -20 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -30 °F

Governing MDMT of all the sub-joints of this Junction  :   -30 °F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification        1 °F
Flange MDMT with Temp reduction per UCS-66(i)(2)         -139 °F
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
Design Pressure/Ambient Rating = 75.00/285.00 = 0.263

Weld Size Calculations, Description: N1 6in Inlet

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.2500  in.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.1750 = 0.7 * tmin.	0.1768 = 0.7 * Wo in.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 75.000 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.1264 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 6.7500 in.

INPUT VALUES, Nozzle Description: Dome 24in Shell From : 20

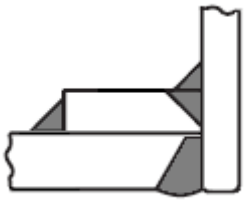
Pressure for Reinforcement Calculations	P	75.000	psig
Temperature for Internal Pressure	Temp	150	°F
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	20000.00	psi
Shell Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	119.2500	in.
Shell Finished (Minimum) Thickness	t	0.3750	in.
Shell Internal Corrosion Allowance	c	0.1250	in.
Shell External Corrosion Allowance	co	0.0000	in.
Distance from Bottom/Left Tangent		3.33	ft.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	17100.00	psi
Allowable Stress At Ambient	Sna	17100.00	psi
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		24.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness	tn	XS	
Flange Material		SA-105	
Flange Type		None	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	10.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.2500	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.3750	in.
Inside Projection	h	0.0000	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	20000.00	psi
Pad Allowable Stress At Ambient	Spa	20000.00	psi
Diameter of Pad along vessel surface	Dp	41.0000	in.
Thickness of Pad	te	0.2500	in.
Weld leg size between Pad and Shell	Wp	0.1875	in.
Groove weld depth between Pad and Nozzle	Wgpn	0.2500	in.
Reinforcing Pad Width		8.5000	in.
Class of attached Flange		150	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle With Pad, no Inside projection

Reinforcement CALCULATION, Description: Dome 24in Shell

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation		24.000	in.
Actual Thickness Used in Calculation		0.500	in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (75.0*59.75)/(20000*1.0-0.6*75.0)
= 0.2246 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= (75.0*12.0)/(17100*1.0+0.4*75.0)
= 0.0525 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

Parallel to Vessel Wall (Diameter Limit)	Dl	46.5000	in.
Parallel to Vessel Wall, opening length	d	23.2500	in.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	0.6250	in.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 17100.0/20000.0)
= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 17100.0/20000.0)
= 0.855

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 20000.0/20000.0)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(0.855, 1.0)

= 0.855

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	5.246	NA	NA
Area in Shell	A1	0.589	NA	NA
Area in Nozzle Wall	A2	0.345	NA	NA
Area in Inward Nozzle	A3	0.000	NA	NA
Area in Welds	A41+A42+A43	0.089	NA	NA
Area in Element	A5	4.250	NA	NA
TOTAL AREA AVAILABLE	Atot	5.272	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	40.9375	0.2500	in.
Based on given Pad Diameter:	41.0000	0.2500	in.
Based on Shell or Nozzle Thickness:	35.3125	0.3750	in.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (23.25*0.2246*1.0+2*0.375*0.2246*1.0*(1-0.86))
= 5.246 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 23.25(1.0 * 0.25 - 1.0 * 0.225) - 2 * 0.375
(1.0 * 0.25 - 1.0 * 0.2246) * (1 - 0.855)
= 0.589 in²

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 0.625) * (0.375 - 0.0525) * 0.855
= 0.345 in²

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 0.25² * 0.86 + (0.0)² * 0.86 + 0.1875² * 1.0
= 0.089 in²

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (41.0 - 24.0) * 0.25 * 1.0
= 4.250 in²

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
Wall Thickness for Internal/External pressures ta = 0.1775 in.
Wall Thickness per UG16(b), tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure trb1 = 0.3496 in.
Wall Thickness tb1 = max(trb1, tr16b) = 0.3496 in.

Wall Thickness tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45 tb3 = 0.4530 in.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[0.453, max(0.3496, 0.1875)]
= 0.3496 in.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(0.1775, 0.3496)
= 0.3496 in.

Available Nozzle Neck Thickness = 0.875 * 0.500 = 0.438 in. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Pad Weld for the Nozzle, Curve: B

Govrn. thk, tg = 0.25, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.898, Temp. Reduction = 10 °F
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B -20 °F
Min Metal Temp. at Required thickness (UCS 66.1) -30 °F

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: B

Govrn. thk, tg = 0.25, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.898, Temp. Reduction = 10 °F
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B -20 °F
Min Metal Temp. at Required thickness (UCS 66.1) -30 °F

Shell to Pad Weld Junction at Pad OD, Curve: B

Govrn. thk, tg = 0.25, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.898, Temp. Reduction = 10 °F
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B -20 °F
Min Metal Temp. at Required thickness (UCS 66.1) -30 °F

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

Govrn. thk, tg = 0.375, tr = 0.225, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.898, Temp. Reduction = 10 °F

Min Metal Temp. w/o impact per UCS-66, Curve B -20 °F
Min Metal Temp. at Required thickness (UCS 66.1) -30 °F

Governing MDMT of the Nozzle : -30 °F
Governing MDMT of the Reinforcement Pad : -30 °F
Governing MDMT of all the sub-joints of this Junction : -30 °F

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c) -20 °F

Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -155 °F

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 75.00/285.00 = 0.263

Weld Size Calculations, Description: Dome 24in Shell

Intermediate Calc. for nozzle/shell Welds Tmin 0.2500 in.
Intermediate Calc. for pad/shell Welds TminPad 0.2500 in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.1750 = 0.7 * tmin.	0.1768 = 0.7 * Wo in.
Pad Weld	0.1250 = 0.5*TminPad	0.1326 = 0.7 * Wp in.

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (5.2456 - 0.5885 + 2 * 0.375 * 0.855 *
(1.0 * 0.25 - 0.2246))20000)
= 93467.94 lb.

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (0.3446 + 4.25 + 0.0886 - 0.0 * 0.86) * 20000
= 93664.48 lb.

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (0.3446 + 0.0 + 0.0534 + (0.1603)) * 20000
= 11167.60 lb.

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (0.3446 + 0.0 + 0.0886 + 4.25 + (0.1603)) * 20000
= 96870.73 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) * 24.0 * 0.25 * 0.49 * 17100
= 78970. lb.

Shear, Pad Element Weld [Spew]:
= (pi/2) * DP * WP * 0.49 * SEW
= (3.1416/2.0) * 41.0 * 0.1875 * 0.49 * 20000
= 118340. lb.

