طرح نگهداشت و افزایش تولید 27 مخزن

THERMAL/MECHANICAL CALCULATION BOOK FOR REBOILER (R-100)

نگهداشت و افزایش تولید میدان نفتی بینک

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Status:

IFA: Issued For Approval
IFI: Issued For Information
AFC: Approved For Construction

REVISION RECORD SHEET

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نگهداشت و افزایش تولید میدان نفتی بینک
سطح الارض و ابنیه تحت الارض

خرید بسته نم زدای گاز ایستگاه تقویت فشار گاز بینک
(قرارداد BK-HD-GCS-CO-0010_08)

شماره پیمان:
053 – 073 – 9184

THERMAL/MECHANICAL CALCULATION BOOK FOR REBOILER (R-100)

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DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

```
ASME Code Version      : 2019

Analysis Performed by :

Job File               : C:\USERS\TECHNICAL2\DESKTOP\BINAK\DESIGN\R-100\R

Date of Analysis       : Dec 28,2024   10:31am

PV Elite 2020, January 2020
```

ASME Code, Section VIII Division 1, 2019

```
Diameter Spec : 1200.000 mm. ID
Vessel Design Length, Tangent to Tangent             6479.52  mm.

Specified Datum Line Distance                           0.00  mm.

Internal Design Temperature                              234  °C
Internal Design Pressure                               4.100  bars

External Design Temperature                              100  °C
External Design Pressure                               1.034  bars

Maximum Allowable Working Pressure                     5.406  bars
External Max. Allowable Working Pressure               1.404  bars
Hydrostatic Test Pressure                              5.330  bars

Required Minimum Design Metal Temperature                5.0  °C
Warmest Computed Minimum Design Metal Temperature      -14.0  °C

Wind Design Code                                   ASCE-2010
Earthquake Design Code                           ASCE 7-2010
```

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-516 70	...	...	K02700	No	No
Head	SA-516 70	...	...	K02700	No	No
Flange	SA-105	...	...	K03504	No	No
Nozzle	SA-105	...	...	K03504	No	No
Nozzle	SA-516 70	...	...	K02700	No	No
Nozzle	SA-106 B	...	...	K03006	No	No
Re-Pad	SA-516 70	...	...	K02700	No	No
Nozzle Flg	SA-105	...	...	K03504	No	No
Rings	SA-516 70	...	...	K02700	No	No
Flg Bolting	SA-193 B7	...	<= 2 1/2	G41400	No	No
Hrz Bolting	SA-193 B7	...	2 1/2 < t <= 4	G41400	No	No

Normalized is determined based on the UCS-66 material curve selection and Figure UCS-66.
Impact Tested is based on material selection and material data properties.

Element Pressures and MAWP (bars & mm.):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
Ellipse	4.155	1.03	16.000	3.0000	No	No
Cylinder	4.100	1.03	16.000	3.0000	N/A	No
Cylinder	4.100	1.03	16.000	3.0000	N/A	No
Cylinder	4.100	1.03	16.000	3.0000	N/A	No

Cylinder	4.100	1.03	16.000	3.0000	N/A	No
Body Flg	4.100	1.03	16.000	3.0000	N/A	No
Body Flg	4.100	1.03	8.000	3.0000	N/A	No

Liquid Level: 550.00 mm. Dens.: 1019.530 kg/m³ Sp. Gr.: 1.020

Stiffener Ring Specifications:

Elevation mm.	Selected Type	User Description
3600.00	Bar 100.0 x 15.	Ring R1 Fr40

Element Types and Properties:

Element Type	"To" Elev mm.	Element Length mm.	Nominal Thickness mm.	Finished Thickness mm.	Reqd Thk Internal mm.	Reqd Thk External mm.	Long Eff	Circ Eff
Ellipse	50.0	50.0	12.0	10.0	4.8	...	1.00	1.00
Cylinder	1550.0	1500.0	...	10.0	4.8	...	1.00	1.00
Cylinder	3550.0	2000.0	...	10.0	4.8	...	1.00	1.00
Cylinder	5550.0	2000.0	...	10.0	4.8	...	1.00	1.00
Cylinder	6250.0	700.0	...	10.0	4.8	...	1.00	1.00
Body Flg	6410.0	160.0	...	130.0	129.6	...	1.00	1.00
Body Flg	6479.5	60.0	...	60.0	49.9	...	1.00	1.00

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	10	6.15855	1.034	4.97328
20	30	10	9.22129	1.034	1.4041
30	40	10	9.22129	1.034	1.4041
40	Ring	10	9.22129	1.034	1.4041
Ring	50	10	8.39371	1.034	1.99374
50	60	10	8.39371	1.034	1.99374
60	70	130	129.565	1.034	No Calc
70	80	60	49.8856	1.034	No Calc

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	3700	4945.73	No Calc	No Calc
30	40	3700	4945.73	No Calc	No Calc
40	Ring	3700	4945.73	No Calc	No Calc
Ring	50	2650	4945.66	41.1436	263.43
50	60	2650	4945.66	No Calc	No Calc
60	70	No Calc	No Calc	No Calc	No Calc
70	80	No Calc	No Calc	No Calc	No Calc

Saddle Parameters:

```
 Saddle Width                                           150.000  mm.
 Saddle Bearing Angle                                   120.000  deg.
 Centerline Dimension                                  1200.000  mm.
 Wear Pad Width                                         260.000  mm.
 Wear Pad Thickness                                      10.000  mm.
 Wear Pad Bearing Angle                                 145.000  deg.
 Distance from Saddle to Tangent                        850.000  mm.

 Baseplate Length                                      1200.000  mm.
 Baseplate Thickness                                     15.000  mm.
 Baseplate Width                                        170.000  mm.
 Number of Ribs (including outside ribs)                      4
 Rib Thickness                                           15.000  mm.
 Web Thickness                                           15.000  mm.
 Height of Center Web                                   585.000  mm.
 Number of Bolts in Baseplate                                 4
```

Baseplate Sketch

```
    |------------------- 1200.000 mm. -------------------|
    ------------------------------------------------------ ---
    |                                                    |
    |                                                    | 170.000 mm.
    |                                                    |
    ------------------------------------------------------ ---
```

Baseplate Plan View

```
    ------------------------------------------------------ ---
    |                                                    | 15.000 mm.
    ------------------------------------------------------ ---
```

Baseplate Side View

```
 Maximum Tensile Bolt Load                                    2.   kN
```

Summary of Maximum Saddle Loads, Operating Case:

```
 Maximum Vertical Saddle Load                             123.00   kN
 Maximum Transverse Saddle Shear Load                      17.52   kN
 Maximum Longitudinal Saddle Shear Load                    35.04   kN
```

Summary of Maximum Saddle Loads, Operating Case, Un-Factored:

```
 Maximum Vertical Saddle Load                             148.17   kN
 Maximum Transverse Saddle Shear Load                      58.73   kN
 Maximum Longitudinal Saddle Shear Load                    50.05   kN
```

Summary of Maximum Saddle Loads, Hydrotest Case :

```
 Maximum Vertical Saddle Load                              91.95   kN
 Maximum Transverse Saddle Shear Load                       0.65   kN
 Maximum Longitudinal Saddle Shear Load                     0.52   kN
```

Local Stress Analysis Results:

```
                 |         Analysis |    Max Stress |   High Stress |          Pass |
     Description |             Type |         Ratio |      Location |          Fail |
-------------------------------------------------------------------------------------
       N02 (2in) |      WRC-107/537 |         0.390 |           n/a |        Passed |
       N05 (2in) |      WRC-107/537 |         0.390 |           n/a |        Passed |
      N01 (10in) |      WRC-107/537 |         0.883 |           n/a |        Passed |
```

Weights:

```
Fabricated - Bare  W/O Removable Internals                7113.8  kg.
Shop Test  - Fabricated + Water ( Full )                 14587.8  kg.
Shipping   - Fab. + Rem. Intls.+ Shipping App.            9516.8  kg.
Erected    - Fab. + Rem. Intls.+ Insul. (etc)            10516.8  kg.
Empty      - Fab. + Intls. + Details + Wghts.            10516.8  kg.
Operating  - Empty + Operating Liquid (No CA)            10643.0  kg.
Field Test - Empty Weight + Water (Full)                 16431.0  kg.
```

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
N08 (1in)	16	OK	...	OK	4.80	OK	Passed
N08 (1in)	16	OK	...	OK	4.80	OK	Passed
N02 (2in)	16	OK	...	OK	4.80	OK	Passed
N12 (1in)	16	OK	...	OK	4.80	OK	Passed
M1 (24in)	11	OK	...	...		OK	Passed
N07C (2in)	16	OK	...	OK	4.80	OK	Passed
N07B (2in)	16	OK	...	OK	4.80	OK	Passed
K9B (3in)	8	OK	...	OK	4.80	OK	Passed
K9B (3in)	8	OK	...	OK	4.80	OK	Passed
K9A (3in)	8	OK	...	OK	4.80	OK	Passed
K9A (3in)	8	OK	...	OK	4.80	OK	Passed
K10A (2in)	16	OK	...	OK	4.80	OK	Passed
K10A (2in)	16	OK	...	OK	4.80	OK	Passed
K10B (2in)	16	OK	...	OK	4.80	OK	Passed
K10B (2in)	16	OK	...	OK	4.80	OK	Passed
K11A (2in)	16	OK	...	OK	4.80	OK	Passed
K11A (2in)	16	OK	...	OK	4.80	OK	Passed
K11B (2in)	16	OK	...	OK	4.80	OK	Passed
K11B (2in)	16	OK	...	OK	4.80	OK	Passed
K7A (3in)	8	OK	...	OK	4.80	OK	Passed
K7A (3in)	8	OK	...	OK	4.80	OK	Passed
K7B (3in)	8	OK	...	OK	4.80	OK	Passed
K7B (3in)	8	OK	...	OK	4.80	OK	Passed
N05 (2in)	16	OK	...	OK	4.80	OK	Passed
K2B (2in)	16	OK	...	OK	4.80	OK	Passed
K2B (2in)	16	OK	...	OK	4.80	OK	Passed
K2A (2in)	16	OK	...	OK	4.80	OK	Passed
K2A (2in)	16	OK	...	OK	4.80	OK	Passed
K3A (3in)	8	OK	...	OK	4.80	OK	Passed
K3A (3in)	8	OK	...	OK	4.80	OK	Passed
K3B (3in)	8	OK	...	OK	4.80	OK	Passed
K3B (3in)	8	OK	...	OK	4.80	OK	Passed
N11 (1in)	16	OK	...	OK	4.80	OK	Passed
M2 (24in)	11	OK	...	...		OK	Passed
K8 (2in)	16	OK	...	OK	4.80	OK	Passed
N04 (6in)	16	OK	...	OK	4.80	OK	Passed
K1B (2in)	16	OK	...	OK	4.80	OK	Passed
N07A (2in)	16	OK	...	OK	4.80	OK	Passed
N09A (1.5in)	16	OK	...	OK	4.80	OK	Passed
N09A (1.5in)	16	OK	...	OK	4.80	OK	Passed
N09B (1.5in)	16	OK	...	OK	4.80	OK	Passed
N09B (1.5in)	16	OK	...	OK	4.80	OK	Passed
K4A (2in)	16	OK	...	OK	4.80	OK	Passed
K4A (2in)	16	OK	...	OK	4.80	OK	Passed
K6 (2in)	16	OK	...	OK	7.50	OK	Passed
K1 (2in)	16	OK	...	OK	4.80	OK	Passed
K1 (2in)	16	OK	...	OK	4.80	OK	Passed
N01 (10in)	12	OK	...	OK	4.80	OK	Passed
N03 (10in)	5	OK	...	OK	11.10	OK	Passed

Chimney Nozzle	5	OK	...	OK	11.10	OK	Passed

Nozzle MAWP Summary:

Minimum MAWP Nozzles	:	5 Nozzle	: Chimney Nozzle
Minimum MAWP Shells/Flanges	:	8 Element	:
Minimum MAPnc Shells/Flanges	:	9 Element	:
Computed Vessel M.A.W.P.	:	5 bars	

Note: MAWPs (Internal Case) shown above are at the High Point.

Check the Spatial Relationship between the Nozzles:

From Node	Nozzle Description	X Coordinate mm.	Layout Angle deg	Dia. Limit mm.
10	N08 (1in)	0.000	270.000	113.600
20	N02 (2in)	200.000	270.000	113.600
20	N12 (1in)	250.000	90.000	65.000
20	M1 (24in)	950.000	90.000	920.000
20	N07C (2in)	450.000	270.000	113.600
20	N07B (2in)	1150.000	270.000	113.600
20	K9B (3in)	200.000	-55.052	163.130
20	K9A (3in)	200.000	55.052	163.130
20	K10A (2in)	450.000	-21.342	113.600
20	K10B (2in)	450.000	-51.592	113.600
20	K11A (2in)	600.000	21.342	113.600
20	K11B (2in)	600.000	51.592	90.000
20	K7A (3in)	1250.000	4.702	163.130
20	K7B (3in)	1250.000	-35.014	163.130
20	N05 (2in)	1415.000	270.000	113.600
30	K2B (2in)	2200.000	-21.948	113.600
30	K2A (2in)	2200.000	2.631	113.600
30	K3A (3in)	2450.000	40.976	163.130
30	K3B (3in)	2450.000	-19.139	163.130
30	N11 (1in)	1750.000	90.000	65.000
30	M2 (24in)	3050.000	0.000	1000.000
30	K8 (2in)	1747.400	0.000	113.600
40	N04 (6in)	4550.000	90.000	310.145
40	K1B (2in)	5400.000	90.000	113.600
40	N07A (2in)	4550.000	270.000	113.600
40	N09A (1.5in)	3750.000	289.139	88.200
40	N09B (1.5in)	3750.000	250.861	88.200
40	K4A (2in)	4650.000	40.976	113.600
40	K6 (2in)	5000.000	90.000	125.600
40	K1 (2in)	5200.000	40.976	113.600
50	N01 (10in)	5900.000	90.000	525.651
70	N03 (10in)	0.000	320.000	450.000
70	Chimney Nozzle	0.000	220.000	450.000

The nozzle spacing is computed by the following:
= Sqrt(ll^2 + lc^2) where
ll - Arc length along the inside vessel surface in the long. direction.
lc - Arc length along the inside vessel surface in the circ. direction

If any interferences/violations are found, they will be noted below.
No interference violations have been detected !

Checking Multiple Nozzles on Flat Head per ASME Sec. VIII Div. 1 UG-39

Comparing Nozzles on Element from Node: 70 to: 80

UG-39 Average Nozzle Diameter and Ligament Checks:

Nozzle Pair Description	Avg. dia. mm.	Head Dia. /4 mm.	Ligament Width mm.	Min. dn /4 mm.
N03 (10in) & Chimney	252.65	312.02	217.22	63.162

UG-39 Nozzle Spacing and Average Area Checks:

Nozzle Pair Description	Center Spacing mm.	Avg. dia. * 1.25 mm.	Avg. Area Available cm²	Avg. Area Reqd. cm²
N03 (10in) & Chimney	490.27	315.81	60.676	59.876

UG-39 Nozzle Diameter and Distance to Edge Checks:

Nozzle Description	Nozzle dia. mm.	Head Dia. /2 mm.	Distance from Edge mm.	Nozzle dia./4 mm.
N03 (10in)	252.65	624.05	253.48	63.162
Chimney Nozzle	252.65	624.05	253.48	63.162

No Multiple Nozzle spacing violations detected!

Bill of Materials:

QTY	DESCRIPTION	MATERIAL
1	ELLIPTICAL HEAD: 2.0 X 1, 12.0mm. THK X 1200.0mm. ID X 50.0mm.	SA-516 70
1	CYLINDER: 10.0mm. THK X 1200.0mm. ID X 1500.0mm.	SA-516 70
2	CYLINDER: 10.0mm. THK X 1200.0mm. ID X 2000.0mm.	SA-516 70
1	CYLINDER: 10.0mm. THK X 1200.0mm. ID X 700.0mm.	SA-516 70
1	BODY FLANGE: 130.0mm. THK X 1200.0mm. OD	SA-105
1	BODY FLANGE: 60.0mm. THK X 1420.0mm. OD	SA-105
1	PLATFORM: 1100mm X 1200mm WIDE	
1	LADDER: 2000mm	...
1	INSULATION: 350mm X 90mm THK	
2	SADDLE: 150mm X 120 DEG	
1	INSULATION: 1500mm X 90mm THK	
2	INSULATION: 2000mm X 90mm THK	
1	BAR RING STIFFENER: 1200mm ID X 1400mm OD X 15mm	SA-516 70
1	INSULATION: 700mm X 90mm THK	
1	INSULATION: 188mm X 90mm THK	
1	INSULATION: 106mm X 90mm THK	
2	CLASS 150 GR 1.1, 24.0" BLIND FLANGE(S)	SA-516 70
1	GASKET: 1265mm. OD X 1220mm. ID	...
44	BODY FLANGE BOLTS: 38mm. DIA	SA-193 B7
88	NUTS FOR BODY FLANGE BOLTS: 38mm. DIA	...
1	NAMEPLATE	...