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 11.8125) * (0.5 - 0.125) * 0.7 * 17100
= 166578. lb.

Tension, Pad Groove Weld [Tpgw]:
= (pi/2) * Dlo * Wgpn * 0.74 * Seg

```
  =  (3.1416/2 ) * 24.0 * 0.25 * 0.74 * 20000
  = 139487. lb.
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 24.0 * ( 0.375 - 0.125 ) * 0.74 * 20000
  = 139487. lb.
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 118340 + 166578 ) = 284918 lb.
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 78970 + 139487 + 139487 + 0 ) = 357944 lb.
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 118340 + 139487 + 0 ) = 257827 lb.
```

Summary of Failure Path Calculations:

```
Path 1-1 = 284917 lb., must exceed W = 93467 lb. or W1 = 93664 lb.
Path 2-2 = 357943 lb., must exceed W = 93467 lb. or W2 = 11167 lb.
Path 3-3 = 257826 lb., must exceed W = 93467 lb. or W3 = 96870 lb.
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case       75.000  psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 1.2200 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 11.5950 in.

INPUT VALUES, Nozzle Description: M1:24 From : 30

Pressure for Reinforcement Calculations	P	77.182	psig
Temperature for Internal Pressure	Temp	150	°F
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	20000.00	psi
Shell Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Elliptical Head	D	119.1250	in.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	0.4375	in.
Head Internal Corrosion Allowance	c	0.1250	in.
Head External Corrosion Allowance	co	0.0000	in.

Note : User defined Limit(s) of Reinforcement specified below:

Physical Maximum for Diameter Limit	Dmax	35.8750	in.
Distance from Head Centerline	L1	25.7500	in.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

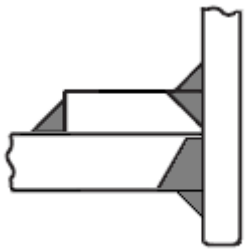
Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	17100.00	psi
Allowable Stress At Ambient	Sna	17100.00	psi
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		24.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness	tn	XS	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	10.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.3750	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.4375	in.
Inside Projection	h	0.7500	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
Pad Material [Impact Tested]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	20000.00	psi
Pad Allowable Stress At Ambient	Spa	20000.00	psi
Diameter of Pad along vessel surface	Dp	31.2500	in.
Thickness of Pad	te	0.3750	in.
Weld leg size between Pad and Shell	Wp	0.3125	in.
Groove weld depth between Pad and Nozzle	Wgpn	0.3750	in.
Reinforcing Pad Width		3.6250	in.

This is a Manway or Access Opening.

Class of attached Flange	150
Grade of attached Flange	GR 1.1

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle With Pad, with Inside projection

Note : Checking Nozzle in the Meridional direction.

Reinforcement CALCULATION, Description: M1:24

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation		24.000	in.
Actual Thickness Used in Calculation		0.500	in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Elliptical Head, Tr [Int. Press]
= (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
= (77.18*0.898*119.375)/(2 *20000.0*1.0-0.2*77.18)
= 0.2070 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= (77.18*12.0)/(17100*1.0+0.4*77.18)
= 0.0541 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

Parallel to Vessel Wall (Diameter Limit)	Dl	37.0498	in.
Parallel to Vessel Wall, opening length	d	18.5249	in.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	0.7812	in.
Normal to Vessel Wall, Inward		0.6250	in.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 17100.0/20000.0)
= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 17100.0/20000.0)
= 0.855

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)

= min(1, 20000.0/20000.0)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(0.855, 1.0)
= 0.855

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	4.992	NA	NA
Area in Shell	A1	1.364	NA	NA
Area in Nozzle Wall	A2	0.432	NA	NA
Area in Inward Nozzle	A3	0.267	NA	NA
Area in Welds	A41+A42+A43	0.218	NA	NA
Area in Element	A5	2.719	NA	NA
TOTAL AREA AVAILABLE	Atot	5.000	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 75.53 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	31.2500	0.3750	in.
Based on given Pad Diameter:	31.2500	0.3750	in.
Based on Shell or Nozzle Thickness:	31.0000	0.4375	in.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (24.0114*0.207*1.0+2*0.375*0.207*1.0*(1-0.86))
= 4.992 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 13.038(1.0 * 0.3125 - 1.0 * 0.207) - 2 * 0.375
(1.0 * 0.3125 - 1.0 * 0.207) * (1 - 0.855)
= 1.364 in²

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2/sin(alpha3)
= (2 * 0.781) * (0.375 - 0.0541) * 0.855/sin(83.1)
= 0.432 in²

Note: See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Inward Nozzle [A3]:
= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.25 * (0.625) * 0.855
= 0.267 in²

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4

= 0.375² * 0.86 + (0.0)² * 0.86 + 0.3125² * 1.0
= 0.218 in²

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (32.0359 - 24.7859) * 0.375 * 1.0
= 2.719 in²

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 0.438, tr = 0.054, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.173, Temp. Reduction = 140 °F

Min Metal Temp. w/o impact per UCS-66, Curve B	-14 °F
Min Metal Temp. at Required thickness (UCS 66.1)	-155 °F
Min Metal Temp. w/o impact per UG-20(f)	-20 °F

Nozzle Neck to Pad Weld for the Nozzle, Curve: B

Govrn. thk, tg = 0.375, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.662, Temp. Reduction = 34 °F
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B	-20 °F
Min Metal Temp. at Required thickness (UCS 66.1)	-54 °F

Nozzle Neck to Pad Weld for Reinf. pad (Impact tested) :

Note: This Element/Detail was specified as being Impact Tested.

Shell to Pad Weld Junction at Pad OD, Curve: B

Govrn. thk, tg = 0.375, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.662, Temp. Reduction = 34 °F
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B	-20 °F
Min Metal Temp. at Required thickness (UCS 66.1)	-54 °F

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

Govrn. thk, tg = 0.438, tr = 0.207, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.662, Temp. Reduction = 34 °F

Min Metal Temp. w/o impact per UCS-66, Curve B	-14 °F
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °F
Min Metal Temp. w/o impact per UG-20(f)	-20 °F

Governing MDMT of the Nozzle	:	-48 °F
Governing MDMT of the Reinforcement Pad	:	-34 °F
Governing MDMT of all the sub-joints of this Junction	:	-34 °F

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)	-20 °F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)	-155 °F

Flange MDMT with Temp reduction per UCS-66(b)(1)(-c) -155 °F

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 77.18/285.00 = 0.271

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: M1:24

Intermediate Calc. for nozzle/shell Welds Tmin 0.3750 in.
Intermediate Calc. for pad/shell Welds TminPad 0.3750 in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.2500 = Min per Code	0.2651 = 0.7 * Wo in.
Pad Weld	0.1875 = 0.5*TminPad	0.2209 = 0.7 * Wp in.

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (4.9922 - 1.3644 + 2 * 0.375 * 0.855 *
(1.0 * 0.3125 - 0.207))20000)
= 73909.29 lb.

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (0.4319 + 2.7188 + 0.2179 - 0.0 * 0.86) * 20000
= 67370.45 lb.

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (0.4319 + 0.2672 + 0.1202 + (0.2004)) * 20000
= 20393.88 lb.

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (0.4319 + 0.2672 + 0.2179 + 2.7188 + (0.2004)) * 20000
= 76722.01 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) * 24.7859 * 0.375 * 0.49 * 17100
= 122334. lb.

Shear, Pad Element Weld [Spew]:
= (pi/2) * DP * WP * 0.49 * SEW
= (3.1416/2.0) * 31.25 * 0.3125 * 0.49 * 20000
= 150330. lb.

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 12.1993) * (0.5 - 0.125) * 0.7 * 17100
= 172033. lb.

Tension, Pad Groove Weld [Tpgw]:
= (pi/2) * Dlo * Wgpn * 0.74 * Seg
= (3.1416/2) * 24.7859 * 0.375 * 0.74 * 20000
= 216082. lb.

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 24.7859 * (0.4375 - 0.125) * 0.74 * 20000
= 180068. lb.

Strength of Failure Paths:

PATH11 = (SPEW + SNW) = (150330 + 172033) = 322363 lb.
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (122334 + 216082 + 180068 + 0) = 518485 lb.
PATH33 = (Spew + Tngw + Sinw)
= (150330 + 180068 + 0) = 330398 lb.

Summary of Failure Path Calculations:
Path 1-1 = 322363 lb., must exceed W = 73909 lb. or W1 = 67370 lb.
Path 2-2 = 518484 lb., must exceed W = 73909 lb. or W2 = 20393 lb.
Path 3-3 = 330398 lb., must exceed W = 73909 lb. or W3 = 76722 lb.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 77.182 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: M1:24

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation 24.000 in.
Actual Thickness Used in Calculation 0.500 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Elliptical Head, Tr [Int. Press]
= (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
= (77.18*0.898*119.375)/(2 *20000.0*1.0-0.2*77.18)
= 0.2070 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= (77.18*12.0)/(17100*1.0+0.4*77.18)
= 0.0541 in.

UG-40, Limits of Reinforcement : [Internal Pressure]
Parallel to Vessel Wall (Diameter Limit) Dl 35.8750 in.
Parallel to Vessel Wall, opening length d 17.9375 in.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp 0.7812 in.
Normal to Vessel Wall, Inward 0.6250 in.

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5	Design	External	Mapnc

Area Required	Ar	4.835	NA	NA
Area in Shell	A1	1.321	NA	NA
Area in Nozzle Wall	A2	0.429	NA	NA
Area in Inward Nozzle	A3	0.267	NA	NA
Area in Welds	A41+A42+A43	0.218	NA	NA
Area in Element	A5	2.719	NA	NA
TOTAL AREA AVAILABLE	Atot	4.953	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	30.9375	0.3750	in.
Based on given Pad Diameter:	31.2500	0.3750	in.
Based on Shell or Nozzle Thickness:	30.0000	0.4375	in.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (23.25*0.207*1.0+2*0.375*0.207*1.0*(1-0.86))
= 4.835 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 12.625(1.0 * 0.3125 - 1.0 * 0.207) - 2 * 0.375
(1.0 * 0.3125 - 1.0 * 0.207) * (1 - 0.855)
= 1.321 in²

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 0.781) * (0.375 - 0.0541) * 0.855
= 0.429 in²

Area Available in Inward Nozzle [A3]:
= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.25 * (0.625) * 0.855
= 0.267 in²

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 0.375² * 0.86 + (0.0)² * 0.86 + 0.3125² * 1.0
= 0.218 in²

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (31.25 - 24.0) * 0.375 * 1.0
= 2.719 in²

Weld Size Calculations, Description: M1:24

Intermediate Calc. for nozzle/shell Welds	Tmin	0.3750	in.
Intermediate Calc. for pad/shell Welds	TminPad	0.3750	in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.2500 = Min per Code	0.2651 = 0.7 * Wo in.
Pad Weld	0.1875 = 0.5*TminPad	0.2209 = 0.7 * Wp in.

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

Weld Load [W]:
```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, (4.8346 - 1.3208 + 2 * 0.375 * 0.855 *
   (1.0 * 0.3125 - 0.207 ) )20000)
 = 71630.14 lb.
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 0.4287 + 2.7188 + 0.2179 - 0.0 * 0.86 ) * 20000
 = 67307.78 lb.
```

Weld Load [W2]:
```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 0.4287 + 0.2672 + 0.1202 + ( 0.2004 ) ) * 20000
 = 20331.22 lb.
```

Weld Load [W3]:
```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = (  0.4287 + 0.2672 + 0.2179 + 2.7188 + ( 0.2004 ) ) * 20000
 = 76659.34 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 ) * 24.0 * 0.375 * 0.49 * 17100
 = 118455. lb.
```

Shear, Pad Element Weld [Spew]:
```
 = (pi/2) * DP * WP * 0.49 * SEW
 = ( 3.1416/2.0 ) * 31.25 * 0.3125 * 0.49 * 20000
 = 150330. lb.
```

Shear, Nozzle Wall [Snw]:
```
 = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
 = (3.1416 * 11.8125) * ( 0.5 - 0.125 ) * 0.7 * 17100
 = 166578. lb.
```

Tension, Pad Groove Weld [Tpgw]:
```
 = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
 =  (3.1416/2 ) * 24.0 * 0.375 * 0.74 * 20000
 = 209230. lb.
```

Tension, Shell Groove Weld [Tngw]:
```
 = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
 = ( 3.1416/2.0 ) * 24.0 * ( 0.4375 - 0.125 ) * 0.74 * 20000
 = 174358. lb.
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 150330 + 166578 ) = 316908 lb.
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 118455 + 209230 + 174358 + 0 ) = 502044 lb.
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 150330 + 174358 + 0 ) = 324689 lb.
```

Summary of Failure Path Calculations:

```
Path 1-1 = 316907 lb., must exceed W = 71630 lb. or W1 = 67307 lb.
Path 2-2 = 502043 lb., must exceed W = 71630 lb. or W2 = 20331 lb.
Path 3-3 = 324688 lb., must exceed W = 71630 lb. or W3 = 76659 lb.
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case       77.182  psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 3.7143 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 14.1648 in.