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk mm	Reinforcing Pad Diameter	Reinforcing Pad Thk mm	Cut Length in	Flg Class
N12 (1in)	1.000 in	Actual	LW	2.008	12.800	...	...	160.5	150
N11 (1in)	1.000 in	Actual	LW	2.008	12.800	...	...	160.5	150
N09A (1.5in)	1.500 in	Actual	LW	2.638	14.450	...	...	173.5	150
N09B (1.5in)	1.500 in	Actual	LW	2.638	14.450	...	...	173.5	150
N08 (1in)	2.000 in	Actual	LW	3.248	15.850	...	...	178.0	150
N02 (2in)	2.000 in	Actual	LW	3.248	15.850	...	...	161.4	150
N07C (2in)	2.000 in	Actual	LW	3.248	15.850	...	...	161.4	150
N07B (2in)	2.000 in	Actual	LW	3.248	15.850	...	...	161.4	150
K10A (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	179.3	300
K10B (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	379.6	300
K11A (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	179.3	300
K11B (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	379.6	300
N05 (2in)	2.000 in	Actual	LW	3.248	15.850	...	...	161.4	150
K2B (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	179.9	300
K2A (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	163.4	300
K8 (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	211.4	300
K1B (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	161.4	300
N07A (2in)	2.000 in	Actual	LW	3.248	15.850	...	...	161.4	150
K4A (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	254.7	300
K6 (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	161.4	300
K1 (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	254.7	300
K9B (3in)	3.000 in	80	WN	3.500	7.620	200.00	10.00	397.2	300
K9A (3in)	3.000 in	80	WN	3.500	7.620	200.00	10.00	397.2	300
K7A (3in)	3.000 in	80	WN	3.500	7.620	200.00	10.00	215.4	300
K7B (3in)	3.000 in	80	WN	3.500	7.620	200.00	10.00	297.4	300
K3A (3in)	3.000 in	80	WN	3.500	7.620	200.00	10.00	307.4	300
K3B (3in)	3.000 in	80	WN	3.500	7.620	200.00	10.00	228.3	300
N04 (6in)	6.000 in	80	WN	6.625	10.973	300.00	10.00	165.9	150
N01 (10in)	10.000 in	40	WN	10.750	9.271	450.00	10.00	175.7	150
N03 (10in)	10.000 in	80	WN	10.750	15.088	450.00	15.00	4260.0	150
Chimney Nozzle	10.000 in	80	Non	10.750	15.088	450.00	15.00	4260.0	150
M1 (24in)	24.000 in	Actual	WN	24.000	10.000	800.00	10.00	243.1	150
M2 (24in)	24.000 in	Actual	WN	24.000	10.000	800.00	10.00	243.1	150

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 (mm.):

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
N12 (1in)	SA-105	10.000	10.000	...	...	...
N11 (1in)	SA-105	10.000	8.000	...	...	...
N09A (1.5in	SA-105	10.000	10.000	...	...	...
N09B (1.5in	SA-105	10.000	10.000	...	...	...
N08 (1in)	SA-105	10.000	10.000	...	...	...
N02 (2in)	SA-105	10.000	10.000	...	...	...
N07C (2in)	SA-105	10.000	10.000	...	...	...
N07B (2in)	SA-105	10.000	10.000	...	...	...
K10A (2in)	SA-105	10.000	10.000	...	...	...
K10B (2in)	SA-105	10.000	10.000	...	...	...
K11A (2in)	SA-105	10.000	10.000	...	...	...
K11B (2in)	SA-105	10.000	10.000	...	...	...
N05 (2in)	SA-105	10.000	10.000	...	...	...
K2B (2in)	SA-105	10.000	10.000	...	...	...
K2A (2in)	SA-105	10.000	10.000	...	...	...
K8 (2in)	SA-105	10.000	10.000	...	...	...
K1B (2in)	SA-105	10.000	10.000	...	...	...
N07A (2in)	SA-105	10.000	10.000	...	...	...
K4A (2in)	SA-105	10.000	10.000	...	...	...
K6 (2in)	SA-105	10.000	10.000	...	...	...
K1 (2in)	SA-105	10.000	10.000	...	...	...
K9B (3in)	SA-106 B	10.000	10.000	8.000	10.000	...
K9A (3in)	SA-106 B	10.000	10.000	8.000	10.000	...
K7A (3in)	SA-106 B	10.000	10.000	8.000	10.000	...
K7B (3in)	SA-106 B	10.000	10.000	8.000	10.000	...
K3A (3in)	SA-106 B	10.000	10.000	8.000	10.000	...
K3B (3in)	SA-106 B	10.000	10.000	8.000	10.000	...
N04 (6in)	SA-106 B	10.000	8.000	6.000	10.000	...
N01 (10in)	SA-106 B	10.000	10.000	10.000	10.000	...
N03 (10in)	SA-106 B	26.000	20.000	12.000	15.000	20.000
Chimney Noz	SA-106 B	26.000	20.000	12.000	15.000	20.000
M1 (24in)	SA-516 70	10.000	10.000	8.000	10.000	...
M2 (24in)	SA-516 70	10.000	10.000	8.000	10.000	...

Note: The Outside projections below do not include the flange thickness.

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
N12 (1in)	250.000	90.0	150.00	0.00	Node: 20
N11 (1in)	1750.000	90.0	150.00	0.00	Node: 30
N09A (1.5in)	3750.000	289.1	150.00	0.00	Node: 40
N09B (1.5in)	3750.000	250.9	150.00	0.00	Node: 40
N08 (1in)	...	270.0	150.00	0.00	Node: 10
N02 (2in)	200.000	270.0	150.00	0.00	Node: 20
N07C (2in)	450.000	270.0	150.00	0.00	Node: 20
N07B (2in)	1150.000	270.0	150.00	0.00	Node: 20

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K10A (2in)       |      450.000 |    -21.3 |      150.00 |    0.00 |           Node:  20 |
K10B (2in)       |      450.000 |    -51.6 |      300.00 |    0.00 |           Node:  20 |
K11A (2in)       |      600.000 |     21.3 |      150.00 |    0.00 |           Node:  20 |
K11B (2in)       |      600.000 |     51.6 |      300.00 |    0.00 |           Node:  20 |
N05 (2in)        |     1415.000 |    270.0 |      150.00 |    0.00 |           Node:  20 |
K2B (2in)        |     2200.000 |    -21.9 |      150.00 |    0.00 |           Node:  30 |
K2A (2in)        |     2200.000 |      2.6 |      150.00 |    0.00 |           Node:  30 |
K8 (2in)         |     1747.400 |      0.0 |      200.00 |    0.00 |           Node:  30 |
K1B (2in)        |     5400.000 |     90.0 |      150.00 |    0.00 |           Node:  40 |
N07A (2in)       |     4550.000 |    270.0 |      150.00 |    0.00 |           Node:  40 |
K4A (2in)        |     4650.000 |     41.0 |      200.00 |    0.00 |           Node:  40 |
K6 (2in)         |     5000.000 |     90.0 |      150.00 |    0.00 |           Node:  40 |
K1 (2in)         |     5200.000 |     41.0 |      200.00 |    0.00 |           Node:  40 |
K9B (3in)        |      200.000 |    -55.1 |      300.00 |    0.00 |           Node:  20 |
K9A (3in)        |      200.000 |     55.1 |      300.00 |    0.00 |           Node:  20 |
K7A (3in)        |     1250.000 |      4.7 |      200.00 |    0.00 |           Node:  20 |
K7B (3in)        |     1250.000 |    -35.0 |      250.00 |    0.00 |           Node:  20 |
K3A (3in)        |     2450.000 |     41.0 |      250.00 |    0.00 |           Node:  30 |
K3B (3in)        |     2450.000 |    -19.1 |      200.00 |    0.00 |           Node:  30 |
N04 (6in)        |     4550.000 |     90.0 |      150.00 |    0.00 |           Node:  40 |
N01 (10in)       |     5900.000 |     90.0 |      150.00 |    0.00 |           Node:  50 |
N03 (10in)       |          ... |    320.0 |      200.00 | 4000.00 |           Node:  70 |
Chimney Nozzle   |          ... |    220.0 |      200.00 | 4000.00 |           Node:  70 |
M1 (24in)        |      950.000 |     90.0 |      150.00 |    0.00 |           Node:  20 |
M2 (24in)        |     3050.000 |      0.0 |      150.00 |    0.00 |           Node:  30 |
```

Minimum Design Metal Temperature Results Summary :

Description	Notes	Curve	Basic MDMT °C	Reduced MDMT °C	UG-20(f) MDMT °C	Thickness ratio	Gov Thk mm.	E*	PWHT reqd
	[11]	A	-8	-104	-29	0.215	10.000	1.00	Yes
	[11]	A	4	-14		0.677	15.000	1.00	Yes
	[10]	B	-29	-104	-29	0.339	10.000	1.00	Yes
	[7]	B	-23	-104	-29	0.266	12.000	1.00	Yes
	[8]	B	-29	-104	-29	0.338	10.000	1.00	Yes
	[8]	B	-29	-104	-29	0.338	10.000	1.00	Yes
	[8]	B	-29	-104	-29	0.338	10.000	1.00	Yes
	[8]	B	-29	-104	-29	0.338	10.000	1.00	Yes
N08 (1in)	[1]	A	-8	-104	-29	0.231	10.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					
N02 (2in)	[1]	A	-8	-104	-29	0.257	10.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
N12 (1in)	[1]	A	-8	-104	-29	0.257	10.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
M1 (24in)	[1]	B	-8	-104	-29	0.129	10.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
N07C (2in)	[1]	A	-8	-104	-29	0.257	10.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
N07B (2in)	[1]	A	-8	-104	-29	0.257	10.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
K9B (3in)	[1]	B	-8	-104	-29	0.039	6.668	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
K9A (3in)	[1]	B	-8	-104	-29	0.039	6.668	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
K10A (2in)	[1]	A	-8	-104	-29	0.257	10.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
K10B (2in)	[1]	A	-8	-104	-29	0.257	10.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
K11A (2in)	[1]	A	-8	-104	-29	0.257	10.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
K11B (2in)	[1]	A	-8	-104	-29	0.257	10.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
K7A (3in)	[1]	B	-8	-104	-29	0.039	6.668	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
K7B (3in)	[1]	B	-8	-104	-29	0.039	6.668	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
N05 (2in)	[1]	A	-8	-104	-29	0.257	10.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
K2B (2in)	[1]	A	-8	-104	-29	0.257	10.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					
K2A (2in)	[1]	A	-8	-104	-29	0.257	10.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					
K3A (3in)	[1]	B	-8	-104	-29	0.039	6.668	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					
K3B (3in)	[1]	B	-8	-104	-29	0.039	6.668	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					
N11 (1in)	[1]	A	-8	-104	-29	0.257	10.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					

```
M2 (24in)          [1]    B     -29      -104                 0.129  10.000    1.00     Yes
Nozzle Flg         [5]    B     -18      -104
K8 (2in)           [1]    A      -8      -104       -29       0.257  10.000    1.00     Yes
Nozzle Flg         [5]    A     -18      -104
N04 (6in)          [1]    B     -29      -104                 0.041   9.601    1.00     Yes
Nozzle Flg         [5]    B     -18      -104
K1B (2in)          [1]    A      -8      -104       -29       0.257  10.000    1.00     Yes
Nozzle Flg         [5]    A     -18      -104
N07A (2in)         [1]    A      -8      -104       -29       0.257  10.000    1.00     Yes
Nozzle Flg         [5]    A     -18      -104
N09A (1.5in)       [1]    A      -8      -104       -29       0.257  10.000    1.00     Yes
Nozzle Flg         [5]    A     -18      -104
N09B (1.5in)       [1]    A      -8      -104       -29       0.257  10.000    1.00     Yes
Nozzle Flg         [5]    A     -18      -104
K4A (2in)          [1]    A      -8      -104       -29       0.257  10.000    1.00     Yes
Nozzle Flg         [5]    A     -18      -104
K6 (2in)           [1]    A      -8      -104       -29       0.257  10.000    1.00     Yes
Nozzle Flg         [5]    A     -18      -104
K1 (2in)           [1]    A      -8      -104       -29       0.257  10.000    1.00     Yes
Nozzle Flg         [5]    A     -18      -104
N01 (10in)         [1]    B     -29      -104                 0.090   8.112    1.00     Yes
Nozzle Flg         [5]    B     -18      -104
N03 (10in)         [1]    A     -20      -104       -29       0.043  13.202    1.00     Yes
Nozzle Flg         [5]    B     -18      -104
Chimney Nozzle[1]         A     -20      -104       -29       0.043  13.202    1.00     Yes
Nozzle Flg         [5]    B     -18      -104
Bolting           [21]          -48
-----------------------------------------------------------------------------------
Warmest MDMT:                     4       -14

Required Minimum Design Metal Temperature              5.0   °C
Warmest Computed Minimum Design Metal Temperature    -14.0   °C
```

Notes:
[!] - This was an impact tested material.
[1] - Governing Nozzle Weld.
[4] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
[5] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
[6] - MDMT Calculations at the Shell/Head Joint.
[7] - MDMT Calculations for the Straight Flange.
[8] - Cylinder/Cone/Flange Junction MDMT.
[9] - Calculations in the Spherical Portion of the Head.
[10] - Calculations in the Knuckle Portion of the Head.
[11] - Calculated (Body Flange) Flange MDMT.
[12] - Calculated Flat Head MDMT per UCS-66.3
[13] - Tubesheet MDMT, shell side, if applicable
[14] - Tubesheet MDMT, tube side, if applicable
[15] - Nozzle Material
[16] - Shell or Head Material
[17] - Impact Testing required
[18] - Impact Testing not required, see UCS-66(b)(3)
[20] - Cylinder/Cone Junction MDMT based on Longitudinal Stress considerations
[21] - Bolting Material

UG-84(b)(2) was not considered.
UCS-66(g) was not considered.
UCS-66(i) was not considered.

Notes:
Impact test temps were not entered in and not considered in the analysis.
UCS-66(i) applies to impact tested materials not by specification and
UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).
The Basic MDMT includes the (30F) PWHT credit if applicable.

```
Class From To : Basic Element Checks.
==========================================================================

Class From To: Check of Additional Element Data
==========================================================================
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There were no geometry errors or warnings.

PV Elite Vessel Analysis Program: Input Data

```
Design Internal Pressure (for Hydrotest)                    4.1  bars
Design Internal Temperature                               234.0  °C
Type of Hydrotest                              UG-99(b) Note [36]
Hydrotest Position                                   Horizontal
Projection of Nozzle from Vessel Top                          0  mm.
Projection of Nozzle from Vessel Bottom                       0  mm.
Minimum Design Metal Temperature                            5.0  °C
Type of Construction                                     Welded
Special Service                                          Lethal
Degree of Radiography                                      RT-1
Use Higher Longitudinal Stresses (Flag)                       Y
Select t for Internal Pressure (Flag)                         N
Select t for External Pressure (Flag)                         N
Select t for Axial Stress (Flag)                              N
Select Location for Stiff. Rings (Flag)                       N
Consider Vortex Shedding                                      Y
Perform a Corroded Hydrotest                                  Y

Load Case 1                                      NP+EW+WI+FW+BW
Load Case 2                                      NP+EW+EE+FS+BS
Load Case 3                                      NP+OW+WI+FW+BW
Load Case 4                                      NP+OW+EQ+FS+BS
Load Case 5                                            NP+HW+HI
Load Case 6                                            NP+HW+HE
Load Case 7                                      IP+OW+WI+FW+BW
Load Case 8                                      IP+OW+EQ+FS+BS
Load Case 9                                      EP+OW+WI+FW+BW
Load Case 10                                     EP+OW+EQ+FS+BS
Load Case 11                                           HP+HW+HI
Load Case 12                                           HP+HW+HE
Load Case 13                                           IP+WE+EW
Load Case 14                                           IP+WF+CW
Load Case 15                                           IP+VO+OW
Load Case 16                                           IP+VE+EW
Load Case 17                                           NP+VO+OW
Load Case 18                                        FS+BS+IP+OW
Load Case 19                                        FS+BS+EP+OW

Wind Design Code                                    ASCE-7 2010
Wind Load Reduction Scale Factor                          0.600
Basic Wind Speed                           [V]              120  Km/hr
Surface Roughness Category                      C: Open Terrain
Importance Factor                                           1.0
Type of Surface                               Moderately Smooth
Base Elevation                                              100  mm.
Percent Wind for Hydrotest                                 33.0
Using User defined Wind Press. Vs Elev.                       N
Height of Hill or Escarpment     H or Hh                      0  mm.
Distance Upwind of Crest              Lh                      0  mm.
Distance from Crest to the Vessel      x                      0  mm.
Type of Terrain ( Hill, Escarpment )                       Flat
```

```
Damping Factor (Beta) for Wind (Ope)                 0.0100
Damping Factor (Beta) for Wind (Empty)               0.0000
Damping Factor (Beta) for Wind (Filled)              0.0000

Seismic Design Code                              ASCE 7-2010
Seismic Load Reduction Scale Factor                   0.700
Importance Factor                                     1.250
Table Value Fa                                        1.111
Table Value Fv                                        1.575
Short Period Acceleration value Ss                    1.377
Long Period Acceleration Value Sl                     0.367
Moment Reduction Factor Tau                           1.000
Force Modification Factor R                           3.000
Site Class                                                C
Component Elevation Ratio             z/h             1.000
Amplification Factor                   Ap             1.000
Force Factor                                          0.000
Consider Vertical Acceleration                           No
Minimum Acceleration Multiplier                       0.000
User Value of Sds (used if > 0 )                      1.020
User Value of Sd1 (used if > 0 )                      0.385

Design Pressure + Static Head                             Y
Consider MAP New and Cold in Noz. Design                  N
Consider External Loads for Nozzle Des.                   Y
Use ASME VIII-1 Appendix 1-9                              N

Material Database Year        Current w/Addenda or Code Year
```

Configuration Directives:

```
Do not use Nozzle MDMT Interpretation VIII-1 01-37        No
Use Table G instead of exact equation for "A"            Yes
Shell Head Joints are Tapered                            Yes
Compute "K" in corroded condition                        Yes
Use Code Case 2286                                        No
Use the MAWP to compute the MDMT                         Yes
For thickness ratios <= 0.35, MDMT will be -155F (-104C) Yes
For PWHT & P1 Materials the MDMT can be < -55F (-48C)     No

Using Metric Material Databases, ASME II D                No
Calculate B31.3 type stress for Nozzles with Loads       Yes
Reduce the MDMT due to lower membrane stress             Yes
Consider Longitudinal Stress in MDMT calcs. (Div. 1)     Yes
```

Complete Listing of Vessel Elements and Details:

```
Element From Node                                    10
Element To Node                                      20
Element Type                                     Elliptical
Description
Distance "FROM" to "TO"                              50   mm.
Inside Diameter                                    1200   mm.
Element Thickness                                    10   mm.
Internal Corrosion Allowance                          3   mm.
```

```
Nominal Thickness                                          12  mm.
External Corrosion Allowance                                0  mm.
Design Internal Pressure                                  4.1  bars
Design Temperature Internal Pressure                      234  °C
Design External Pressure                                1.034  bars
Design Temperature External Pressure                      100  °C
Effective Diameter Multiplier                             1.2
Material Name                                       SA-516 70
    Allowable Stress, Ambient                           137.9  N./mm²
    Allowable Stress, Operating                         137.9  N./mm²
    Allowable Stress, Hydrotest                        235.81  N./mm²
    Material Density                                   7750.4  kg/m³
    P Number Thickness                                  31.75  mm.
    Yield Stress, Operating                            218.59  N./mm²
    UCS-66 Chart Curve Designation                          B
    External Pressure Chart Name                         CS-2
    UNS Number                                         K02700
    Product Form                                        Plate
Efficiency, Longitudinal Seam                             1.0
Efficiency, Circumferential Seam                          1.0
Elliptical Head Factor                                    2.0
Weld is pre-Heated                                         No

    Element From Node                                      10
    Detail Type                                      Platform
    Detail ID                                    PLAT:[1 OF 1]
    Dist. from "FROM" Node / Offset dist                    0  mm.
    Platform Start Angle (degrees)                        0.0
    Platform End Angle   (degrees)                        0.0
    Platform Wind Area                                  31680  cm²
    Platform Weight                                    19.243  kN
    Platform Railing Weight                                 0  kN/mm.
    Platform Grating Weight                             0.025  Kgs/cm²
    Platform Width                                       1200  mm.
    Platform Height                                      1100  mm.
    Platform Clearance or End Offset                      150  mm.
    Platform Force Coefficient                            1.2
    Ladder Layout Angle                                   0.0
    Ladder Start Elevation                                  0  mm.
    Ladder End Elevation                                 2000  mm.
    Unit Weight of Ladder                             0.00035  kN/mm.
    Platform Length (top head platform)                  6300  mm.

    Element From Node                                      10
    Detail Type                                        Liquid
    Detail ID                                      Liquid: 10
    Dist. from "FROM" Node / Offset dist                    0  mm.
    Height/Length of Liquid                               550  mm.
    Liquid Density                                     1019.5  kg/m³

    Element From Node                                      10
    Detail Type                                    Insulation
    Detail ID                                         Ins: 20
    Dist. from "FROM" Node / Offset dist                 -300  mm.
    Height/Length of Insulation                           350  mm.
```

```
    Thickness of Insulation                                90  mm.
    Density                                               125  kg/m³

    Element From Node                                      10
    Detail Type                                        Nozzle
    Detail ID                                       N08 (1in)
    Dist. from "FROM" Node / Offset dist                  400  mm.
    Nozzle Diameter                                         2  in.
    Nozzle Schedule                                      None
    Nozzle Class                                          150
    Layout Angle                                        270.0
    Blind Flange (Y/N)                                      N
    Weight of Nozzle ( Used if > 0 )                  0.07081  kN
    Grade of Attached Flange                           GR 1.1
    Nozzle Matl                                        SA-105

--------------------------------------------------------------------

Element From Node                                          20
Element To Node                                            30
Element Type                                         Cylinder
Description
Distance "FROM" to "TO"                                  1500  mm.
Inside Diameter                                          1200  mm.
Element Thickness                                          10  mm.
Internal Corrosion Allowance                                3  mm.
Nominal Thickness                                           0  mm.
External Corrosion Allowance                                0  mm.
Design Internal Pressure                                  4.1  bars
Design Temperature Internal Pressure                      234  °C
Design External Pressure                                1.034  bars
Design Temperature External Pressure                      100  °C
Effective Diameter Multiplier                             1.2
Material Name                                       SA-516 70
Efficiency, Longitudinal Seam                             1.0
Efficiency, Circumferential Seam                          1.0
Weld is pre-Heated                                         No

    Element From Node                                      20
    Detail Type                                        Saddle
    Detail ID                                         Lft Sdl
    Dist. from "FROM" Node / Offset dist                  850  mm.
    Width of Saddle                                       150  mm.
    Height of Saddle at Bottom                           1200  mm.
    Saddle Contact Angle                                120.0
    Height of Composite Ring Stiffener                      0  mm.
    Width of Wear Plate                                   260  mm.
    Thickness of Wear Plate                                10  mm.
    Contact Angle, Wear Plate (degrees)                 145.0
    Friction coefficient                           0.30000001
    Moment Factor                                         3.0
    Dimension E at base (optional)                          0  mm.
    Circumferential Eff. over Saddle                      1.0
    Circumferential Eff. at Midspan                       1.0
    Tangent to Tangent dist. (optional)                     0  mm.
```

```
Element From Node                                        20
Detail Type                                      Insulation
Detail ID                                           Ins: 20
Dist. from "FROM" Node / Offset dist                      0  mm.
Height/Length of Insulation                            1500  mm.
Thickness of Insulation                                  90  mm.
Density                                                 125  kg/m³

Element From Node                                        20
Detail Type                                          Nozzle
Detail ID                                        N02 (2in)
Dist. from "FROM" Node / Offset dist                    150  mm.
Nozzle Diameter                                           2  in.
Nozzle Schedule                                        None
Nozzle Class                                            150
Layout Angle                                          270.0
Blind Flange (Y/N)                                        N
Weight of Nozzle ( Used if > 0 )                    0.07081  kN
Grade of Attached Flange                             GR 1.1
Nozzle Matl                                          SA-105

Element From Node                                        20
Detail Type                                          Nozzle
Detail ID                                        N12 (1in)
Dist. from "FROM" Node / Offset dist                    200  mm.
Nozzle Diameter                                           1  in.
Nozzle Schedule                                        None
Nozzle Class                                            150
Layout Angle                                           90.0
Blind Flange (Y/N)                                        N
Weight of Nozzle ( Used if > 0 )                      0.032  kN
Grade of Attached Flange                             GR 1.1
Nozzle Matl                                          SA-105

Element From Node                                        20
Detail Type                                          Nozzle
Detail ID                                        M1 (24in)
Dist. from "FROM" Node / Offset dist                    900  mm.
Nozzle Diameter                                          24  in.
Nozzle Schedule                                         STD
Nozzle Class                                            150
Layout Angle                                           90.0
Blind Flange (Y/N)                                        Y
Weight of Nozzle ( Used if > 0 )                     3.5021  kN
Grade of Attached Flange                             GR 1.1
Nozzle Matl                                       SA-516 70

Element From Node                                        20
Detail Type                                          Nozzle
Detail ID                                       N07C (2in)
Dist. from "FROM" Node / Offset dist                    400  mm.
Nozzle Diameter                                           2  in.
Nozzle Schedule                                        None
Nozzle Class                                            150
```

```
Layout Angle                                      270.0
Blind Flange (Y/N)                                    N
Weight of Nozzle ( Used if > 0 )                0.07081  kN
Grade of Attached Flange                         GR 1.1
Nozzle Matl                                      SA-105

Element From Node                                    20
Detail Type                                      Nozzle
Detail ID                                    N07B (2in)
Dist. from "FROM" Node / Offset dist               1100  mm.
Nozzle Diameter                                       2  in.
Nozzle Schedule                                    None
Nozzle Class                                        150
Layout Angle                                      270.0
Blind Flange (Y/N)                                    N
Weight of Nozzle ( Used if > 0 )                0.07081  kN
Grade of Attached Flange                         GR 1.1
Nozzle Matl                                      SA-105

Element From Node                                    20
Detail Type                                      Nozzle
Detail ID                                     K9B (3in)
Dist. from "FROM" Node / Offset dist                150  mm.
Nozzle Diameter                                       3  in.
Nozzle Schedule                                      80
Nozzle Class                                        300
Layout Angle                                 -55.051998
Blind Flange (Y/N)                                    N
Weight of Nozzle ( Used if > 0 )                 0.1413  kN
Grade of Attached Flange                         GR 1.1
Nozzle Matl                                    SA-106 B

Element From Node                                    20
Detail Type                                      Nozzle
Detail ID                                     K9A (3in)
Dist. from "FROM" Node / Offset dist                150  mm.
Nozzle Diameter                                       3  in.
Nozzle Schedule                                      80
Nozzle Class                                        300
Layout Angle                                  55.051998
Blind Flange (Y/N)                                    N
Weight of Nozzle ( Used if > 0 )                 0.1413  kN
Grade of Attached Flange                         GR 1.1
Nozzle Matl                                    SA-106 B

Element From Node                                    20
Detail Type                                      Nozzle
Detail ID                                    K10A (2in)
Dist. from "FROM" Node / Offset dist                400  mm.
Nozzle Diameter                                       2  in.
Nozzle Schedule                                    None
Nozzle Class                                        300
Layout Angle                                 -21.341999
Blind Flange (Y/N)                                    N
Weight of Nozzle ( Used if > 0 )                0.08459  kN
```

```
Grade of Attached Flange                                GR 1.1
Nozzle Matl                                             SA-105

Element From Node                                           20
Detail Type                                             Nozzle
Detail ID                                           K10B (2in)
Dist. from "FROM" Node / Offset dist                       400  mm.
Nozzle Diameter                                              2  in.
Nozzle Schedule                                           None
Nozzle Class                                               300
Layout Angle                                        -51.591999
Blind Flange (Y/N)                                           N
Weight of Nozzle ( Used if > 0 )                        0.1247  kN
Grade of Attached Flange                                GR 1.1
Nozzle Matl                                             SA-105

Element From Node                                           20
Detail Type                                             Nozzle
Detail ID                                           K11A (2in)
Dist. from "FROM" Node / Offset dist                       550  mm.
Nozzle Diameter                                              2  in.
Nozzle Schedule                                           None
Nozzle Class                                               300
Layout Angle                                         21.341999
Blind Flange (Y/N)                                           N
Weight of Nozzle ( Used if > 0 )                       0.08459  kN
Grade of Attached Flange                                GR 1.1
Nozzle Matl                                             SA-105

Element From Node                                           20
Detail Type                                             Nozzle
Detail ID                                           K11B (2in)
Dist. from "FROM" Node / Offset dist                       550  mm.
Nozzle Diameter                                              2  in.
Nozzle Schedule                                           None
Nozzle Class                                               300
Layout Angle                                         51.591999
Blind Flange (Y/N)                                           N
Weight of Nozzle ( Used if > 0 )                        0.1247  kN
Grade of Attached Flange                                GR 1.1
Nozzle Matl                                             SA-105

Element From Node                                           20
Detail Type                                             Nozzle
Detail ID                                            K7A (3in)
Dist. from "FROM" Node / Offset dist                      1200  mm.
Nozzle Diameter                                              3  in.
Nozzle Schedule                                             80
Nozzle Class                                               300
Layout Angle                                         4.7016501
Blind Flange (Y/N)                                           N
Weight of Nozzle ( Used if > 0 )                        0.1285  kN
Grade of Attached Flange                                GR 1.1
Nozzle Matl                                           SA-106 B
```

```
    Element From Node                                        20
    Detail Type                                          Nozzle
    Detail ID                                         K7B (3in)
    Dist. from "FROM" Node / Offset dist                   1200  mm.
    Nozzle Diameter                                           3  in.
    Nozzle Schedule                                          80
    Nozzle Class                                            300
    Layout Angle                                     -35.013599
    Blind Flange (Y/N)                                        N
    Weight of Nozzle ( Used if > 0 )                     0.1349  kN
    Grade of Attached Flange                             GR 1.1
    Nozzle Matl                                        SA-106 B

    Element From Node                                        20
    Detail Type                                          Nozzle
    Detail ID                                         N05 (2in)
    Dist. from "FROM" Node / Offset dist                   1365  mm.
    Nozzle Diameter                                           2  in.
    Nozzle Schedule                                        None
    Nozzle Class                                            150
    Layout Angle                                          270.0
    Blind Flange (Y/N)                                        N
    Weight of Nozzle ( Used if > 0 )                    0.07081  kN
    Grade of Attached Flange                             GR 1.1
    Nozzle Matl                                          SA-105

    Element From Node                                        20
    Detail Type                                          Weight
    Detail ID                                            WEIR 1
    Dist. from "FROM" Node / Offset dist                    700  mm.
    Miscellaneous Weight                                 0.9806  kN
    Offset from Element Centerline                            0  mm.

    Element From Node                                        20
    Detail Type                                          Weight
    Detail ID                                      GAS SPARGER
    Dist. from "FROM" Node / Offset dist                   1325  mm.
    Miscellaneous Weight                                 0.4903  kN
    Offset from Element Centerline                          400  mm.

--------------------------------------------------------------------

Element From Node                                            30
Element To Node                                              40
Element Type                                           Cylinder
Description
Distance "FROM" to "TO"                                    2000  mm.
Inside Diameter                                            1200  mm.
Element Thickness                                            10  mm.
Internal Corrosion Allowance                                  3  mm.
Nominal Thickness                                             0  mm.
External Corrosion Allowance                                  0  mm.
Design Internal Pressure                                    4.1  bars
Design Temperature Internal Pressure                        234  °C
Design External Pressure                                  1.034  bars
```

```
Design Temperature External Pressure                     100  °C
Effective Diameter Multiplier                            1.2
Material Name                                      SA-516 70
Efficiency, Longitudinal Seam                            1.0
Efficiency, Circumferential Seam                         1.0
Weld is pre-Heated                                        No

    Element From Node                                     30
    Detail Type                                   Insulation
    Detail ID                                        Ins: 30
    Dist. from "FROM" Node / Offset dist                   0  mm.
    Height/Length of Insulation                         2000  mm.
    Thickness of Insulation                               90  mm.
    Density                                              125  kg/m³

    Element From Node                                     30
    Detail Type                                       Nozzle
    Detail ID                                      K2B (2in)
    Dist. from "FROM" Node / Offset dist                 650  mm.
    Nozzle Diameter                                        2  in.
    Nozzle Schedule                                     None
    Nozzle Class                                         300
    Layout Angle                                    -21.9484
    Blind Flange (Y/N)                                     N
    Weight of Nozzle ( Used if > 0 )                 0.08459  kN
    Grade of Attached Flange                          GR 1.1
    Nozzle Matl                                       SA-105

    Element From Node                                     30
    Detail Type                                       Nozzle
    Detail ID                                      K2A (2in)
    Dist. from "FROM" Node / Offset dist                 650  mm.
    Nozzle Diameter                                        2  in.
    Nozzle Schedule                                     None
    Nozzle Class                                         300
    Layout Angle                                   2.6308999
    Blind Flange (Y/N)                                     N
    Weight of Nozzle ( Used if > 0 )                 0.08459  kN
    Grade of Attached Flange                          GR 1.1
    Nozzle Matl                                       SA-105

    Element From Node                                     30
    Detail Type                                       Nozzle
    Detail ID                                      K3A (3in)
    Dist. from "FROM" Node / Offset dist                 900  mm.
    Nozzle Diameter                                        3  in.
    Nozzle Schedule                                       80
    Nozzle Class                                         300
    Layout Angle                                   40.975601
    Blind Flange (Y/N)                                     N
    Weight of Nozzle ( Used if > 0 )                  0.1349  kN
    Grade of Attached Flange                          GR 1.1
    Nozzle Matl                                     SA-106 B

    Element From Node                                     30
```

```
Detail Type                                              Nozzle
Detail ID                                             K3B (3in)
Dist. from "FROM" Node / Offset dist                        900  mm.
Nozzle Diameter                                               3  in.
Nozzle Schedule                                              80
Nozzle Class                                                300
Layout Angle                                           -19.1395
Blind Flange (Y/N)                                            N
Weight of Nozzle ( Used if > 0 )                         0.1285  kN
Grade of Attached Flange                                 GR 1.1
Nozzle Matl                                            SA-106 B

Element From Node                                            30
Detail Type                                              Nozzle
Detail ID                                             N11 (1in)
Dist. from "FROM" Node / Offset dist                        200  mm.
Nozzle Diameter                                               1  in.
Nozzle Schedule                                            None
Nozzle Class                                                150
Layout Angle                                               90.0
Blind Flange (Y/N)                                            N
Weight of Nozzle ( Used if > 0 )                          0.032  kN
Grade of Attached Flange                                 GR 1.1
Nozzle Matl                                              SA-105

Element From Node                                            30
Detail Type                                              Nozzle
Detail ID                                             M2 (24in)
Dist. from "FROM" Node / Offset dist                       1500  mm.
Nozzle Diameter                                              24  in.
Nozzle Schedule                                             STD
Nozzle Class                                                150
Layout Angle                                                0.0
Blind Flange (Y/N)                                            Y
Weight of Nozzle ( Used if > 0 )                         3.5021  kN
Grade of Attached Flange                                 GR 1.1
Nozzle Matl                                           SA-516 70

Element From Node                                            30
Detail Type                                              Nozzle
Detail ID                                              K8 (2in)
Dist. from "FROM" Node / Offset dist                      197.4  mm.
Nozzle Diameter                                               2  in.
Nozzle Schedule                                            None
Nozzle Class                                                300
Layout Angle                                                0.0
Blind Flange (Y/N)                                            N
Weight of Nozzle ( Used if > 0 )                        0.09794  kN
Grade of Attached Flange                                 GR 1.1
Nozzle Matl                                              SA-105

Element From Node                                            30
Detail Type                                              Weight
Detail ID                                                WEIR 2
Dist. from "FROM" Node / Offset dist                        450  mm.
```

```
    Miscellaneous Weight                                    0.9806  kN
    Offset from Element Centerline                               0  mm.

    Element From Node                                           30
    Detail Type                                             Weight
    Detail ID                                            SMOKE BOX
    Dist. from "FROM" Node / Offset dist                      1000  mm.
    Miscellaneous Weight                                    1.9612  kN
    Offset from Element Centerline                             200  mm.

--------------------------------------------------------------------

Element From Node                                               40
Element To Node                                                 50
Element Type                                              Cylinder
Description
Distance "FROM" to "TO"                                       2000  mm.
Inside Diameter                                               1200  mm.
Element Thickness                                               10  mm.
Internal Corrosion Allowance                                     3  mm.
Nominal Thickness                                                0  mm.
External Corrosion Allowance                                     0  mm.
Design Internal Pressure                                       4.1  bars
Design Temperature Internal Pressure                           234  °C
Design External Pressure                                     1.034  bars
Design Temperature External Pressure                           100  °C
Effective Diameter Multiplier                                  1.2
Material Name                                            SA-516 70
Efficiency, Longitudinal Seam                                  1.0
Efficiency, Circumferential Seam                               1.0
Weld is pre-Heated                                              No

    Element From Node                                           40
    Detail Type                                         Insulation
    Detail ID                                              Ins: 40
    Dist. from "FROM" Node / Offset dist                         0  mm.
    Height/Length of Insulation                               2000  mm.
    Thickness of Insulation                                     90  mm.
    Density                                                    125  kg/m³

    Element From Node                                           40
    Detail Type                                               Ring
    Detail ID                                          Ring R1 Fr40
    Dist. from "FROM" Node / Offset dist                        50  mm.
    Inside Diameter of Ring                                   1200  mm.
    Thickness of Ring                                           15  mm.
    Outside Diameter of Ring                                  1400  mm.
    Material Name                                        SA-516 70
    Height of Section Ring                                       0  mm.
    Using Custom Stiffener Section                              No

    Element From Node                                           40
    Detail Type                                             Nozzle
    Detail ID                                            N04 (6in)
    Dist. from "FROM" Node / Offset dist                      1000  mm.
```

```
Nozzle Diameter                                       6   in.
Nozzle Schedule                                      80
Nozzle Class                                        150
Layout Angle                                       90.0
Blind Flange (Y/N)                                    N
Weight of Nozzle ( Used if > 0 )                 0.2147   kN
Grade of Attached Flange                         GR 1.1
Nozzle Matl                                    SA-106 B

Element From Node                                    40
Detail Type                                      Nozzle
Detail ID                                     K1B (2in)
Dist. from "FROM" Node / Offset dist               1850   mm.
Nozzle Diameter                                       2   in.
Nozzle Schedule                                    None
Nozzle Class                                        300
Layout Angle                                       90.0
Blind Flange (Y/N)                                    N
Weight of Nozzle ( Used if > 0 )                0.08459   kN
Grade of Attached Flange                         GR 1.1
Nozzle Matl                                      SA-105

Element From Node                                    40
Detail Type                                      Nozzle
Detail ID                                    N07A (2in)
Dist. from "FROM" Node / Offset dist               1000   mm.
Nozzle Diameter                                       2   in.
Nozzle Schedule                                    None
Nozzle Class                                        150
Layout Angle                                      270.0
Blind Flange (Y/N)                                    N
Weight of Nozzle ( Used if > 0 )                0.07081   kN
Grade of Attached Flange                         GR 1.1
Nozzle Matl                                      SA-105

Element From Node                                    40
Detail Type                                      Nozzle
Detail ID                                  N09A (1.5in)
Dist. from "FROM" Node / Offset dist                200   mm.
Nozzle Diameter                                     1.5   in.
Nozzle Schedule                                    None
Nozzle Class                                        150
Layout Angle                                  289.13901
Blind Flange (Y/N)                                    N
Weight of Nozzle ( Used if > 0 )                0.05009   kN
Grade of Attached Flange                         GR 1.1
Nozzle Matl                                      SA-105

Element From Node                                    40
Detail Type                                      Nozzle
Detail ID                                  N09B (1.5in)
Dist. from "FROM" Node / Offset dist                200   mm.
Nozzle Diameter                                     1.5   in.
Nozzle Schedule                                    None
Nozzle Class                                        150
```

```
    Layout Angle                                  250.86099
    Blind Flange (Y/N)                                    N
    Weight of Nozzle ( Used if > 0 )                0.05009   kN
    Grade of Attached Flange                         GR 1.1
    Nozzle Matl                                      SA-105

    Element From Node                                    40
    Detail Type                                      Nozzle
    Detail ID                                    K4A (2in)
    Dist. from "FROM" Node / Offset dist               1100   mm.
    Nozzle Diameter                                       2   in.
    Nozzle Schedule                                    None
    Nozzle Class                                        300
    Layout Angle                                  40.975601
    Blind Flange (Y/N)                                    N
    Weight of Nozzle ( Used if > 0 )                0.09794   kN
    Grade of Attached Flange                         GR 1.1
    Nozzle Matl                                      SA-105

    Element From Node                                    40
    Detail Type                                      Nozzle
    Detail ID                                      K6 (2in)
    Dist. from "FROM" Node / Offset dist               1450   mm.
    Nozzle Diameter                                       2   in.
    Nozzle Schedule                                    None
    Nozzle Class                                        300
    Layout Angle                                       90.0
    Blind Flange (Y/N)                                    N
    Weight of Nozzle ( Used if > 0 )                0.08459   kN
    Grade of Attached Flange                         GR 1.1
    Nozzle Matl                                      SA-105

    Element From Node                                    40
    Detail Type                                      Nozzle
    Detail ID                                      K1 (2in)
    Dist. from "FROM" Node / Offset dist               1650   mm.
    Nozzle Diameter                                       2   in.
    Nozzle Schedule                                    None
    Nozzle Class                                        300
    Layout Angle                                  40.975601
    Blind Flange (Y/N)                                    N
    Weight of Nozzle ( Used if > 0 )                0.09794   kN
    Grade of Attached Flange                         GR 1.1
    Nozzle Matl                                      SA-105

    Element From Node                                    40
    Detail Type                                      Weight
    Detail ID                                    SPARGER 2
    Dist. from "FROM" Node / Offset dist               1000   mm.
    Miscellaneous Weight                             0.9806   kN
    Offset from Element Centerline                      400   mm.

--------------------------------------------------------------------

Element From Node                                        50
```