INPUT VALUES, Nozzle Description: N5 10in Water From : 30

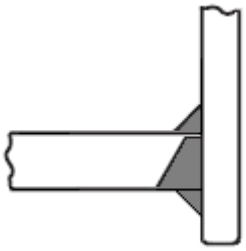
Pressure for Reinforcement Calculations	P	78.555	psig
Temperature for Internal Pressure	Temp	150	°F
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	20000.00	psi
Shell Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Elliptical Head	D	119.1250	in.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	0.4375	in.
Head Internal Corrosion Allowance	c	0.1250	in.
Head External Corrosion Allowance	co	0.0000	in.
Distance from Head Centerline	L1	45.9028	in.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	20000.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		ID	
Layout Angle		145.88	deg
Diameter		10.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	1.0000	in.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	3.4425	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.3750	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.4375	in.
Inside Projection	h	0.3125	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
Class of attached Flange		150	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, with Inside projection

Note : Checking Nozzle in the Meridional direction.

Reinforcement CALCULATION, Description: N5 10in Water

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation	10.000	in.
Actual Thickness Used in Calculation	1.000	in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Elliptical Head, Tr [Int. Press]
= (P*D*K)/(2*Sv*E-0.2*P) Appendix 1-4(c)
= (78.55*119.375*0.997)/(2*20000.0*1.0-0.2*78.55)
= 0.2339 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
= (78.55*5.12)/(20000*1.0-0.6*78.55)
= 0.0202 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

Parallel to Vessel Wall (Diameter Limit)	Dl	24.1355	in.
Parallel to Vessel Wall, opening length	d	12.0677	in.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	0.7812	in.
Normal to Vessel Wall, Inward		0.1875	in.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 20000.0/20000.0)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 20000.0/20000.0)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5	Design	External	Mapnc

Area Required	Ar	2.822	NA	NA
Area in Shell	A1	0.949	NA	NA
Area in Nozzle Wall	A2	1.472	NA	NA
Area in Inward Nozzle	A3	0.281	NA	NA
Area in Welds	A41+A42+A43	0.141	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	2.843	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 58.14 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (12.0677*0.2339*1.0+2*0.875*0.2339*1.0*(1-1.0))
= 2.822 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 12.068(1.0 * 0.3125 - 1.0 * 0.234) - 2 * 0.875
(1.0 * 0.3125 - 1.0 * 0.2339) * (1 - 1.0)
= 0.949 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 0.781)(0.875 - 0.0202)1.0/sin(65.1)
= 1.472 in²

Note: See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Inward Nozzle [A3]:
= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.75 * (0.1875) * 1.0
= 0.281 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.375² * 1.0 + (0.0)² * 1.0
= 0.141 in²

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.438, tr = 0.234, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.748, Temp. Reduction = 25 °F

Min Metal Temp. w/o impact per UCS-66, Curve B -14 °F
Min Metal Temp. at Required thickness (UCS 66.1) -39 °F
Min Metal Temp. w/o impact per UG-20(f) -20 °F

Governing MDMT of all the sub-joints of this Junction : -39 °F

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c) -20 °F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -155 °F

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 78.55/285.00 = 0.276

Weld Size Calculations, Description: N5 10in Water

Intermediate Calc. for nozzle/shell Welds Tmin 0.3750 in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.2500 = Min per Code	0.2651 = 0.7 * Wo in.

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (2.8224 - 0.9488 + 2 * 0.875 * 1.0 *
(1.0 * 0.3125 - 0.2339))20000)
= 40222.62 lb.

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (1.472 + 0.0 + 0.1406 - 0.0 * 1.0) * 20000
= 32252.78 lb.

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (1.472 + 0.2812 + 0.1406 + (0.5469)) * 20000
= 48815.28 lb.

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (1.472 + 0.2812 + 0.1406 + 0.0 + (0.5469)) * 20000
= 48815.28 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) * 14.1281 * 0.375 * 0.49 * 20000
= 81557. lb.

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 6.549) * (1.0 - 0.125) * 0.7 * 20000
= 252033. lb.

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 14.1281 * (0.4375 - 0.125) * 0.74 * 20000
= 102640. lb.

Strength of Failure Paths:

PATH11 = (SONW + SNW) = (81557 + 252033) = 333590 lb.

PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (81557 + 0 + 102640 + 0) = 184197 lb.
PATH33 = (Sonw + Tngw + Sinw)
= (81557 + 102640 + 0) = 184197 lb.

Summary of Failure Path Calculations:
Path 1-1 = 333590 lb., must exceed W = 40222 lb. or W1 = 32252 lb.
Path 2-2 = 184196 lb., must exceed W = 40222 lb. or W2 = 48815 lb.
Path 3-3 = 184196 lb., must exceed W = 40222 lb. or W3 = 48815 lb.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 78.555 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: N5 10in Water

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation 10.000 in.
Actual Thickness Used in Calculation 1.000 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Elliptical Head, Tr [Int. Press]
= (P*D*K)/(2*Sv*E-0.2*P) Appendix 1-4(c)
= (78.55*119.375*0.997)/(2*20000.0*1.0-0.2*78.55)
= 0.2339 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
= (78.55*5.12)/(20000*1.0-0.6*78.55)
= 0.0202 in.

UG-40, Limits of Reinforcement : [Internal Pressure]
Parallel to Vessel Wall (Diameter Limit) Dl 20.5000 in.
Parallel to Vessel Wall, opening length d 10.2500 in.
Normal to Vessel Wall (Thickness Limit), no pad Tlnp 0.7812 in.
Normal to Vessel Wall, Inward 0.1875 in.

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.397	NA	NA
Area in Shell	A1	0.806	NA	NA
Area in Nozzle Wall	A2	1.336	NA	NA
Area in Inward Nozzle	A3	0.281	NA	NA
Area in Welds	A41+A42+A43	0.141	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	2.563	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (10.25*0.2339*1.0+2*0.875*0.2339*1.0*(1-1.0))
= 2.397 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 10.25(1.0 * 0.3125 - 1.0 * 0.234) - 2 * 0.875
(1.0 * 0.3125 - 1.0 * 0.2339) * (1 - 1.0)
= 0.806 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 0.781)(0.875 - 0.0202)1.0
= 1.336 in²

Area Available in Inward Nozzle [A3]:
= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.75 * (0.1875) * 1.0
= 0.281 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.375² * 1.0 + (0.0)² * 1.0
= 0.141 in²

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

```
Wall Thickness for Internal/External pressures      ta = 0.1452 in.
Wall Thickness per UG16(b),                      tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure     trb1 = 0.3589 in.
Wall Thickness                 tb1 = max(trb1, tr16b) = 0.3589 in.
Wall Thickness                 tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45                   tb3 = 0.4530 in.
```

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[0.453, max(0.3589, 0.1875)]
= 0.3589 in.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(0.1452, 0.3589)
= 0.3589 in.

Available Nozzle Neck Thickness = 1.0000 in. --> OK

Weld Size Calculations, Description: N5 10in Water

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.3750  in.
```

Results Per UW-16.1:

```
                     Required Thickness    Actual Thickness
Nozzle Weld         0.2500 = Min per Code 0.2651 = 0.7 * Wo in.
```

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (2.3972 - 0.8059 + 2 * 0.875 * 1.0 *
(1.0 * 0.3125 - 0.2339))20000)
= 34578.46 lb.

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (1.3357 + 0.0 + 0.1406 - 0.0 * 1.0) * 20000
= 29525.71 lb.

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (1.3357 + 0.2812 + 0.1406 + (0.5469)) * 20000
= 46088.21 lb.

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (1.3357 + 0.2812 + 0.1406 + 0.0 + (0.5469)) * 20000
= 46088.21 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) * 12.0 * 0.375 * 0.49 * 20000
= 69272. lb.

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 5.5625) * (1.0 - 0.125) * 0.7 * 20000
= 214070. lb.

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 12.0 * (0.4375 - 0.125) * 0.74 * 20000
= 87179. lb.

Strength of Failure Paths:

PATH11 = (SONW + SNW) = (69272 + 214070) = 283342 lb.
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (69272 + 0 + 87179 + 0) = 156451 lb.
PATH33 = (Sonw + Tngw + Sinw)
= (69272 + 87179 + 0) = 156451 lb.

Summary of Failure Path Calculations:
Path 1-1 = 283342 lb., must exceed W = 34578 lb. or W1 = 29525 lb.
Path 2-2 = 156451 lb., must exceed W = 34578 lb. or W2 = 46088 lb.
Path 3-3 = 156451 lb., must exceed W = 34578 lb. or W3 = 46088 lb.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 78.555 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 3.0646 in.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 6.9906 in.

INPUT VALUES, Nozzle Description: N6 10in. OIL LL From : 40

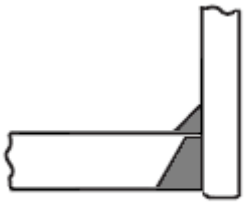
Pressure for Reinforcement Calculations	P	75.000	psig
Temperature for Internal Pressure	Temp	150	°F
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	20000.00	psi
Shell Allowable Stress At Ambient	Sva	20000.00	psi
Outside Diameter of Bolted Blind Flange	D	32.0000	in.
Head Finished (Minimum) Thickness	t	1.8800	in.
Head Internal Corrosion Allowance	c	0.1250	in.
Head External Corrosion Allowance	co	0.0000	in.
Distance from Head Centerline	L1	0.0000	in.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	20000.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		ID	
Layout Angle		0.00	deg
Diameter		10.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	7.8125	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.3750	in.
Groove weld depth between Nozzle and Vessel	Wgnv	1.8800	in.
Inside Projection	h	0.0000	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
Class of attached Flange		150	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: N6 10in. OIL LL

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              9.562  in.
Actual Thickness Used in Calculation                    0.594  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
= (75.0*4.91)/(20000*1.0-0.6*75.0)
= 0.0184 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)            Dl    19.6240  in.
Parallel to Vessel Wall, opening length              d     9.8120  in.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.1725  in.
```

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 20000.0/20000.0)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 20000.0/20000.0)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	5.251	NA	NA
Area in Shell	A1	6.719	NA	NA
Area in Nozzle Wall	A2	1.057	NA	NA
Area in Inward Nozzle	A3	0.000	NA	NA
Area in Welds	A41+A42+A43	0.141	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	7.916	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5 * d * t + t * tn(1-fr1) per UG-39(a)(1)
= 0.5*9.812*1.0702+1.0702*0.469(1-1.0)
= 5.251 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 9.812(1.0 * 1.755 - 1.0 * 1.07) - 2 * 0.469
(1.0 * 1.755 - 1.0 * 1.0702) * (1 - 1.0)
= 6.719 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 1.172)(0.469 - 0.0184)1.0
= 1.057 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.375² * 1.0 + (0.0)² * 1.0
= 0.141 in²

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

Wall Thickness for Internal/External pressures ta = 0.1434 in.
Wall Thickness per UG16(b), tr16b = 0.1875 in.
Wall Thickness, shell/head, internal pressure trb1 = 1.1952 in.
Wall Thickness tb1 = max(trb1, tr16b) = 1.1952 in.
Wall Thickness tb2 = max(trb2, tr16b) = 0.1875 in.
Wall Thickness per table UG-45 tb3 = 0.4440 in.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[0.444, max(1.1952, 0.1875)]
= 0.4440 in.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(0.1434, 0.444)
= 0.4440 in.

Available Nozzle Neck Thickness = 0.875 * 0.594 = 0.520 in. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

Note:
This Material was specified as being an Impact Tested (Low Temperature) Material.

Impact Test Temperature provided per Specification -50 °F

Calculated Minimum Design Metal Temperature -155 °F

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

Govrn. thk, tg = 0.52, tr = 0.018, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.047, Temp. Reduction = 140 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -4 °F
Min Metal Temp. at Required thickness (UCS 66.1)          -155 °F
Min Metal Temp. w/o impact per UG-20(f)                    -20 °F

Governing MDMT of all the sub-joints of this Junction  :  -155 °F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification       -50 °F
Flange MDMT with Temp reduction per UCS-66(i)(2)          -155 °F
Flange MDMT with Temp reduction per UCS-66(i)(3)          -155 °F
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
`Design Pressure/Ambient Rating = 75.00/285.00 = 0.263`

Note:
Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: N6 10in. OIL LL

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.4690  in.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          0.2500 = Min per Code 0.2651 = 0.7 * Wo in.
```

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

Weld Load [W]:

```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, (5.2506 - 6.7188 + 2 * 0.469 * 1.0 *
   (1.0 * 1.755 - 1.0702 ) )20000)
 = max( 0, -16517.97) lb.
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 1.0566 + 0.0 + 0.1406 - 0.0 * 1.0 ) * 20000
 = 23943.81 lb.
```

Weld Load [W2]:

```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 1.0566 + 0.0 + 0.1406 + ( 1.6462 ) ) * 20000
 = 56867.61 lb.
```

Weld Load [W3]:

```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = ( 1.0566 + 0.0 + 0.1406 + 0.0 + ( 1.6462 ) ) * 20000
 = 56867.61 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) * 10.75 * 0.375 * 0.49 * 20000
= 62056. lb.