Element To Node	60	
Element Type	Cylinder	
Description		
Distance "FROM" to "TO"	700	mm.
Inside Diameter	1200	mm.
Element Thickness	10	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	0	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	4.1	bars
Design Temperature Internal Pressure	234	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	

Element From Node	50	
Detail Type	Saddle	
Detail ID	New Sdl	
Dist. from "FROM" Node / Offset dist	303.33	mm.
Width of Saddle	150	mm.
Height of Saddle at Bottom	1200	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	260	mm.
Thickness of Wear Plate	10	mm.
Contact Angle, Wear Plate (degrees)	145.0	
Friction coefficient	0.0	
Moment Factor	3.0	
Dimension E at base (optional)	0	mm.
Circumferential Eff. over Saddle	1.0	
Circumferential Eff. at Midspan	1.0	
Tangent to Tangent dist. (optional)	0	mm.

Element From Node	50	
Detail Type	Insulation	
Detail ID	Ins: 50	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	700	mm.
Thickness of Insulation	90	mm.
Density	125	kg/m³

Element From Node	50	
Detail Type	Nozzle	
Detail ID	N01 (10in)	
Dist. from "FROM" Node / Offset dist	350	mm.
Nozzle Diameter	10	in.
Nozzle Schedule	40	
Nozzle Class	150	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.5796	kN

```
    Grade of Attached Flange                          GR 1.1
    Nozzle Matl                                    SA-106 B

    Element From Node                                    50
    Detail Type                                      Weight
    Detail ID                                 E-100 & C-200
    Dist. from "FROM" Node / Offset dist                350  mm.
    Miscellaneous Weight                              9.806  kN
    Offset from Element Centerline                      600  mm.

--------------------------------------------------------------------

Element From Node                                        60
Element To Node                                          70
Element Type                                         Flange
Description
Distance "FROM" to "TO"                                 160  mm.
Flange Inside Diameter                                 1200  mm.
Element Thickness                                       130  mm.
Internal Corrosion Allowance                              3  mm.
Nominal Thickness                                         0  mm.
External Corrosion Allowance                              0  mm.
Design Internal Pressure                                4.1  bars
Design Temperature Internal Pressure                    234  °C
Design External Pressure                              1.034  bars
Design Temperature External Pressure                    100  °C
Effective Diameter Multiplier                           1.2
Material Name                                        SA-105
    Allowable Stress, Ambient                         137.9  N./mm²
    Allowable Stress, Operating                       136.4  N./mm²
    Allowable Stress, Hydrotest                       223.4  N./mm²
    Material Density                                 7750.4  kg/m³
    P Number Thickness                               30.988  mm.
    Yield Stress, Operating                           206.9  N./mm²
    UCS-66 Chart Curve Designation                        A
    External Pressure Chart Name                       CS-2
    UNS Number                                       K03504
    Product Form                                   Forgings
Perform Flange Stress Calculation (Y/N)                   Y
Weight of Standard Flange                                 0  kN
Class of Standard Flange
Grade of Standard Flange
Weld is pre-Heated                                       No

    Element From Node                                    60
    Detail Type                                  Insulation
    Detail ID                                       Ins: 60
    Dist. from "FROM" Node / Offset dist                  0  mm.
    Height/Length of Insulation                      188.98  mm.
    Thickness of Insulation                              90  mm.
    Density                                             125  kg/m³

--------------------------------------------------------------------

Element From Node                                        70
```

```
Element To Node                                          80
Element Type                                         Flange
Description
Distance "FROM" to "TO"                                  60  mm.
Flange Outside Diameter                                1420  mm.
Element Thickness                                        60  mm.
Internal Corrosion Allowance                              3  mm.
Nominal Thickness                                         0  mm.
External Corrosion Allowance                              0  mm.
Design Internal Pressure                                4.1  bars
Design Temperature Internal Pressure                    234  °C
Design External Pressure                              1.034  bars
Design Temperature External Pressure                    100  °C
Effective Diameter Multiplier                           1.2
Material Name                                        SA-105
Perform Flange Stress Calculation (Y/N)                   Y
Weight of Standard Flange                                 0  kN
Class of Standard Flange
Grade of Standard Flange
Weld is pre-Heated                                       No

    Element From Node                                    70
    Detail Type                                  Insulation
    Detail ID                                      Ins: 70
    Dist. from "FROM" Node / Offset dist                  0  mm.
    Height/Length of Insulation                      106.43  mm.
    Thickness of Insulation                              90  mm.
    Density                                             125  kg/m³

    Element From Node                                    70
    Detail Type                                      Nozzle
    Detail ID                                    N03 (10in)
    Dist. from "FROM" Node / Offset dist                320  mm.
    Nozzle Diameter                                      10  in.
    Nozzle Schedule                                      80
    Nozzle Class                                        150
    Layout Angle                                      320.0
    Blind Flange (Y/N)                                    N
    Weight of Nozzle ( Used if > 0 )                 3.7756  kN
    Grade of Attached Flange                         GR 1.1
    Nozzle Matl                                    SA-106 B

    Element From Node                                    70
    Detail Type                                      Nozzle
    Detail ID                                Chimney Nozzle
    Dist. from "FROM" Node / Offset dist                320  mm.
    Nozzle Diameter                                      10  in.
    Nozzle Schedule                                      80
    Nozzle Class                                        150
    Layout Angle                                      220.0
    Blind Flange (Y/N)                                    N
    Weight of Nozzle ( Used if > 0 )                 3.7756  kN
    Grade of Attached Flange                         GR 1.1
    Nozzle Matl                                    SA-106 B
```

```
Element From Node                                       70
Detail Type                                         Weight
Detail ID                                          CHIMNEY
Dist. from "FROM" Node / Offset dist                   106  mm.
Miscellaneous Weight                                7.8448  kN
Offset from Element Centerline                         320  mm.
```

XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
10	20	50	...	50	...
20	30	1550	...	1500	...
30	40	3550	...	2000	...
40	50	5550	...	2000	...
50	60	6250	...	700	...
60	70	6410	...	160	...
70	80	6479.52	...	60	...

Flange Input Data Values **Description: FLANGE :**

Item: Node 60 to 70

```
Description of Flange Geometry (Type)            Integral Weld Neck
Design Pressure                              P          4.10  bars
Design Temperature                                       234  °C
Internal Corrosion Allowance                ci        3.0000  mm.
External Corrosion Allowance                ce        0.0000  mm.
Use Corrosion Allowance in Thickness Calcs.               Yes

Flange Inside Diameter                       B      1200.000  mm.
Flange Outside Diameter                      A      1420.000  mm.
Flange Thickness                             t      130.0000  mm.
Thickness of Hub at Small End               go       10.0000  mm.
Thickness of Hub at Large End               g1       15.0000  mm.
Length of Hub                                h       30.0000  mm.

Flange Material                                       SA-105
Flange Material UNS number                            K03504
Flange Allowable Stress At Temperature     Sfo        136.40  N./mm²
Flange Allowable Stress At Ambient         Sfa        137.90  N./mm²

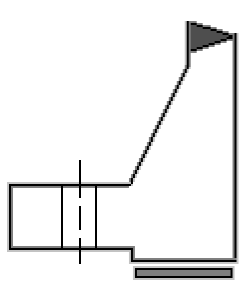
Bolt Material                                      SA-193 B7
Bolt Allowable Stress At Temperature        Sb        172.38  N./mm²
Bolt Allowable Stress At Ambient            Sa        172.38  N./mm²

Diameter of Bolt Circle                      C      1335.000  mm.
Nominal Bolt Diameter                        a       38.1000  mm.
Type of Threads                            TEMA Thread Series
Number of Bolts                                           44

Flange Face Outside Diameter               Fod      1270.000  mm.
Flange Face Inside Diameter                Fid      1200.000  mm.
Flange Facing Sketch                         1, Code Sketch 1a

Gasket Outside Diameter                     Go      1265.000  mm.
Gasket Inside Diameter                      Gi      1220.000  mm.
Gasket Factor                                m        3.0000
Gasket Design Seating Stress                 y         68.95  N./mm²

Column for Gasket Seating                    2, Code Column II
Gasket Thickness                            tg        3.1750  mm.
```



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Hub Small End Required Thickness due to Internal Pressure:
```
  = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
  = (4.1*(1200.0/2+3.0))/(136.4*1.0-0.6*4.1)+Ca
  = 4.8159 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (136.4 * 1.0 * 7.0)/(603.0 + 0.6 * 7.0 )
  = 15.724 bars
```

```
 Corroded Flange Thickness, tc = T-ci                    127.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor               1206.000  mm.
 Corroded Large Hub,     g1Cor = g1-ci                    12.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                     7.000  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor       52.500  mm.

 Gasket Contact Width,       N = (Go - Gi) / 2            22.500  mm.
 Basic Gasket Width,        bo = N / 2                    11.250  mm.
 Effective Gasket Width,     b = Cb sqrt(bo)               8.452  mm.
 Gasket Reaction Diameter,   G = Go - 2 * b             1248.096  mm.
```

<u>Basic Flange and Bolt Loads:</u>

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 1248.0959² * 4.1
  = 501.600 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P
  = 2 * 8.4521 * 3.1416 * 1248.0959 * 3.0 * 4.1
  = 81.524 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 1206.0² *4.1/4
  = 468.335 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 502 - 468
  = 33.265 kN
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 502 + 82 + 0, 0 )
  = 583.124 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.95*8.4521*3.141*1248.096+0.0*0.0*0.0
  = 2284.852 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 583/172, 2285/172
  = 132.563 cm²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
= 2a + 6t/(m + 0.5)
= 2 * 38.1 + 6 * 127.0/(3.0 + 0.5)
= 293.914 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
= C * sin( pi / n )
= 1335.0 * sin( 3.142/44 )
= 95.238 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
= max( sqrt( Bs/( 2a + t )), 1 )
= max( sqrt( 95.238/( 2 * 38.1 + 127.0 )), 1 )
= 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area, cm²	132.563	398.838	
Radial Distance between Hub and Bolts:	50.800	52.500	
Radial Distance between Bolts and Edge:	38.100	42.500	
Circ. Spacing between the Bolts:	82.550	95.238	293.914

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
= Ab * Sa/( y * Pi * (Go + Gi) )
= 398.838 * 172.38/(68.95 * 3.14 * (1265.0 + 1220.0) )
= 12.772 mm.
```

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :
```
= 32.000 mm.[Note: Exceeds actual gasket width, 22.500  ]
```

Flange Design Bolt Load, Gasket Seating [W]:
```
= Sa * ( Am + Ab ) / 2
= 172.38 * ( 132.5625 + 398.8379 )/2
= 4579.62 kN
```
Gasket Load for the Operating Condition [HG]:
```
= Wm1 - H
= 583 - 502
= 81.52 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
```
= (C - G ) / 2
= ( 1335.0 - 1248.0959 )/2
= 43.4520 mm.
```
Distance to Face Pressure Reaction [ht]:
```
= ( R + g1 + hg ) / 2
= ( 52.5 + 12.0 + 43.452 )/2
= 53.9760 mm.
```
Distance to End Pressure Reaction [hd]:
```
= R + ( g1 / 2 )
```

```
  = 52.5 + ( 12.0/2.0 )
  = 58.5000 mm.
```

Summary of Moments for Internal Pressure: (N-m)

```
 Loading                  Force  |   Distance |  Bolt Corr |         Moment  |
 ---------------------------------------------------------------------------
 End Pressure,    Md        468. |    58.5000 |     1.0000 |         27409.  |
 Face Pressure,   Mt         33. |    53.9760 |     1.0000 |          1796.  |
 Gasket Load,     Mg         82. |    43.4520 |     1.0000 |          3544.  |
 Gasket Seating, Matm      4580. |    43.4520 |     1.0000 |        199074.  |

 Total Moment for Operation,       Mop                               32749. N-m
 Total Moment for Gasket seating, Matm                              199074. N-m

 Effective Hub Length, ho = sqrt(Bcor*goCor)           91.880  mm.
 Hub Ratio,           h/h0 = HL / H0                     0.327
 Thickness Ratio,    g1/g0 = (g1Cor/goCor)               1.714
```

Flange Factors for Integral Flange:

```
 Factor F                                                0.869
 Factor V                                                0.323
 Factor f                                                1.417
 Factors from Figure 2-7.1                    K =        1.177
                    T =       1.848           U =       13.152
                    Y =      11.968           Z =        6.176
                    d = 0.18312E+06 mm.³       e =       0.0095 mm.^-1
 Stress Factors                           ALPHA =        2.201
                 BETA =       2.601       GAMMA =        1.191
                DELTA =      11.186       Lamda =       12.377
```

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.4167*32749/1206.0)/(12.377*12.0²)
  = 21.58 N./mm²
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.4167*199074/1206.0)/(12.377*12.0²)
  = 131.17 N./mm²
```

Radial Flange Stress, Operating [SRo]:

```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2.6013*32749/1206.0)/(12.377*127.0²)
  = 0.35 N./mm²
```

Radial Flange Stress, Seating [SRa]:

```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2.6013*199074/1206.0)/(12.377*127.0²)
  = 2.15 N./mm²
```

Tangential Flange Stress, Operating [STo]:

```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (11.9679*32749/(127.0²*1206.0))-6.1763*0.4
  = 17.96 N./mm²
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (11.9679*199074/(127.0²*1206.0))-6.1763*2
  = 109.16 N./mm²
```

Average Flange Stress, Operating [SAo]:

```
  = ( SHo + max( SRo, STo ) ) / 2
  = (22+max(0.4,18))/2
  = 19.77 N./mm²
```

Average Flange Stress, Seating [SAa]:

```
  = ( SHa + max( SRa, STa ) ) / 2
  = (131+max(2,109))/2
  = 120.17 N./mm²
```

Bolt Stress, Operating [BSo]:

```
  = Wm1 / Ab
  = 583/398.8379
  = 14.62 N./mm²
```

Bolt Stress, Seating [BSa]:

```
  = ( Wm2 / Ab )
  = (2285/398.8379)
  = 57.29 N./mm²
```

Flange Stress Analysis Results: N./mm²

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	21.58	204.60	131.17	206.85
Radial Flange	0.35	136.40	2.15	137.90
Tangential Flange	17.96	136.40	109.16	137.90
Maximum Average	19.77	136.40	120.17	137.90
Bolting	14.62	172.38	57.29	172.38

```
Minimum Required Flange Thickness [Rigidity]         129.565 mm.
Estimated M.A.W.P. ( Operating )                        24 bars
Estimated Finished Weight of Flange at given Thk.      467.2 kg.
Estimated Unfinished Weight of Forging at given Thk    561.4 kg.
```

<u>Flange Rigidity Based on Required Thickness [ASME]:</u>

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14*199074.5/1.0*999.68*0.323/(12.254*202713*7.0²*91.88*0.3)
  = 1.000    (should be <= 1)
```

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

```
  = 52.14 * Mo / Bsc * Cnv_fac * V / ( Lambda * Eop * goc² * ho * Ki )
  = 52.14*32748.8/1.0*999.68*0.323/(12.254*190171*7.0²*91.88*0.3)
  = 0.175    (should be <= 1)
```

<u>Flange Rigidity Based on Given Thickness [ASME]:</u>

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
```

```
  = 52.14*199074.5/1.0*999.68*0.323/(12.377*202713*7.0²*91.88*0.3)
  = 0.990   (should be <= 1)
```

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

```
  = 52.14 * Mo / Bsc * Cnv_fac * V / ( Lambda * Eop * goc² * ho * Ki )
  = 52.14*32748.8/1.0*999.68*0.323/(12.377*190171*7.0²*91.88*0.3)
  = 0.174   (should be <= 1)
```

Minimum Design Metal Temperature Results:

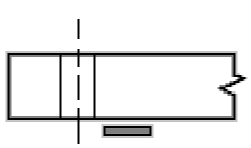
Thickness Ratio = 0.215, Temperature Reduction per Fig. UCS 66.1 = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A             -8 °C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                   -29 °C
```

Flange Input Data Values **Description: FLANGE :**

Item: Node 70 to 80

Description of Flange Geometry (Type)		Blind	
Design Pressure	P	4.10	bars
Design Temperature		234	°C
Internal Corrosion Allowance	ci	3.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Outside Diameter	A	1420.000	mm.
Flange Thickness	t	60.0000	mm.
Flange Material		SA-105	
Flange Material UNS number		K03504	
Flange Allowable Stress At Temperature	Sfo	136.40	N./mm²
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm²
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm²
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm²
Diameter of the Load Reaction, Long Span	D	0.000	mm.
Diameter of the Load Reaction, Short Span	d	0.000	mm.
Perimeter along the Center of the Bolts	L	4194.026	mm.
Diameter of Bolt Circle	C	1335.000	mm.
Nominal Bolt Diameter	a	38.1000	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		44	
Flange Face Outside Diameter	Fod	1270.000	mm.
Flange Face Inside Diameter	Fid	1200.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	1265.000	mm.
Gasket Inside Diameter	Gi	1220.000	mm.
Gasket Factor	m	3.0000	
Gasket Design Seating Stress	y	68.95	N./mm²
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.1750	mm.



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```
Gasket Contact Width,        N = (Go - Gi) / 2            22.500  mm.
Basic Gasket Width,         bo = N / 2                    11.250  mm.
Effective Gasket Width,      b = Cb sqrt(bo)               8.452  mm.
Gasket Reaction Diameter,    G = Go - 2 * b             1248.096  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 1248.0959² * 4.1
  = 501.600 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P
  = 2 * 8.4521 * 3.1416 * 1248.0959 * 3.0 * 4.1
  = 81.524 kN
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 502 + 82 + 0, 0 )
  = 583.124 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.95*8.4521*3.141*1248.096+0.0*0.0*0.0
  = 2284.852 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 583/172, 2285/172
  = 132.563 cm²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 38.1 + 6 * 57.0/(3.0 + 0.5)
  = 173.914 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 1335.0 * sin( 3.142/44 )
  = 95.238 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 95.238/( 2 * 38.1 + 57.0 )), 1 )
  = 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area, cm²	132.563	398.838	
Radial Distance between Bolts and Edge:	38.100	42.500	
Circ. Spacing between the Bolts:	82.550	95.238	173.914

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 398.838 * 172.38/(68.95 * 3.14 * (1265.0 + 1220.0) )
  = 12.772 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa * ( Am + Ab ) / 2
  = 172.38 * ( 132.5625 + 398.8379 )/2
  = 4579.62 kN
```
Gasket Load for the Operating Condition [HG]:
```
  = Wm1
  = 583.12 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
```
  = (C - G ) / 2
  = ( 1335.0 - 1248.0959 )/2
  = 43.4520 mm.
```
Tangential Flange Stress, Flat Head (UG-34), Operating [STo]:
```
  = 1.9 * Wm1 * hG * Bsc/(t² * G) + C * Z * Peq * G²/t²
  = 1.9*583*43.452*1.0/(57.0²*1248.0959)+
    0.3*1.0*4.1*1248.0959²/57.0²
  = 70.85 N./mm²
```
Tangential Flange Stress, Flat Head (UG-34), Seating [STa]:
```
  = 1.9 * W * hG * Bsc/ (t² * G)
  = 1.9*4580*43.452*1.0/(57.0²*1248.0959)
  = 93.25 N./mm²
```

Bolt Stress, Operating [BSo]:
```
  = Wm1 / Ab
  = 583/398.8379
  = 14.62 N./mm²
```
Bolt Stress, Seating [BSa]:
```
  = ( Wm2 / Ab )
  = (2285/398.8379)
  = 57.29 N./mm²
```

Flange Stress Analysis Results: N./mm²

```
                                  Operating |            Gasket Seating |
                         Actual      Allowed |       Actual      Allowed |
 ----------------------------------------------------------------------------
 Tangential Flange        70.85 |      136.40 |        93.25 |      137.90 |
 Bolting                  14.62 |      172.38 |        57.29 |      172.38 |
 Reqd. Blind Flange Thickness at Center               49.872 mm.
 Reqd. Blind Flange Thickness at Gasket               49.872 mm.
 Estimated M.A.W.P. ( Operating )                          8 bars
 Estimated Finished Weight of Flange at given Thk.     736.5 kg.
 Estimated Unfinished Weight of Forging at given Thk   736.5 kg.
```

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.677, Temperature Reduction per Fig. UCS 66.1 = 18 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A              4 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -14 °C
```

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd bars	Nominal Thickness mm.	Total Corr Allowance mm.	Element Diameter mm.	Allowable Stress(SE) N./mm²
10	20	4.1553	12	3	1200	137.9
20	30	4.1	...	3	1200	137.9
30	40	4.1	...	3	1200	137.9
40	50	4.1	...	3	1200	137.9
50	60	4.1	...	3	1200	137.9
60	70	4.1	...	3	1200	136.4
70	80	4.1	...	3	1420	136.4

Element Required Thickness and MAWP :

From	To	Design Pressure bars	M.A.W.P. Corroded bars	M.A.P. New & Cold bars	Minimum Thickness mm.	Required Thickness mm.
10	20	4.1	16.0394	22.9438	10	4.80568
20	30	4.1	15.8966	22.7545	10	4.79613
30	40	4.1	15.8966	22.7545	10	4.79613
40	50	4.1	15.8966	22.7545	10	4.79613
50	60	4.1	15.8966	22.7545	10	4.79613
60	70	4.1	15.7237	27.3405	130	129.565
70	80	4.1	7.89294	8.84163	60	49.8715
Minimum			8	9		

MAWP: 5 bars, limited by: Nozzle Reinforcement.

Elements Suitable for Design Internal Pressure.

<u>Internal Pressure Calculation Results:</u>

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<u>Elliptical Head From 10 To 20 SA-516 70 , UCS-66 Crv. B at 234 °C</u>

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
 = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
 = (4.155*1206.0*0.993)/(2*137.9*1.0-0.2*4.155)
 = 1.8057 + 3.0000 = 4.8057 mm.
```

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

Less Operating Hydrostatic Head Pressure of 0.055 bars

```
 = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
 = (2*137.9*1.0*7.0)/(0.993*1206.0+0.2*7.0)
 = 16 - 0.1 = 16  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
  = (2*137.9*1.0*10.0)/(1.0*1200.0+0.2*10.0)
  = 23 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (4.155*(0.993*1206.0+0.2*7.0))/(2*1.0*7.0)
  = 35.603 N./mm²
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (4.155*603.0)/(137.9*1.0-0.6*4.155)+3.0
  = 4.820 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.055 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 9.0)/(603.0 + 0.6 * 9.0 )
  = 20 - 0.1 = 20  bars
```

Factor K, corroded condition [Kcor]:
```
  = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
  = ( 2 + ( 1206.0/( 2 * 303.0 ))²)/6
  = 0.993416
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 4.286 %

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 10.0, tr = 2.373, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.339, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 12.0, tr = 2.394, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.266, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -23 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

Note:
Post Weld Heat Treatment is required for this Element/Joint and it was specified as being heat treated.

Cylindrical Shell From 20 To 30 SA-516 70 , UCS-66 Crv. B at 234 °C
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
```

```
  = (4.1*603.0)/(137.9*1.0-0.6*4.1)
  = 1.7961 + 3.0000 = 4.7961 mm.
```

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

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*7.0)/(603.0+0.6*7.0)
  = 16 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*10.0)/(600.0+0.6*10.0)
  = 23 bars
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (4.1*(603.0+0.6*7.0))/(1.0*7.0)
  = 35.567 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 0.826 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 10.0, tr = 2.369, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.338, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

Note:
Post Weld Heat Treatment is required for this Element/Joint and it was specified as being heat treated.

<u>Cylindrical Shell From 30 To 40 SA-516 70 , UCS-66 Crv. B at 234 °C</u>
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (4.1*603.0)/(137.9*1.0-0.6*4.1)
  = 1.7961 + 3.0000 = 4.7961 mm.
```

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

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*7.0)/(603.0+0.6*7.0)
  = 16 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*10.0)/(600.0+0.6*10.0)
  = 23 bars
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (4.1*(603.0+0.6*7.0))/(1.0*7.0)
  = 35.567 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 0.826 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 10.0, tr = 2.369, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.338, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

Note:
Post Weld Heat Treatment is required for this Element/Joint and it was specified as being heat treated.

Cylindrical Shell From 40 To 50 SA-516 70 , UCS-66 Crv. B at 234 °C
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (4.1*603.0)/(137.9*1.0-0.6*4.1)
  = 1.7961 + 3.0000 = 4.7961 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*7.0)/(603.0+0.6*7.0)
  = 16 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*10.0)/(600.0+0.6*10.0)
  = 23 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (4.1*(603.0+0.6*7.0))/(1.0*7.0)
  = 35.567 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 0.826 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 10.0, tr = 2.369, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.338, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

Note:
Post Weld Heat Treatment is required for this Element/Joint and it was specified as being heat treated.

Cylindrical Shell From 50 To 60 SA-516 70 , UCS-66 Crv. B at 234 °C

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (4.1*603.0)/(137.9*1.0-0.6*4.1)
  = 1.7961 + 3.0000 = 4.7961 mm.
```

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

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*7.0)/(603.0+0.6*7.0)
  = 16 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*10.0)/(600.0+0.6*10.0)
  = 23 bars
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (4.1*(603.0+0.6*7.0))/(1.0*7.0)
  = 35.567 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 0.826 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 10.0, tr = 2.369, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.338, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

Note:
Post Weld Heat Treatment is required for this Element/Joint and it was specified as being heat treated.

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          7.027  bars
 Pressure per UG99b[36]  = 1.30 * Design Pres * Sa/S       5.330  bars
 Pressure per UG99c      = 1.30 * M.A.P. - Head(Hyd)      11.355  bars
 Pressure per UG100      = 1.10 * M.A.W.P. * Sa/S          5.946  bars
 Pressure per PED        = max(1.43*DP, 1.25*DP*ratio)     5.863  bars
 Pressure per App 27-4   = M.A.W.P.                        5.406  bars
```

UG-99(b) Note 36, Test Pressure Calculation:

```
  = Test Factor * Design Pressure * Stress Ratio
  = 1.3 * 4.1 * 1.0
  = 5.330 bars
```

Horizontal Test performed per: UG-99b (Note 36)

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 (N./mm² & bars):

From	To	Stress	Allowable	Ratio	Pressure
10	20	46.7	235.8	0.198	5.45
20	30	47.3	235.8	0.200	5.45
30	40	47.3	235.8	0.200	5.45
40	50	47.3	235.8	0.200	5.45
50	60	47.3	235.8	0.200	5.45

Stress ratios for Nozzle and Pad Materials (N./mm²):

Description	Pad/Nozzle	Ambient	Operating	Ratio
N08 (1in)	Nozzle	137.90	136.43	1.011
N02 (2in)	Nozzle	137.90	136.43	1.011
N12 (1in)	Nozzle	137.90	136.43	1.011
M1 (24in)	Nozzle	137.90	137.90	1.000
M1 (24in)	Pad	137.90	137.90	1.000
N07C (2in)	Nozzle	137.90	136.43	1.011
N07B (2in)	Nozzle	137.90	136.43	1.011
K9B (3in)	Nozzle	117.90	117.90	1.000
K9B (3in)	Pad	137.90	137.90	1.000
K9A (3in)	Nozzle	117.90	117.90	1.000
K9A (3in)	Pad	137.90	137.90	1.000
K10A (2in)	Nozzle	137.90	136.43	1.011
K10B (2in)	Nozzle	137.90	136.43	1.011
K11A (2in)	Nozzle	137.90	136.43	1.011
K11B (2in)	Nozzle	137.90	136.43	1.011
K7A (3in)	Nozzle	117.90	117.90	1.000
K7A (3in)	Pad	137.90	137.90	1.000
K7B (3in)	Nozzle	117.90	117.90	1.000
K7B (3in)	Pad	137.90	137.90	1.000
N05 (2in)	Nozzle	137.90	136.43	1.011
K2B (2in)	Nozzle	137.90	136.43	1.011
K2A (2in)	Nozzle	137.90	136.43	1.011
K3A (3in)	Nozzle	117.90	117.90	1.000
K3A (3in)	Pad	137.90	137.90	1.000
K3B (3in)	Nozzle	117.90	117.90	1.000
K3B (3in)	Pad	137.90	137.90	1.000
N11 (1in)	Nozzle	137.90	136.43	1.011
M2 (24in)	Nozzle	137.90	137.90	1.000
M2 (24in)	Pad	137.90	137.90	1.000
K8 (2in)	Nozzle	137.90	136.43	1.011
N04 (6in)	Nozzle	117.90	117.90	1.000
N04 (6in)	Pad	137.90	137.90	1.000
K1B (2in)	Nozzle	137.90	136.43	1.011

N07A (2in)	Nozzle	137.90	136.43	1.011
N09A (1.5in)	Nozzle	137.90	136.43	1.011
N09B (1.5in)	Nozzle	137.90	136.43	1.011
K4A (2in)	Nozzle	137.90	136.43	1.011
K6 (2in)	Nozzle	137.90	136.43	1.011
K1 (2in)	Nozzle	137.90	136.43	1.011
N01 (10in)	Nozzle	117.90	117.90	1.000
N01 (10in)	Pad	137.90	137.90	1.000
N03 (10in)	Nozzle	117.90	117.90	1.000
N03 (10in)	Pad	137.90	137.90	1.000
Chimney Nozzle	Nozzle	117.90	117.90	1.000
Chimney Nozzle	Pad	137.90	137.90	1.000
Minimum				1.000

Stress ratios for Stiffening Ring Materials (N./mm²):

Description	Ambient	Operating	Ratio
Ring R1 Fr40	137.90	137.90	1.000
Minimum			1.000

Stress ratios for Pressurized Vessel Elements (N./mm²):

Description	Ambient	Operating	Ratio
	137.90	137.90	1.000
	137.90	137.90	1.000
	137.90	137.90	1.000
	137.90	137.90	1.000
	137.90	137.90	1.000
	137.90	136.40	1.011
	137.90	136.40	1.011
Minimum			1.000

Hoop Stress in Nozzle Wall during Pressure Test (N./mm²):

Description	Ambient	Operating	Ratio
N08 (1in)	1.53	223.40	0.007
N02 (2in)	1.53	223.40	0.007
N12 (1in)	1.20	223.40	0.005
M1 (24in)	23.50	235.81	0.100
N07C (2in)	1.53	223.40	0.007
N07B (2in)	1.53	223.40	0.007
K9B (3in)	6.38	217.19	0.029
K9A (3in)	6.38	217.19	0.029
K10A (2in)	1.46	223.40	0.007
K10B (2in)	1.46	223.40	0.007
K11A (2in)	1.46	223.40	0.007
K11B (2in)	1.46	223.40	0.007
K7A (3in)	6.38	217.19	0.029

```
K7B (3in)                          |       6.38 |       217.19 |    0.029 |
N05 (2in)                          |       1.53 |       223.40 |    0.007 |
K2B (2in)                          |       1.46 |       223.40 |    0.007 |
K2A (2in)                          |       1.46 |       223.40 |    0.007 |
K3A (3in)                          |       6.38 |       217.19 |    0.029 |
K3B (3in)                          |       6.38 |       217.19 |    0.029 |
N11 (1in)                          |       1.20 |       223.40 |    0.005 |
M2 (24in)                          |      23.50 |       235.81 |    0.100 |
K8 (2in)                           |       1.46 |       223.40 |    0.007 |
N04 (6in)                          |       6.73 |       217.19 |    0.031 |
K1B (2in)                          |       1.46 |       223.40 |    0.007 |
N07A (2in)                         |       1.53 |       223.40 |    0.007 |
N09A (1.5in)                       |       1.38 |       223.40 |    0.006 |
N09B (1.5in)                       |       1.38 |       223.40 |    0.006 |
K4A (2in)                          |       1.46 |       223.40 |    0.007 |
K6 (2in)                           |       1.94 |       223.40 |    0.009 |
K1 (2in)                           |       1.46 |       223.40 |    0.007 |
N01 (10in)                         |      14.33 |       217.19 |    0.066 |
N03 (10in)                         |       7.10 |       217.19 |    0.033 |
Chimney Nozzle                     |       7.10 |       217.19 |    0.033 |
-----------------------------------------------------------------------
```

Elements Suitable for Test Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm²
10	20	No Calc	1220	7	0.0007969	78.0139
20	30	3700	1220	7	0.00018359	18.3547
30	40	3700	1220	7	0.00018359	18.3547
40	Ring	3700	1220	7	0.00018359	18.3547
Ring	50	2650	1220	7	0.00026068	26.0625
50	60	2650	1220	7	0.00026068	26.0625
60	70	No Calc	...	127	No Calc	No Calc
70	80	No Calc	...	57	No Calc	No Calc

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	10	6.15855	1.034	4.97328
20	30	10	9.22129	1.034	1.4041
30	40	10	9.22129	1.034	1.4041
40	Ring	10	9.22129	1.034	1.4041
Ring	50	10	8.39371	1.034	1.99374
50	60	10	8.39371	1.034	1.99374
60	70	130	129.565	1.034	No Calc
70	80	60	49.8856	1.034	No Calc
Minimum					1

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	3700	4945.73	No Calc	No Calc
30	40	3700	4945.73	No Calc	No Calc
40	Ring	3700	4945.73	No Calc	No Calc
Ring	50	2650	4945.66	41.1436	263.43
50	60	2650	4945.66	No Calc	No Calc
60	70	No Calc	No Calc	No Calc	No Calc
70	80	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

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Elliptical Head From 10 to 20 Ext. Chart: CS-2 at 100 °C

Elastic Modulus from Chart: CS-2 at 100 °C: 199943392.000 KPa.