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 5.1405) * (0.594 - 0.125) * 0.7 * 20000
= 106037. lb.

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 10.75 * (1.88 - 0.125) * 0.74 * 20000
= 438599. lb.

Strength of Failure Paths:

PATH11 = (SONW + SNW) = (62056 + 106037) = 168093 lb.
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (62056 + 0 + 438599 + 0) = 500655 lb.
PATH33 = (Sonw + Tngw + Sinw)
= (62056 + 438599 + 0) = 500655 lb.

Summary of Failure Path Calculations:
Path 1-1 = 168092 lb., must exceed W = 0 lb. or W1 = 23943 lb.
Path 2-2 = 500654 lb., must exceed W = 0 lb. or W2 = 56867 lb.
Path 3-3 = 500654 lb., must exceed W = 0 lb. or W3 = 56867 lb.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 75.000 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 9.6945 in.

INPUT VALUES, Nozzle Description: N2 6in. GAS OUT From : 50

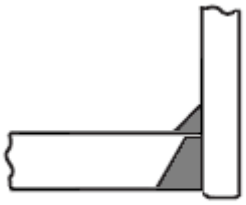
Pressure for Reinforcement Calculations	P	75.000	psig
Temperature for Internal Pressure	Temp	150	°F
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	20000.00	psi
Shell Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Elliptical Head	D	23.2500	in.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	0.3750	in.
Head Internal Corrosion Allowance	c	0.1250	in.
Head External Corrosion Allowance	co	0.0000	in.
Distance from Head Centerline	L1	0.0000	in.
User Entered Minimum Design Metal Temperature		-20.00	°F

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	17100.00	psi
Allowable Stress At Ambient	Sna	17100.00	psi
Diameter Basis (for tr calc only)		ID	
Layout Angle		0.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness	tn	XS	
Flange Material		SA-105	
Flange Type		None	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	6.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.2500	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.3750	in.
Inside Projection	h	0.0000	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
This is a Manway or Access Opening.			
Class of attached Flange		150	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: N2 6in. GAS OUT

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              5.761  in.
Actual Thickness Used in Calculation                    0.432  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Elliptical Head, Tr [Int. Press]
= (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
= (75.0*0.891*23.5)/(2 *20000.0*1.0-0.2*75.0)
= 0.0393 in.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
= (75.0*3.01)/(17100*1.0-0.6*75.0)
= 0.0132 in.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)            Dl    12.0220  in.
Parallel to Vessel Wall, opening length              d     6.0110  in.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.6250  in.
```

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 17100.0/20000.0)
= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 17100.0/20000.0)
= 0.855

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(0.855, 1.0)
= 0.855

Results of Nozzle Reinforcement Area Calculations: (in²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.240	NA	NA
Area in Shell	A1	1.248	NA	NA
Area in Nozzle Wall	A2	0.314	NA	NA

Area in Inward Nozzle	A3	0.000	NA	NA
Area in Welds	A41+A42+A43	0.053	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	1.615	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (6.011*0.0393*1.0+2*0.307*0.0393*1.0*(1-0.86))
= 0.240 in²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 6.011(1.0 * 0.25 - 1.0 * 0.039) - 2 * 0.307
(1.0 * 0.25 - 1.0 * 0.0393) * (1 - 0.855)
= 1.248 in²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 0.625)(0.307 - 0.0132) 0.855
= 0.314 in²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 0.25² * 0.855 + (0.0)² * 0.855
= 0.053 in²

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.375, tr = 0.039, c = 0.125 in., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.157, Temp. Reduction = 140 °F

Min Metal Temp. w/o impact per UCS-66, Curve B -20 °F
Min Metal Temp. at Required thickness (UCS 66.1) -155 °F

Governing MDMT of all the sub-joints of this Junction : -155 °F

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c) -20 °F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -155 °F

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 75.00/285.00 = 0.263

Weld Size Calculations, Description: N2 6in. GAS OUT

Intermediate Calc. for nozzle/shell Welds Tmin 0.2500 in.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.1750 = 0.7 * tmin.	0.1768 = 0.7 * Wo in.

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

Weld Load [W]:
```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, ( 0.2396 - 1.2479 + 2 * 0.307 * 0.855 *
   (1.0 * 0.25 - 0.0393 ) )20000)
 = max( 0, -17954.62) lb.
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 0.314 + 0.0 + 0.0534 - 0.0 * 0.86 ) * 20000
 = 7348.37 lb.
```

Weld Load [W2]:
```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 0.314 + 0.0 + 0.0534 + ( 0.1312 ) ) * 20000
 = 9973.22 lb.
```

Weld Load [W3]:
```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = (  0.314 + 0.0 + 0.0534 + 0.0 + ( 0.1312 ) ) * 20000
 = 9973.22 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 ) * 6.625 * 0.25 * 0.49 * 17100
 = 21799. lb.
```

Shear, Nozzle Wall [Snw]:
```
 = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
 = (3.1416 * 3.159) * ( 0.432 - 0.125 ) * 0.7 * 17100
 = 36470. lb.
```

Tension, Shell Groove Weld [Tngw]:
```
 = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
 = ( 3.1416/2.0 ) * 6.625 * ( 0.375 - 0.125 ) * 0.74 * 20000
 = 38504. lb.
```

Strength of Failure Paths:

```
 PATH11 = ( SONW + SNW ) = ( 21799 + 36470 ) = 58269 lb.
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
        = ( 21799 + 0 + 38504 + 0 ) = 60303 lb.
 PATH33 = ( Sonw + Tngw + Sinw )
        = ( 21799 + 38504 + 0 ) = 60303 lb.
```

Summary of Failure Path Calculations:
```
Path 1-1 = 58268 lb., must exceed W = 0 lb. or W1 = 7348 lb.
Path 2-2 = 60303 lb., must exceed W = 0 lb. or W2 = 9973 lb.
Path 3-3 = 60303 lb., must exceed W = 0 lb. or W3 = 9973 lb.
```

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 75.000 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.2601 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 6.6351 in.

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk in.	Reinforcing Pad Diameter in.	Pad Thk in.	Cut Length in.	Flg Class
N13 2in PI	2.000 in	XXS	None	2.375	0.436	...	...	3.39	...
N14A 2in T	2.000 in	XXS	None	2.375	0.436	...	...	3.64	...
N16 2in LLSD	2.000 in	XXS	None	2.375	0.436	...	...	4.14	...
N22 2in. HLSD	2.000 in	XXS	None	2.375	0.436	...	...	3.39	...
N14B 2in. THER	2.000 in	XXS	None	2.375	0.436	...	...	3.64	...
N15 2in. THER.	2.000 in	XXS	None	2.375	0.436	...	...	3.64	...
N23 2in. T-12	2.000 in	XXS	None	2.375	0.436	...	...	3.64	...
N17B 2in Gauge	2.000 in	XXS	None	2.375	0.436	...	...	3.51	...
N18A 2 Gauge	2.000 in	XXS	None	2.375	0.436	...	...	3.48	...
N18B 2in Gauge	2.000 in	XXS	None	2.375	0.436	...	...	4.02	...
N17A 2in Gauge	2.000 in	XXS	None	2.375	0.436	...	...	4.03	...
N19A 2in. GG	2.000 in	XXS	None	2.375	0.436	...	...	4.03	...
N19B 2in. GG	2.000 in	XXS	None	2.375	0.436	...	...	3.51	...
N20A 2in. GG	2.000 in	XXS	None	2.375	0.436	...	...	3.48	...
N20B 2in. GG	2.000 in	XXS	None	2.375	0.436	...	...	4.02	...
N8A 4in Drain	4.000 in	XXS	None	4.500	0.674	...	...	3.62	...
N9 4in OilDrain	4.000 in	XXS	None	4.500	0.674	...	...	3.75	...
N10 4in Anode	4.000 in	XS	None	4.500	0.337	8.50	0.25	8.16	...
N8B 4in. DRAIN	4.000 in	XXS	None	4.500	0.674	...	...	3.62	...
N11 4in. ANODE	4.000 in	XS	None	4.500	0.337	8.50	0.25	8.16	...
N12 4in. ANODE	4.000 in	XS	None	4.500	0.337	8.50	0.25	8.16	...
N3:6in Outlet	6.000 in	XXS	None	6.625	0.864	...	...	7.13	...
N7 6in PSV	6.000 in	Actual	LWN	7.760	0.880	...	...	6.75	150
N1 6in Inlet	6.000 in	Actual	LWN	7.760	0.880	...	...	6.75	150
N4 6in. OIL OUT	6.000 in	XXS	None	6.625	0.864	...	...	6.97	...
N2 6in. GAS OUT	6.000 in	XS	None	6.625	0.432	...	...	6.64	150
N5 10in Water	10.000 in	Actual	LWN	12.000	1.000	...	...	6.99	150
N6 10in. OIL LL	10.000 in	80	WNF	10.750	0.594	...	...	9.69	150
Firebox Small	24.000 in	Actual	None	24.000	0.750	...	...	14.07	...
M2:24in ShellMW	24.000 in	XS	WNF	24.000	0.500	45.50	0.25	17.46	150
Dome 24in Shell	24.000 in	XS	None	24.000	0.500	41.00	0.25	11.60	150
M1:24	24.000 in	XS	WNF	24.000	0.500	31.25	0.38	14.16	150
Firebox Tall	49.500 in	Actual	None	49.500	0.750	...	...	12.56	...

General Notes for the above table:

The Cut Length is the Outside Projection + Inside Projection + Drop + In Plane Shell Thickness. This value does not include weld gaps, nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must be increased. The Re-Pad WIDTH around the nozzle is calculated as follows: Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller and thinner section.

Nozzle Material and Weld Fillet Leg Size Details (in.):

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld

N13 2in PI	SA-106 B	0.375	0.250	...	...	...
N14A 2in T	SA-106 B	0.375	0.250	...	...	...
N16 2in LLS	SA-106 B	0.375	0.250	...	...	...
N22 2in. HL	SA-106 B	0.375	0.250	...	...	...
N14B 2in. T	SA-106 B	0.375	0.250	...	...	...
N15 2in. TH	SA-106 B	0.375	0.250	...	...	...
N23 2in. T-	SA-106 B	0.375	0.250	...	...	...
N17B 2in Ga	SA-106 B	0.438	0.312	...	...	...
N18A 2 Gaug	SA-106 B	0.438	0.312	...	...	...
N18B 2in Ga	SA-106 B	0.438	0.312	...	...	...
N17A 2in Ga	SA-106 B	0.438	0.312	...	...	...
N19A 2in. G	SA-106 B	0.438	0.312	...	...	...
N19B 2in. G	SA-106 B	0.438	0.312	...	...	...
N20A 2in. G	SA-106 B	0.438	0.312	...	...	...
N20B 2in. G	SA-106 B	0.438	0.312	...	...	...
N8A 4in Dra	SA-106 B	0.375	0.438	...	...	0.250
N9 4in OilD	SA-106 B	0.375	0.250	...	...	...
N10 4in Ano	SA-106 B	0.375	0.250	0.188	0.250	...
N8B 4in. DR	SA-106 B	0.375	0.438	...	...	0.250
N11 4in. AN	SA-106 B	0.375	0.250	0.188	0.250	...
N12 4in. AN	SA-106 B	0.375	0.250	0.188	0.250	...
N3:6in Outl	SA-106 B	0.375	0.468	...	...	...
N7 6in PSV	SA-105	0.375	0.250	...	...	...
N1 6in Inle	SA-350 LF2	0.375	0.250	...	...	...
N4 6in. OIL	SA-106 B	0.375	0.468	...	...	...
N2 6in. GAS	SA-106 B	0.375	0.250	...	...	...
N5 10in Wat	SA-105	0.438	0.375	...	...	...
N6 10in. OI	SA-350 LF2	1.880	0.375	...	...	...
Firebox Sma	SA-516 70	0.562	0.375	...	...	...
M2:24in She	SA-106 B	0.375	0.250	0.188	0.250	...