```
                                                           |                                    |
 Results for Maximum Allowable Ext. Pressure               |                               MAEP |
 -----------------------------------------------------------------------------------------------
     Tca |  Outer Dia |         Do/t |  Factor A |                                   Factor B |
   7.000 |    1220.00 |       174.29 | 0.0007969 |                                      78.01 |
 -----------------------------------------------------------------------------------------------
 MAEP = B/(K0*Do/t) = 78.0139/( 0.9 *174.2857 ) = 4.9733 bars

                                                           |                                    |
 Results for Required Thickness                            |                                Tca |
 -----------------------------------------------------------------------------------------------
     Tca |  Outer Dia |         Do/t |  Factor A |                                   Factor B |
   3.159 |    1220.00 |       386.25 | 0.0003596 |                                      35.95 |
 -----------------------------------------------------------------------------------------------
 MAEP = B/(K0*Do/t) = 35.9499/( 0.9 *386.2534 ) = 1.0341 bars
```

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (1.727*1206.0*0.993)/(2*137.9*1.0-0.2*1.727)
  = 0.7502 + 3.0000 = 3.7502 mm.
```

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*137.9*1.0*7.0)/(0.993*1206.0+0.2*7.0))/1.67
  = 10 bars
```

Maximum Allowable External Pressure [MAEP]:
```
  = min( MAEP, MAWP )
  = min( 4.97, 9.6375 )
  = 4.973 bars
```

Thickness requirements per UG-33(a)(1) do not govern the required thickness of this head.

Cylindrical Shell From 20 to 30 Ext. Chart: CS-2 at 100 °C

Elastic Modulus from Chart: CS-2 at 100 °C: 199943392.000 KPa.

```
                                                 |                                    |
Results for Maximum Allowable Ext. Pressure      |                               MAEP |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |        L/D |   Factor A | Factor B |
  7.000 |    1220.00 |     3700.00 |    174.29 |     3.0328 |  0.0001836 |    18.35 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*18.3547)/(3*174.2857) = 1.4041 bars

                                                 |                                    |
Results for Required Thickness                   |                                Tca |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |        L/D |   Factor A | Factor B |
  6.221 |    1220.00 |     3700.00 |    196.10 |     3.0328 |  0.0001521 |    15.21 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*15.209)/(3*196.1009) = 1.034 bars

                                                 |                                    |
Results for Maximum Stiffened Length             |                               Slen |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |        L/D |   Factor A | Factor B |
  7.000 |    1220.00 |     4945.73 |    174.29 |     4.0539 |  0.0001353 |    13.53 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*13.5259)/(3*174.2857) = 1.0347 bars

-----------------------------------------------------------------------------------------------
```

Cylindrical Shell From 30 to 40 Ext. Chart: CS-2 at 100 °C

Elastic Modulus from Chart: CS-2 at 100 °C: 199943392.000 KPa.

```
                                                 |                                    |
Results for Maximum Allowable Ext. Pressure      |                               MAEP |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |        L/D |   Factor A | Factor B |
  7.000 |    1220.00 |     3700.00 |    174.29 |     3.0328 |  0.0001836 |    18.35 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*18.3547)/(3*174.2857) = 1.4041 bars

                                                 |                                    |
Results for Required Thickness                   |                                Tca |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |        L/D |   Factor A | Factor B |
  6.221 |    1220.00 |     3700.00 |    196.10 |     3.0328 |  0.0001521 |    15.21 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*15.209)/(3*196.1009) = 1.034 bars

                                                 |                                    |
Results for Maximum Stiffened Length             |                               Slen |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |        L/D |   Factor A | Factor B |
```

```
  7.000 |    1220.00 |     4945.73 |     174.29 |     4.0539 |  0.0001353 |     13.53 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*13.5259)/(3*174.2857) = 1.0347 bars

-----------------------------------------------------------------------------------------------
```

Cylindrical Shell From 40 to Ring R1 Fr40 Ext. Chart: CS-2 at 100 °C

Elastic Modulus from Chart: CS-2 at 100 °C: 199943392.000 KPa.

```
                                             |                                    |
Results for Maximum Allowable Ext. Pressure  |                               MAEP |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |       Do/t |        L/D |   Factor A | Factor B |
  7.000 |    1220.00 |     3700.00 |     174.29 |     3.0328 |  0.0001836 |    18.35 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*18.3547)/(3*174.2857) = 1.4041 bars

                                             |                                    |
Results for Required Thickness               |                                Tca |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |       Do/t |        L/D |   Factor A | Factor B |
  6.221 |    1220.00 |     3700.00 |     196.10 |     3.0328 |  0.0001521 |    15.21 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*15.209)/(3*196.1009) = 1.034 bars

                                             |                                    |
Results for Maximum Stiffened Length         |                               Slen |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |       Do/t |        L/D |   Factor A | Factor B |
  7.000 |    1220.00 |     4945.73 |     174.29 |     4.0539 |  0.0001353 |    13.53 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*13.5259)/(3*174.2857) = 1.0347 bars

-----------------------------------------------------------------------------------------------
```

Cylindrical Shell From Ring R1 Fr40 to 50 Ext. Chart: CS-2 at 100 °C

Elastic Modulus from Chart: CS-2 at 100 °C: 199943392.000 KPa.

```
                                             |                                    |
Results for Maximum Allowable Ext. Pressure  |                               MAEP |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |       Do/t |        L/D |   Factor A | Factor B |
  7.000 |    1220.00 |     2650.00 |     174.29 |     2.1721 |  0.0002607 |    26.06 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*26.0625)/(3*174.2857) = 1.9937 bars

                                             |                                    |
Results for Required Thickness               |                                Tca |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |       Do/t |        L/D |   Factor A | Factor B |
  5.394 |    1220.00 |     2650.00 |     226.19 |     2.1721 |  0.0001755 |    17.54 |
-------------------------------------------------------------------------------------
```

```
MAEP = (4*B)/(3*(Do/t)) = (4*17.5426)/(3*226.1893) = 1.034 bars

                                                  |                                    |
Results for Maximum Stiffened Length              |                              Slen  |
------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  7.000 |    1220.00 |     4945.66 |    174.29 |    4.0538 |  0.0001353 |    13.53 |
------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*13.5261)/(3*174.2857) = 1.0347 bars

-----------------------------------------------------------------------------------------------
```

Cylindrical Shell From 50 to 60 Ext. Chart: CS-2 at 100 °C

Elastic Modulus from Chart: CS-2 at 100 °C: 199943392.000 KPa.

```
                                                  |                                    |
Results for Maximum Allowable Ext. Pressure       |                              MAEP  |
------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  7.000 |    1220.00 |     2650.00 |    174.29 |    2.1721 |  0.0002607 |    26.06 |
------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*26.0625)/(3*174.2857) = 1.9937 bars

                                                  |                                    |
Results for Required Thickness                    |                               Tca  |
------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  5.394 |    1220.00 |     2650.00 |    226.19 |    2.1721 |  0.0001755 |    17.54 |
------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*17.5426)/(3*226.1893) = 1.034 bars

                                                  |                                    |
Results for Maximum Stiffened Length              |                              Slen  |
------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  7.000 |    1220.00 |     4945.66 |    174.29 |    4.0538 |  0.0001353 |    13.53 |
------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*13.5261)/(3*174.2857) = 1.0347 bars

-----------------------------------------------------------------------------------------------
```

Stiffening Ring Calcs for : Ring R1 Fr40 , SA-516 70 , Bar Ring: 100 x 15 mm.

```
Effective Length of Shell:                           102 mm.

                Area (cm²)   Distance (mm.)    Area*Dist
--------------------------------------------------------
Shell:              7.116         3.5000          24.905
Ring :             15.000        57.0000         855.000
Total:             22.116                        879.905
--------------------------------------------------------
Centroid of Ring plus Shell:                          40 mm.
```

```
                  Inertia         Distance         A*Dist²
---------------------------------------------------------
Shell:              0.291          36.2864        9369.297
Ring :            125.000         -17.2136        4444.628
Total:            125.290                        13813.925
---------------------------------------------------------
Available Moment of Inertia, Ring plus Shell:        263 cm**4

Required Stress in Ring plus Shell      Breq       12.66 N./mm²
Required Strain in Ring plus Shell      Areq   0.0001270
```

Required Moment of Inertia, Ring plus Shell:

```
  = ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
  = (1220.0²*3175.0(7.0+15.0/3175.0)0.000127)/10.9
  = 41 cm**4
```

Element and Detail Weights:

From	To	Element Metal Wgt. kg.	Element ID Volume Cm.	Corroded Metal Wgt. kg.	Corroded ID Volume Cm.	Extra due Misc % kg.
10	20	181.221	282794	135.916	286772	9.06107
20	30	441.935	1696763	310.121	1713774	22.0968
30	40	589.248	2262351	413.494	2285032	29.4624
40	50	589.248	2262351	413.494	2285032	29.4624
50	60	206.237	791823	144.723	799761	10.3118
60	70	467.2	182462	453.14	182803	23.36
70	80	736.458	...	736.458	...	36.8229
Total		3211	7478547.00	2607	7553174.50	160

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Plat	2060.48	3150	686.2	PLAT:[1 OF 1]
10	Liqd	126.161	-100	325	Liquid: 10
10	Insl	28.4793	-125	...	Ins: 20
10	Nozl	7.58193	-223.607	...	N08 (1in)
20	Sadl	218.003	850	890	Lft Sdl
20	Insl	69.4507	750	...	Ins: 20
20	Nozl	7.58193	150	625.4	N02 (2in)
20	Nozl	3.4263	200	612.7	N12 (1in)
20	Nozl	374.995	900	904.8	M1 (24in)
20	Nozl	7.58193	400	625.4	N07C (2in)
20	Nozl	7.58193	1100	625.4	N07B (2in)
20	Nozl	15.1297	150	637.782	K9B (3in)
20	Nozl	15.1297	150	637.782	K9A (3in)
20	Nozl	9.05726	400	625.4	K10A (2in)
20	Nozl	13.3479	400	625.4	K10B (2in)
20	Nozl	9.05726	550	625.4	K11A (2in)
20	Nozl	13.3479	550	625.4	K11B (2in)
20	Nozl	13.7604	1200	637.782	K7A (3in)
20	Nozl	14.445	1200	637.782	K7B (3in)
20	Nozl	7.58193	1365	625.4	N05 (2in)
20	Wght	100	700	...	WEIR 1
20	Wght	50	1325	400	GAS SPARGER
30	Insl	92.601	1000	...	Ins: 30
30	Nozl	9.05726	650	625.4	K2B (2in)
30	Nozl	9.05726	650	625.4	K2A (2in)
30	Nozl	14.445	900	637.782	K3A (3in)
30	Nozl	13.7604	900	637.782	K3B (3in)
30	Nozl	3.4263	200	612.7	N11 (1in)
30	Nozl	374.995	1500	904.8	M2 (24in)
30	Nozl	10.4875	197.4	625.4	K8 (2in)
30	Wght	100	450	...	WEIR 2
30	Wght	200	1000	200	SMOKE BOX

```
   40|Insl|     92.601 |        1000 |         ... |   Ins: 40
   40|Ring|    49.8544 |          50 |         ... |   Ring R1 Fr40
   40|Nozl|     22.992 |        1000 |     674.536 |   N04  (6in)
   40|Nozl|    9.05726 |        1850 |       625.4 |   K1B  (2in)
   40|Nozl|    7.58193 |        1000 |       625.4 |   N07A  (2in)
   40|Nozl|    5.36388 |         200 |      619.05 |   N09A  (1.5in)
   40|Nozl|    5.36388 |         200 |      619.05 |   N09B  (1.5in)
   40|Nozl|    10.4875 |        1100 |       625.4 |   K4A  (2in)
   40|Nozl|    9.05726 |        1450 |       625.4 |   K6  (2in)
   40|Nozl|    10.4875 |        1650 |       625.4 |   K1  (2in)
   40|Wght|        100 |        1000 |         400 |   SPARGER 2
   50|Sadl|    218.003 |     303.333 |         890 |   New Sdl
   50|Insl|    32.4103 |         350 |         ... |   Ins: 50
   50|Nozl|    62.0567 |         350 |     728.413 |   N01  (10in)
   50|Wght|       1000 |         350 |         600 |   E-100 & C-200
   60|Insl|    6.38356 |      94.488 |         ... |   Ins: 60
   70|Insl|    20.6037 |      53.213 |         ... |   Ins: 70
   70|Nozl|    404.278 |         ... |     833.323 |   N03  (10in)
   70|Nozl|    404.278 |         ... |     833.323 |   Chimney Nozzle
   70|Wght|        800 |         106 |         320 |   CHIMNEY
-------------------------------------------------
```

Total Weight of Each Detail Type:

```
Saddles                           436.0
Platforms                        2060.5
Liquid                            126.2
Insulation                        342.5
Stiffeners                         49.9
Nozzles                          1905.8
Weights                          2350.0
-------------------------------------------
Sum of the Detail Weights        7270.9 kg.
```

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	3372.1	3372.1	3372.1	3372.1	3372.1	3372.1
Saddles	436.0	436.0	436.0	436.0	436.0	436.0
Stif. Rings	49.9	49.9	49.9	49.9	49.9	49.9
Nozzles	1905.8	1905.8	1905.8	1905.8	1905.8	1905.8
Wld Weights	1350.0	1350.0	1350.0	1350.0	1350.0	1350.0
Platforms	...	...	2060.5	2060.5	2060.5	2060.5
Insulation	...	...	342.5	342.5	342.5	342.5
Empty Weights	...	...	...	1000.0	1000.0	...
Ope Weights	...	...	...	...	...	1000.0
Ope. Liquid	...	...	...	...	...	126.2
Test Liquid	...	7474.0	...	...	...	...
Totals	7113.8	14587.8	9516.8	10516.8	10516.8	10643.0

Field Installation Options:

Miscellaneous Weight Percent: 5.0 %

Note that the above value for the miscellaneous weight percent has been applied to the shells/heads/flange/tubesheets/tubes etc. in the weight calculations for metallic components.

Weight Summary:

```
Fabricated Wt.  - Bare Weight without Removable Internals              7113.8 kg.
Shop Test Wt.   - Fabricated Weight + Water ( Full )                  14587.8 kg.
Shipping Wt.    - Fab. Weight + removable Intls.+ Shipping App.        9516.8 kg.
Erected  Wt.    - Fab. Wt + or - loose items (trays,platforms etc.)   10516.8 kg.
Ope. Wt. no Liq - Fab. Weight + Internals. + Details + Weights        10516.8 kg.
Operating Wt.   - Empty Weight + Operating Liq. Uncorroded            10643.0 kg.
Oper. Wt. + CA  - Corr Wt. + Operating Liquid                         10008.6 kg.
Field Test Wt.  - Empty Weight + Water (Full)                         16431.0 kg.
```

Note:
The Corroded Weight and thickness are used in the Horizontal Vessel Analysis (Ope Case) and Earthquake Load Calculations.

Note: The Field Test weight as computed in the corroded condition.

Outside Surface Areas of Elements:

```
     |    |        Surface |
 From| To |           Area |
     |    |            cm² |
----------------------------
   10|  20|        18162.7 |
   20|  30|        57491.1 |
   30|  40|        76654.9 |
   40|  50|        76654.9 |
   50|  60|        26829.2 |
   60|  70|        11485.7 |
   70|  80|        18513.4 |
----------------------------
  Total        285791.812 cm²
```

Nozzle Flange MAWP Results: (bars & °C)

Nozzle Description	Flange Rating Ope.	Flange Rating Ambient	Design Temp	Class	Grade/ Group	Equiv. Press	Max Pressure UG-44(b)	Max Pressure 50%	Max Pressure DNV
N08 (1in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
N02 (2in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
N12 (1in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
M1 (24in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
N07C (2in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
N07B (2in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
K9B (3in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
K9A (3in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
K10A (2in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
K10B (2in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
K11A (2in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
K11B (2in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
K7A (3in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
K7B (3in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
N05 (2in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
K2B (2in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
K2A (2in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
K3A (3in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
K3B (3in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
N11 (1in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
M2 (24in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
K8 (2in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
N04 (6in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
K1B (2in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
N07A (2in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
N09A (1.5in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
N09B (1.5in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
K4A (2in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
K6 (2in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
K1 (2in)	42.51	51.10	234	300	GR 1.1	...	...	...	...
N01 (10in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
N03 (10in)	12.64	19.60	234	150	GR 1.1	...	...	...	...
Chimney Nozzle	12.64	19.60	234	150	GR 1.1	...	...	...	...
Min Rating	12.644	19.600 bars [for Core Elements]					0.000	0.000	0.000

ANSI Ratings are per ANSI/ASME B16.5 2013 Metric Edition

Warning:
There are nozzles in this model, but no flange MAWPs were de-rated. Be sure this is what you intended. There is a check box in the nozzle dialog that instructs PV Elite to perform the de-rating for each nozzle flange. See ASME VIII-1, UG-44(b) for more information.

Input Values:

```
Wind Design Code                                            ASCE-7 2010
Wind Load Reduction Scale Factor                                  0.600
Basic Wind Speed                          [V]                       120  Km/hr
Surface Roughness Category                               C: Open Terrain
Importance Factor                                                   1.0
Type of Surface                                       Moderately Smooth
Base Elevation                                                      100  mm.
Percent Wind for Hydrotest                                         33.0
Using User defined Wind Press. Vs Elev.                               N
Height of Hill or Escarpment       H or Hh                            0  mm.
Distance Upwind of Crest                Lh                            0  mm.
Distance from Crest to the Vessel        x                            0  mm.
Type of Terrain ( Hill, Escarpment )                               Flat
Damping Factor (Beta) for Wind (Ope)                             0.0100
Damping Factor (Beta) for Wind (Empty)                           0.0000
Damping Factor (Beta) for Wind (Filled)                          0.0000
```

Wind Analysis Results

Static Gust-Effect Factor, Operating Case [G]:

```
  = min(0.85, 0.925((1 + 1.7 * gQ * Izbar * Q )/( 1 + 1.7 * gV * Izbar)))
  = min(0.85,0.925((1+1.7*3.4*0.228*0.982)/(1+1.7*3.4*0.228)))
  = min(0.85, 0.915 )
  = 0.850

Natural Frequency of Vessel (Operating)                  33.000 Hz
Natural Frequency of Vessel (Empty)                      33.000 Hz
Natural Frequency of Vessel (Test)                       33.000 Hz

Force Coefficient                                   [Cf] 0.561
Structure Height to Diameter ratio                       4.631
```

This is classified as a rigid structure. Static analysis performed.

Sample Calculation for the First Element

The ASCE code performs all calculations in Imperial Units only. The wind pressure is therefore computed in these units.

Value of [Alpha] and [Zg]:

```
  Exposure Category: C from Table 26.9.1
  Alpha = 9.5: Zg = 274320. mm.
```

Effective Height [z]:

```
  = Centroid Height + Vessel Base Elevation
  = 1200.0 + 100.0 = 1300.0 mm.
  = 4.265 ft. Imperial Units
```

Velocity Pressure coefficient evaluated at height z [Kz]:

```
  Because z (4.265 ft.) < 15 ft.
  = 2.01 * ( 15 / Zg ) ^ (2 / Alpha)
```

```
  = 2.01 * ( 15/900.0 )^(2/9.5)
  = 0.849
```

Type of Hill: No Hill

Wind Directionality Factor [Kd]:
```
  = 0.95, per Table 26.6-1
```

As there is No Hill Present: [Kzt]:
```
  K1 = 0, K2 = 0, K3 = 0
```

Topographical Factor [Kzt]:
```
  = ( 1 + K1 * K2 * K3 )²
  = ( 1 + 0.0* 0.0* 0.0 )²
  = 1.0
```

Velocity Pressure evaluated at height z, Imperial Units [qz]:
```
  = max( 16, 0.00256 * Kz * Kzt * Kd * V(mph)² )
  = max( 16, 0.00256 * 0.849 * 1.0 * 0.95 * 74.567² )
  = 16.0 psf [78.12] Kgs/m²
```

Force on the first element [F]:
```
  = qz * G * Cf * WindArea
  = 16.0 * 0.85 * 0.561 * 5.638
  = 43.0 lbs. [ 0.2] kN
```

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m²
Node 10 to 20	1300.0	0.000	0.000	0.000	0.849	1.000	78.120
Node 20 to 30	1300.0	0.000	0.000	0.000	0.849	1.000	78.120
Node 30 to 40	1300.0	0.000	0.000	0.000	0.849	1.000	78.120
Node 40 to 50	1300.0	0.000	0.000	0.000	0.849	1.000	78.120
Node 50 to 60	1300.0	0.000	0.000	0.000	0.849	1.000	78.120
Node 60 to 70	1300.0	0.000	0.000	0.000	0.849	1.000	78.120
Node 70 to 80	1300.0	0.000	0.000	0.000	0.849	1.000	78.120

Platform Load Calculations

ID	Wind Area cm²	Elevation mm.	Pressure Kgs/m²	Force kN	Cf
PLAT:[1 OF 1]	31680.00	1300.00	78.12	2.43	1.20

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm²	Elevation mm.	Pressure Kgs/m²	Force kN
WEIR 1	0.00	1300.00	78.12	0.00
GAS SPARGER	0.00	100.00	78.12	0.00
WEIR 2	0.00	1300.00	78.12	0.00

```
SMOKE BOX             0.00       100.00        78.12         0.00
SPARGER 2             0.00       100.00        78.12         0.00
E-100 & C-200         0.00      1900.00        78.12         0.00
CHIMNEY               0.00       100.00        78.12         0.00
```

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm²	Wind Pressure Kgs/m²	Element Wind Load kN
10	20	1300	1680	5238.23	78.12	1.57081
20	30	1300	1680	25200	78.12	0.55183
30	40	1300	1680	33600	78.12	0.73578
40	50	1300	1680	33600	78.12	0.73578
50	60	1300	1680	11760	78.12	0.25752
60	70	1300	1656	2649.6	78.12	0.058021
70	80	1300	1920	1152	78.12	0.025227

Note:
The Wind Loads calculated and printed in the Wind Load calculation report have been factored by the input scalar/load reduction factor of: 0.600.

Be sure the wind speed is in accordance with the specified wind design code.

Earthquake Load Calculation:

Input Values:

```
Seismic Design Code                                         ASCE 7-2010
Seismic Load Reduction Scale Factor                               0.700
Importance Factor                                                 1.250
Table Value Fa                                                    1.111
Table Value Fv                                                    1.575
Short Period Acceleration value Ss                                1.377
Long Period Acceleration Value Sl                                 0.367
Moment Reduction Factor Tau                                       1.000
Force Modification Factor R                                       3.000
Site Class                                                            C
Component Elevation Ratio                z/h                      1.000
Amplification Factor                      Ap                      1.000
Force Factor                                                      0.000
Consider Vertical Acceleration                                       No
Minimum Acceleration Multiplier                                   0.000
User Value of Sds (used if > 0 )                                  1.020
User Value of Sd1 (used if > 0 )                                  0.385
```

Seismic Analysis Results:

```
Sms = Fa * Ss = 1.111 * 1.377 = 1.53
Sm1 = Fv * S1 = 1.575 * 0.367 = 0.578
Sds = 2/3 * Sms = 2/3 * 1.53 = 1.02

Sds = Max( 0.8*Sds, SdsUser )
    = Max( 0.816, 1.02 )
    = 1.020

Sd1 = 2/3 * Sm1 = 2/3 * 0.578 = 0.385

Sd1 = Max( 0.8*Sd1, Sd1User )
    = Max( 0.308, 0.385 )
    = 0.385
```

Check Approximate Fundamental Period from 12.8-7 [Ta]:

$= Ct * hn^{x}$ where Ct = 0.020, x = 0.75 and hn = Structural Height (ft.)

$= 0.020 * (6.2664^{0.75})$

= 0.079 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 * 0.079, 0.03 ) per 12.8.2
= 0.030
```

Compute the Seismic Force per equation 13.3-1, [Fp]:

```
  = 0.4 * Ap * Sds * W * ( 1 + 2*(z/h) ) / ( R / Ie )
  = 0.4 * 1.0 * 1.02 * 98 * ( 1 + 2*1.0 )/( 3.0/1.25 )
  = 50.053 kN
```

Check the Maximum value of Fp per equation 13.3-2:

```
  = 1.6 * Sds * I * W
  = 1.6 * 1.02 * 1.25 * 98 = 200.21 kN
```

Check the Minimum value of Fp per equation 13.3-3:

```
  = 0.3 * 1.02 * 1.25 * 98
  = 37.540 kN
```

Compute the Total Base Shear V = Fp, [V]:

```
  = 50.053 kN

 Final Base Shear,       V = 35.04 kN
```

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	600	10.9049	3.81533
20	30	600	10.9049	3.81533
20	30	600	10.9049	3.81533
30	40	600	10.9049	3.81533
40	50	600	10.9049	3.81533
50	0	600	10.9049	3.81533
50	60	600	10.9049	3.81533
60	70	600	10.9049	3.81533
70	80	710	10.9049	4.51481

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.

Shop/Field Installation Options :

Platform(s) installed in the Shop.
Insulation is installed in the Shop.

Note : The CG is computed from the first Element From Node

```
Center of Gravity of the Saddles                           3376.667 mm.
Center of Gravity of the Platforms                         3150.000 mm.
Center of Gravity of the Liquid                            -100.000 mm.
Center of Gravity of the Insulation                        3137.105 mm.
Center of Gravity of the Stiffening Rings                  3600.000 mm.
Center of Gravity of the Nozzles                           4016.682 mm.
Center of Gravity of the Added Weights (Operating)         5289.008 mm.
Center of Gravity of the Added Weights (Empty)             5289.008 mm.

Center of Gravity of Bare Shell New and Cold               4184.072 mm.
Center of Gravity of Bare Shell Corroded                   4463.569 mm.

Vessel CG in the Operating Condition                       4147.287 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition         4127.698 mm.
Vessel CG in the Test Condition                            3702.211 mm.
```

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       606.50  mm.
Stiffened Vessel Length per 4.15.6               L      6250.00  mm.
Distance from Saddle to Vessel tangent           a       850.00  mm.

Saddle Width                                     b       150.00  mm.
Saddle Bearing Angle                         theta       120.00  degrees

Wear Plate Width                                b1       260.00  mm.
Wear Plate Bearing Angle                    theta1       145.00  degrees
Wear Plate Thickness                            tr         10.0  mm.
Wear Plate Allowable Stress                     Sr       137.90  N./mm²

Inside Depth of Head                            h2       303.00  mm.

Shell Allowable Stress used in Calculation               137.90  N./mm²
Head Allowable Stress used in Calculation                137.90  N./mm²
Circumferential Efficiency in Plane of Saddle              1.00
Circumferential Efficiency at Mid-Span                     1.00

Distance from Saddle Base to Centerline          B      1200.00  mm.
Coefficient of Friction                         mu         0.30

Saddle Force Q, Operating Case                            90.47   kN

Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                         N./mm² |       N./mm² |
----------------------------------------------------------------
Long. Stress at Top    of Midspan         10.62 |       137.90 |
Long. Stress at Bottom of Midspan         24.90 |       137.90 |
Long. Stress at Top    of Saddles         32.39 |       137.90 |
Long. Stress at Bottom of Saddles          9.65 |       137.90 |
----------------------------------------------------------------
Tangential Shear in Shell                 17.06 |       110.32 |
Circ. Stress at Horn of Saddle            30.11 |       172.38 |
Circ. Compressive Stress in Shell          3.90 |       137.90 |
----------------------------------------------------------------
```

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( 3.9/2 + 0 ) * 1200.0/1073.8717
 = 6.6 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

```
 = max( Fl, Friction Load, Sum of X Forces) * B / Ls
 = max( 1.58, 10.16, 0 ) * 1200.0/4953.3335
```

```
  = 2.5 kN
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:

```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 35.04, 10.16, 0 ) * 1200.0/4953.3335
  = 8.5 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0( 35/2 + 0 ) * 1200.0/1073.8717
  = 58.7 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 32 + max( 2, 7, 8, 59 )
  = 90.5 kN
```

Longitudinal Wind Force [Fl]:

```
  = WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
  = 0.6 * 766.08( 1.584 + ( 1.539 * 1.2 ))
  = 1577.182 N
```

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)                92.60  kN
 Transverse Shear Load Saddle          Ft               17.52  kN
 Longitudinal Shear Load Saddle                         35.04  kN
```

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = min( 2( ShellID/2 + t + WearPadThickness )sin( theta/2 ), 2*Rm )
  = min( 2( 1200.0/2 + 10.0 + 10.0 )sin( 60.0/2 ), 2*606.5 )
  = 1073.872 mm.
```

The Computed K values from Table 4.15.1:

```
 K1   = 0.1066      K2  = 1.1707      K3  = 0.8799      K4  = 0.4011
 K5   = 0.7603      K6  = 0.0529      K7  = 0.0529      K8  = 0.3405
 K9   = 0.2711      K10 = 0.0581      K1* = 0.1923      K6p = 0.0347
 K7p = 0.0347
```

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 + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -90*850.0[1-(1-850.0/6250.0+(606.5²-303.0²)/
    (2*850.0*6250.0))/(1+(4*303.0)/(3*6250.0))]
  = -12620.4 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
```

```
 = 90*6250/4(1+2(607²-303²)/(6250²))/(1+(4*303)/
   (3*6250))-4*850/6250
 = 57774.6 N-m
```

Longitudinal Stress at Top of Shell (4.15.6)   [Sigma1]:
```
 = P * Rm/(2t) - M2/(pi*Rm²t)
 = 4.1 * 606.5/(2*7.0) - 57774.6/(pi*606.5²*7.0)
 = 10.62 N./mm²
```

Longitudinal Stress at Bottom of Shell (4.15.7)   [Sigma2]:
```
 = P * Rm/(2t) + M2/(pi * Rm² * t)
 = 4.1 * 606.5/(2 * 7.0) + 57774.6/(pi * 606.5² * 7.0 )
 = 24.90 N./mm²
```

Longitudinal Stress at Top of Shell at Support (4.15.10)   [Sigma*3]:
```
 = P * Rm/(2t) - M1/(K1*pi*Rm²t)
 = 4.1*606.5/(2*7.0)--12620.4/(0.1066*pi*606.5²*7.0)
 = 32.39 N./mm²
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11)   [Sigma*4]:
```
 = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
 = 4.1*606.5/(2*7.0)+-12620.4/(0.1923*pi*606.5²*7.0)
 = 9.65 N./mm²
```

Maximum Shear Force in the Saddle (4.15.5)   [T]:
```
 = Q(L-2a)/(L+(4*h2/3))
 = 90( 6250.0 - 2 * 850.0)/(6250.0 + ( 4 * 303.0/3))
 = 61.9 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14)   [tau2]:
```
 = K2 * T / ( Rm * t )
 = 1.1707 * 61.86/( 606.5 * 7.0 )
 = 17.06 N./mm²
```

Decay Length (4.15.22)   [x1,x2]:
```
 = 0.78 * sqrt( Rm * t )
 = 0.78 * sqrt( 606.5 * 7.0 )
 = 50.823 mm.
```

Circumferential Stress in shell, no rings (4.15.23)   [sigma6]:
```
 = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
 = - 0.7603 * 90 * 0.1/( 7.0 * ( 150.0 + 50.82 + 50.82 ) )
 = -3.90 N./mm²
```

Effective reinforcing plate width (4.15.1)   [B1]:
```
 = min( b + 1.56 * sqrt( Rm * t ), 2a   )
 = min( 150.0 + 1.56 * sqrt( 606.5 * 7.0 ), 2 * 850.0 )
 = 251.65 mm.
```

Wear Plate/Shell Stress ratio (4.15.29)   [eta]:
```
 = min( Sr/S, 1 )
 = min( 137.9/137.9, 1 )
 = 1.0000
```

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:

```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = - 0.7603 * 90 * 0.1/( 251.646( 7.0 + 1.0 * 10.0 ) )
  = -1.61 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27) [sigma7,r]:

```
  = -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)
  = -90/(4(7.0 + 1.0 * 10.0)251.646) -
     3 * 0.053 * 90/(2(7.0 + 1.0 * 10.0)²)
  = -30.11 N./mm²
```

Distance between Saddle Supports [Ls]:

```
  = 4953.3 mm.
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:

```
  = Alpha * Ls( Design Temperature - Ambient Temperature )
  = 0.000013 * 4953.333( 234.0 - 21.1 )
  = 13.677 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1200.0000	mm.
Baseplate Thickness	Bpthk	15.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	15.0000	mm.
Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	585.0	mm.
Friction Coefficient	mu	0.300	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	361.4	7.0	3.5	25.3	8853.1	0.157E+05
Wearplate	260.0	10.0	12.0	26.0	31200.0	0.151E+05
Web	15.0	565.0	299.5	84.8	2538262.8	0.244E+05
BasePlate	170.0	15.0	589.5	25.5	1503225.0	0.289E+05
Totals	...	...	...	161.5	4081541.2	0.841E+05

Distance to Centroid [C1]:

```
  = AY / A
  = 1606.906/161.545
  = 252.657 mm.
```

Angle [beta]:

```
  = 180 - Saddle Angle/2
  = 180 - 120.0/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:

```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120.0) - 0.5*sin(120.0)² )/(pi - 2.094 + sin(120.0)cos(120.0) )
  = 0.2035
```

Saddle Splitting Force [Fh]:

```
  = K1 * Q
  = 0.204 * 90.466
  = 18.4118 kN

 Tension Stress, St = ( Fh/As )        =          1.3514  N./mm²
 Allowed Stress, Sa = 0.6 * Yield Str =        143.9676  N./mm²
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 1200.0 - 603.0 * sin(120.0/2)/1.0472
  = 701.323 mm.