Dome 24in S	SA-106 B	0.375	0.250	0.188	0.250	...
M1:24	SA-106 B	0.438	0.375	0.312	0.375	...
Firebox Tal	SA-516 70	0.562	0.375	...	...	...

Note: The Outside projections below do not include the flange thickness.

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum ft.	Layout Angle deg	Proj Outside in.	Proj Inside in.	Installed in Component
N13 2in PI	16.583	0.0	3.00	0.00	Node: 20
N14A 2in T	28.000	78.5	3.00	0.25	Node: 20
N16 2in LLSD	25.000	60.0	3.00	0.25	Node: 20
N22 2in. HLSD	7.000	0.0	3.00	0.00	Node: 20
N14B 2in. THER	28.000	281.5	3.00	0.25	Node: 20
N15 2in. THER.	27.000	78.5	3.00	0.25	Node: 20
N23 2in. T-12	26.000	78.5	3.00	0.25	Node: 20
N17B 2in Gauge	...	252.0	3.00	0.00	Node: 30
N18A 2 Gauge	...	315.0	3.00	0.00	Node: 30
N18B 2in Gauge	...	183.0	3.00	0.00	Node: 30
N17A 2in Gauge	...	352.0	3.00	0.00	Node: 30
N19A 2in. GG	...	8.0	3.00	0.00	Node: 30
N19B 2in. GG	...	108.0	3.00	0.00	Node: 30
N20A 2in. GG	...	45.0	3.00	0.00	Node: 30
N20B 2in. GG	...	177.0	3.00	0.00	Node: 30
N8A 4in Drain	16.500	180.0	3.00	0.25	Node: 20
N9 4in OilDrain	29.417	185.7	3.00	0.38	Node: 20

N10 4in Anode	7.500	137.2	5.00	0.00	Node: 20
N8B 4in. DRAIN	24.333	180.0	3.00	0.25	Node: 20
N11 4in. ANODE	17.083	137.2	5.00	0.25	Node: 20
N12 4in. ANODE	28.333	137.2	5.00	0.00	Node: 20
N3:6in Outlet	0.583	154.6	5.00	0.38	Node: 20
N7 6in PSV	13.167	0.0	6.00	0.38	Node: 20
N1 6in Inlet	28.000	0.0	6.00	0.38	Node: 20
N4 6in. OIL OUT	0.583	203.3	5.00	0.38	Node: 20
N2 6in. GAS OUT	...	0.0	6.00	0.00	Node: 50
N5 10in Water	...	145.9	3.44	0.31	Node: 30
N6 10in. OIL LL	...	0.0	7.81	0.00	Node: 40
Firebox Small	...	270.0	10.00	1.00	Node: 10
M2:24in ShellMW	13.500	113.6	10.00	0.00	Node: 20
Dome 24in Shell	3.167	0.0	10.00	0.00	Node: 20
M1:24	...	270.0	10.00	0.75	Node: 30
Firebox Tall	...	90.0	3.00	1.23	Node: 10

ASME Code, Section VIII Division 1, 2017

Diameter Spec : 120.000 in. OD

Vessel Design Length, Tangent to Tangent	30.33	ft.
Specified Datum Line Distance	0.17	ft.
Shell Material	SA-516 70	
Nozzle Material	SA-106 B	
Nozzle Material	SA-105	
Nozzle Material	SA-350 LF2 [Impact Tested]	
Re-Pad Material	SA-516 70	
Internal Design Temperature	150	°F
Internal Design Pressure	75.000	psig
External Design Temperature	150	°F
Maximum Allowable Working Pressure	75.000	psig
Hydrostatic Test Pressure	98.000	psig
Required Minimum Design Metal Temperature	-20	°F
Warmest Computed Minimum Design Metal Temperature	-25	°F
Wind Design Code	NBC-2015	
Earthquake Design Code	ASCE/SEI 7-16	

Element Pressures and MAWP (psig):

Element Description	Design Pres. + Stat. head	External Pressure	M.A.W.P	Corrosion Allowance	Str. Flange Governing
Ellipse	79.338	0.000	142.869	0.1250	No
Cylinder	79.293	0.000	79.180	0.1250	N/A
Ellipse	79.338	0.000	100.611	0.1250	No
Body Flg	75.000	0.000	227.180	0.1250	N/A
Ellipse	75.000	0.000	420.168	0.1250	Yes

Liquid Level: 10.00 ft. Dens.: 62.400 lb./ft³ Sp. Gr.: 1.000

Element Types and Properties:

Element Type	"To" Elev ft.	Length ft.	Element Thk in.	R e q d Thk Int.	Thk Ext.	Joint Eff Long	Circ
Ellipse	0.00	0.167	0.625	0.362	0.188	1.00	0.85
Cylinder	30.00	30.000	0.375	0.363	No Calc	1.00	0.70
Ellipse	30.17	0.167	0.500	0.362	0.188	1.00	0.85
Body Flg	32.15	0.000	1.880	1.203	1.156	1.00	1.00
Ellipse	3.17	0.000	0.375	0.188	0.188	1.00	0.85

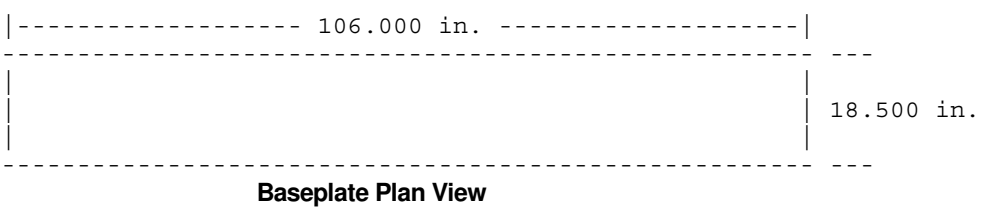
Element thicknesses are shown as Nominal if specified, otherwise are Minimum

Saddle Parameters:

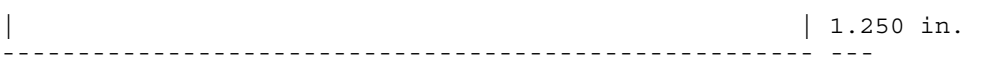
Saddle Width	18.000	in.
Saddle Bearing Angle	154.000	deg.
Centerline Dimension	78.750	in.
Wear Pad Width	25.000	in.

Wear Pad Thickness	0.250	in.
Wear Pad Bearing Angle	167.000	deg.
Distance from Saddle to Tangent	50.000	in.
Baseplate Length	106.000	in.
Baseplate Thickness	1.250	in.
Baseplate Width	18.500	in.
Number of Ribs (including outside ribs)	2	
Rib Thickness	0.375	in.
Web Thickness	0.375	in.
Height of Center Web	17.500	in.
Number of Bolts in Baseplate	2	

Baseplate Sketch



Baseplate Plan View



Baseplate Side View

Summary of Maximum Saddle Loads, Operating Case :

Maximum Vertical Saddle Load	126730.12	lb.
Maximum Transverse Saddle Shear Load	13202.12	lb.
Maximum Longitudinal Saddle Shear Load	39452.40	lb.

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	103311.38	lb.
Maximum Transverse Saddle Shear Load	830.07	lb.
Maximum Longitudinal Saddle Shear Load	740.66	lb.

Weights:

Fabricated - Bare W/O Removable Internals	27415.8	lbm
Shop Test - Fabricated + Water (Full)	195075.4	lbm
Shipping - Fab. + Rem. Intls.+ Shipping App.	27415.8	lbm
Erected - Fab. + Rem. Intls.+ Insul. (etc)	31915.8	lbm
Empty - Fab. + Intls. + Details + Wghts.	31915.8	lbm
Operating - Empty + Operating Liquid (No CA)	194577.4	lbm
Field Test - Empty Weight + Water (Full)	190421.3	lbm