 Bending Moment, M  = Fh * d           =      12917.8691  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =          3.8793  N./mm²
 Allowed Stress, Sa = 2/3 * Yield Str =        159.9640  N./mm²
```

Minimum Thickness of Baseplate per Moss:

```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(90 + 2)170.0/( 4 * 1200.0 * 159.964 ))½
  = 7.843 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:

```
  = 2 * cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )
  = 2 * cos( 90 - 120.0/2 )( 600.0 + 10.0 + 10.0 )
  = 1073.872 mm.
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1073.8716/( 4 - 1 )
  = 357.957 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 357.9572 * 170.0/2
  = 304.264 cm²
```

Bearing Pressure [Bp]:

```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 90.466/( 1200.0 * 170.0 )
  = 0.044 kN/cm²
```

Axial Load [P]:

```
  = Ap * Bp
  = 304.3 * 0.04
  = 13.493 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 20.25 + 26.847
  = 47.097 cm²
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 13.5/47.0968
  = 2.865 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	15.0	150.0	...	22.5	...	422.

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 150.0 - 15.0
  = 135.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/47.097
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 150.0/2
  = 75.000 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 421.9/47.097 )
  = 29.929 mm.
```

Length of Outer Rib [L]:
```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 1200.0 - cos( 120.0/2 )( 600.0 + 10.0 + 10.0 ) - 15.0
  = 875.000 mm.
```

Intermediate Term [Cc]:
```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 0.19994E+09/239.9 )
  = 128.255
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 875.0/29.929
  = 29.236
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
```

```
  = 35.0/( 2 * 1200.0 ) * 357.957 * 875.0/2
  = 2287.212 N-m
```

Compressive Allowable, KL/r < Cc (29.2356 < 128.2549) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 29.24 )²/(2 * 128.25² ))240/
    ( 5/3+3*(29.24)/(8* 128.25)-( 29.24³)/(8*128.25³)
  = 133.5 N./mm²
```

AISC Unity Check of Outside Ribs (must be <= 1)

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 2.87/133.5 + ( 2287.21 * 75.0/4218750 )/159.96
  = 0.276
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	15.0	135.0	0.0	20.2	0.0	421.
Web	358.0	15.0	0.0	53.7	0.0	10.1
Totals	...	...	...	73.9	...	432.

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 0.0/73.944
  = 0.000 mm.
```

Distance to Centroid [C1]:

```
  = Saddle Width / 2
  = 150.0/2
  = 75.000 mm.
```

Length of Inner Rib [L]:

```
  = Saddle Height - sqrt( (Ro + Wpdthk)^2 - (Pitch/2)^2 ) - Bpthk
  = 1200.0 - sqrt( (620.0 + 10.0)^2 - (357.957/2)^2 ) - 15.0
  = 591.395 mm.
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 431.5/73.944 )
  = 24.157 mm.
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 591.395/24.157
  = 24.481
```

Unit Force [Force,u]:

```
  = Fl / ( 2 * Baseplate Length )
  = 35.037/( 2 * 1200.0 )
  = 0.015 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:

```
  = Unit Force * e * L
  = 0.015 * 357.957 * 591.395
  = 3091.762 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

```
  = Bending Moment / Section Modulus
  = 3091.762/57536.086
  = 53.719 N./mm²
```

Compressive Allowable, KL/r < Cc (24.4809 < 128.2549) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 24.48 )²/(2 * 128.25² ))240/
    ( 5/3+3*(24.48)/(8* 128.25)-( 24.48³)/(8*128.25³)
  = 135.6 N./mm²
```

AISC Unity Check of Inside Ribs (must be <= 1)

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 3.69/135.59 + ( 3091.76 * 75.0/431.52 )/159.96
  = 0.363
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	300.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	150.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	95.15	N./mm²
Area Available in a Single Bolt	BltArea	2.1705	cm²
Saddle Load QO (Weight)	QO	33.9	kN
Saddle Load QL (Wind/Seismic contribution)	QL	8.5	kN
Maximum Transverse Force	Ft	17.5	kN
Maximum Longitudinal Force	Fl	35.0	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

```
  = Fl / ( Bolt Area * Number of Bolts )
  = 35/( 2.17 * 4 )
  = 40.4 N./mm².  Must be less than 180.0 N./mm².
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

```
  = Ft / ( Bolt Area * Number of Bolts )
  = 18/( 2.17 * 4 )
  = 20.2 N./mm².  Must be less than 180.0 N./mm².
```

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 / ( BoltShearAllowable * Nbolts )
  = 35.04/(180.0 * 4.0)
  = 0.4867 cm²
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 1200.0 * 17.52 + 0.0
  = 21030.99 N-m
```

Eccentricity (e):

```
  = Rmom / QO
  = 21030.99/33.87
  = 620.59 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 1200.0/2 - 150.0
   = 450.00 mm.

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (620.59 - 0.5*1200.0)
    = 61.77 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1.0 * 4.34/170.0 * (450.0 + 620.59)
    = 16402.80 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -16402.79 * (0.5 * 1200.0 + 450.0)
    = -17222935.44 mm.³
```

Iteratively Solving for the Effective Bearing Length:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + 61.77 * Y² + 16402.79 * Y + -0.2E+08 = 0
 Y  = 219.88 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (1200.0/2 - 219.88/3 - 620.59)
     = -93.88

 Denom = (Bplen / 2 - Y / 3 + f)
       = (1200.0/2 - 219.88/3 + 450.0)
       = 976.71
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 33.87 * -93.88/976.71
  = 3.26 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
  = Tforce / (Stba * Nbt)
  = 3.26/( 300.0 * 2.0 )
  = 0.0543 cm²
```

Required Area of a Single Bolt [Bltarear]:
```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 0.4867, 0.0543]
  = 0.4867 cm²
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(33.87 + 3.26)/(219.88 * 170.0)
  = 19.87 bars
```

Distance from Baseplate Edge to the Web [ADIST]:
```
  = (Bplen - Weblngth) / 2
  = (1200.0 - 1149.2)/2
  = 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:
```
  = Tforce * Adist
  = 3.26 * 25.4
  = 82.74 N-m
```

Equivalent Bearing Pressure (f1):
```
  = fc * (Y - Adist) / Y
  = 19.87 * (219.88 - 25.4)/219.88
  = 17.57 bars
```

Overturning Moment due to Bearing Pressure [Mc]:
```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (25.4² * 170.0/6) * (17.57 + 2 * 19.87)
  = 104.80 N-m
```

Baseplate Required Thickness [Treq]:
```
  = (6 * max(Mt,Mc) / (Bpwid * Sba))½
  = (6 *max(82.74,104.8/(170.0 * 142.73))½
  = 5.0898 mm.
```

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       606.50   mm.
 Stiffened Vessel Length per 4.15.6               L      6250.00   mm.
 Distance from Saddle to Vessel tangent           a       850.00   mm.

 Saddle Width                                     b       150.00   mm.
 Saddle Bearing Angle                         theta       120.00   degrees

 Wear Plate Width                                b1       260.00   mm.
 Wear Plate Bearing Angle                    theta1       145.00   degrees
```

```
Wear Plate Thickness                              tr        10.0  mm.
Wear Plate Allowable Stress                       Sr      137.90  N./mm²

Shell Allowable Stress used in Calculation                137.90  N./mm²
Head Allowable Stress used in Calculation                 136.40  N./mm²
Circumferential Efficiency in Plane of Saddle               1.00
Circumferential Efficiency at Mid-Span                      1.00

Distance from Saddle Base to Centerline            B     1200.00  mm.
Coefficient of Friction                           mu        0.00

Saddle Force Q, Operating Case                            120.86  kN

Horizontal Vessel Analysis Results:       Actual |     Allowable |
                                          N./mm² |        N./mm² |
----------------------------------------------------------------
Long. Stress at Top    of Midspan           6.68 |        137.90 |
Long. Stress at Bottom of Midspan          28.85 |        137.90 |
Long. Stress at Top    of Saddles          29.84 |        137.90 |
Long. Stress at Bottom of Saddles          11.07 |        137.90 |
----------------------------------------------------------------
Tangential Shear in Shell                  24.26 |        110.32 |
Circ. Stress at Horn of Saddle             40.22 |        172.38 |
Circ. Compressive Stress in Shell           5.22 |        137.90 |
----------------------------------------------------------------
```

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( 3.9/2 + 0 ) * 1200.0/1073.8717
  = 6.6 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 1.58, 0.0, 0 ) * 1200.0/4953.3335
  = 0.4 kN
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:

```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 35.04, 0.0, 0 ) * 1200.0/4953.3335
  = 8.5 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0( 35/2 + 0 ) * 1200.0/1073.8717
  = 58.7 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 62 + max( 0.4, 7, 8, 59 )
  = 120.9 kN
```

Longitudinal Wind Force [Fl]:

```
  = WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
```

```
  = 0.6 * 766.08( 1.584 + ( 1.539 * 1.2 ))
  = 1577.182 N
```

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)                  123.00  kN
 Transverse Shear Load Saddle            Ft                17.52  kN
 Longitudinal Shear Load Saddle                            35.04  kN
```

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = min( 2( ShellID/2 + t + WearPadThickness )sin( theta/2 ), 2*Rm )
  = min( 2( 1200.0/2 + 10.0 + 10.0 )sin( 60.0/2 ), 2*606.5 )
  = 1073.872 mm.
```

The Computed K values from Table 4.15.1:

```
 K1  = 0.1066     K2  = 1.1707     K3  = 0.8799     K4  = 0.4011
 K5  = 0.7603     K6  = 0.0529     K7  = 0.0529     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0347
 K7p = 0.0347
```

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 + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -121*850.0[1-(1-850.0/6250.0+(606.5²-0.0²)/
    (2*850.0*6250.0))/(1+(4*0.0)/(3*6250.0))]
  = -10419.1 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 121*6250/4(1+2(607²-0²)/(6250²))/(1+(4*0)/
    (3*6250))-4*850/6250
  = 89706.1 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 4.1 * 606.5/(2*7.0) - 89706.1/(pi*606.5²*7.0)
  = 6.68 N./mm²
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 4.1 * 606.5/(2 * 7.0) + 89706.1/(pi * 606.5² * 7.0 )
  = 28.85 N./mm²
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 4.1*606.5/(2*7.0)--10419.1/(0.1066*pi*606.5²*7.0)
  = 29.84 N./mm²
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11)   [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 4.1*606.5/(2*7.0)+-10419.1/(0.1923*pi*606.5²*7.0)
  = 11.07 N./mm²
```

Maximum Shear Force in the Saddle (4.15.5)   [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 121( 6250.0 - 2 * 850.0)/(6250.0 + ( 4 * 0.0/3))
  = 88.0 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14)   [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 87.99/( 606.5 * 7.0 )
  = 24.26 N./mm²
```

Decay Length (4.15.22)   [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 606.5 * 7.0 )
  = 50.823 mm.
```

Circumferential Stress in shell, no rings (4.15.23)   [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 121 * 0.1/( 7.0 * ( 150.0 + 50.82 + 50.82 ) )
  = -5.22 N./mm²
```

Effective reinforcing plate width (4.15.1)   [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 150.0 + 1.56 * sqrt( 606.5 * 7.0 ), 2 * 850.0 )
  = 251.65 mm.
```

Wear Plate/Shell Stress ratio (4.15.29)   [eta]:
```
  = min( Sr/S, 1 )
  = min( 137.9/137.9, 1 )
  = 1.0000
```

Circumferential Stress at Saddle Base with Wear Plate (4.15.26)   [sigma6,r]:
```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = - 0.7603 * 121 * 0.1/( 251.646( 7.0 + 1.0 * 10.0 ) )
  = -2.15 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27)   [sigma7,r]:
```
  = -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)
  = -121/(4(7.0 + 1.0 * 10.0)251.646) -
     3 * 0.053 * 121/(2(7.0 + 1.0 * 10.0)²)
  = -40.22 N./mm²
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1200.0000	mm.
Baseplate Thickness	Bpthk	15.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	15.0000	mm.
Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	

Saddle Yield Stress Sy 239.9 N./
Height of Web at Center Hw,c 585.0 mm.
Friction Coefficient mu 0.000

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	361.4	7.0	3.5	25.3	8853.1	0.157E+05
Wearplate	260.0	10.0	12.0	26.0	31200.0	0.151E+05
Web	15.0	565.0	299.5	84.8	2538262.8	0.244E+05
BasePlate	170.0	15.0	589.5	25.5	1503225.0	0.289E+05
Totals	...	...	...	161.5	4081541.2	0.841E+05

Distance to Centroid [C1]:
= AY / A
= 1606.906/161.545
= 252.657 mm.

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120.0/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)^2)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120.0) - 0.5*sin(120.0)^2)/(pi - 2.094 + sin(120.0)cos(120.0))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 120.86
= 24.5977 kN

Tension Stress, St = (Fh/As) = 1.8055 N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str = 143.9676 N./mm^2

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 1200.0 - 603.0 * sin(120.0/2)/1.0472
= 701.323 mm.

Bending Moment, M = Fh * d = 17257.9473 N-m

Bending Stress, Sb = (M * C1 / I) = 5.1826 N./mm^2
Allowed Stress, Sa = 2/3 * Yield Str = 159.9640 N./mm^2

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (4 * BasePlateLength * AllStress))½
= (3(121 + 2)170.0/(4 * 1200.0 * 159.964))½
= 9.039 mm.

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
  = 2 * cos(90 - Saddle Angle/2)(Inside Radius + Shell Thk + Wear Plate Thk)
  = 2 * cos(90 - 120.0/2)(600.0 + 10.0 + 10.0)
  = 1073.872 mm.

Distance between Ribs [e]:
  = Web Length / (Nribs - 1)
  = 1073.8716/(4 - 1)
  = 357.957 mm.

Baseplate Pressure Area [Ap]:
  = e * Bpwid / 2
  = 357.9572 * 170.0/2
  = 304.264 cm^2

Bearing Pressure [Bp]:
  = Q / (BasePlateLength * BasePlateWidth)
  = 120.86/(1200.0 * 170.0)
  = 0.059 kN/cm^2

Axial Load [P]:
  = Ap * Bp
  = 304.3 * 0.06
  = 18.026 kN

Area of the Rib and Web [Ar]:
  = Rib Area + Web Area
  = 20.25 + 26.847
  = 47.097 cm^2

Compressive Stress [Sc]:
  = P/Ar
  = 18.0/47.0968
  = 3.828 N./mm^2

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	15.0	150.0	...	22.5	...	422.

Rib dimension [D]:
  = Saddle Width - Web Thickness
  = 150.0 - 15.0
  = 135.000 mm.

Distance to Centroid from Datum [ytot]:
  = AY / A
  = 0.0/47.097
  = 0.000 mm.

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 150.0/2
  = 75.000 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 421.9/47.097 )
  = 29.929 mm.
```

Length of Outer Rib [L]:
```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 1200.0 - cos( 120.0/2 )( 600.0 + 10.0 + 10.0 ) - 15.0
  = 875.000 mm.
```

Intermediate Term [Cc]:
```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 0.19994E+09/239.9 )
  = 128.255
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 875.0/29.929
  = 29.236
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 35.0/( 2 * 1200.0 ) * 357.957 * 875.0/2
  = 2287.212 N-m
```

Compressive Allowable, KL/r < Cc (29.2356 < 128.2549) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 29.24 )²/(2 * 128.25² ))240/
    ( 5/3+3*(29.24)/(8* 128.25)-( 29.24³)/(8*128.25³)
  = 133.5 N./mm²
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 3.83/133.5 + ( 2287.21 * 75.0/4218750 )/159.96
  = 0.283
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	15.0	135.0	0.0	20.2	0.0	421.
Web	358.0	15.0	0.0	53.7	0.0	10.1
Totals	...	...	...	73.9	...	432.

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/73.944
```

```
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 150.0/2
  = 75.000 mm.
```

Length of Inner Rib [L]:
```
  = Saddle Height - sqrt( (Ro + Wpdthk)^2 - (Pitch/2)^2 ) - Bpthk
  = 1200.0 - sqrt( (620.0 + 10.0)^2 - (357.957/2)^2 ) - 15.0
  = 591.395 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 431.5/73.944 )
  = 24.157 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 591.395/24.157
  = 24.481
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 35.037/( 2 * 1200.0 )
  = 0.015 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0.015 * 357.957 * 591.395
  = 3091.762 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 3091.762/57536.086
  = 53.719 N./mm²
```

Compressive Allowable, KL/r < Cc (24.4809 < 128.2549) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 24.48 )²/(2 * 128.25² ))240/
    ( 5/3+3*(24.48)/(8* 128.25)-( 24.48³)/(8*128.25³)
  = 135.6 N./mm²
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 4.93/135.59 + ( 3091.76 * 75.0/431.52 )/159.96
  = 0.372
```

<u>Input Data for Base Plate Bolting Calculations:</u>

```
 Total Number of Bolts per BasePlate          Nbolts            4
 Total Number of Bolts in Tension/Baseplate      Nbt            2
 Bolt Material Specification                            SA-193 B7
 Bolt Allowable Stress                          Stba       300.00   N./mm²
 Bolt Corrosion Allowance                        Bca          0.0   mm.
```

```
Distance from Bolts to Edge                        Edgedis       150.0  mm.
Nominal Bolt Diameter                                  Bnd     20.0000  mm.
Thread Series                                       Series    TEMA Metric
BasePlate Allowable Stress                               S       95.15  N./mm²
Area Available in a Single Bolt                    BltArea      2.1705  cm²
Saddle Load QO (Weight)                                 QO        64.3  kN
Saddle Load QL (Wind/Seismic contribution)              QL         8.5  kN
Maximum Transverse Force                                Ft        17.5  kN
Maximum Longitudinal Force                              Fl        35.0  kN
Saddle Bolted to Steel Foundation                                Yes
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
```
  = Ft / ( Bolt Area * Number of Bolts )
  = 18/( 2.17 * 4 )
  = 20.2 N./mm².  Must be less than 180.0 N./mm².
```

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 / ( BoltShearAllowable * Nbolts )
  = 35.04/(180.0 * 4.0)
  = 0.4867 cm²
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 1200.0 * 17.52 + 0.0
  = 21030.99 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 21030.99/64.27
  = 327.10 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 1200.0/2 - 150.0
   = 450.00 mm.

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (327.1 - 0.5*1200.0)
    = -818.70 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1.0 * 4.34/170.0 * (450.0 + 327.1)
    = 11906.14 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -11906.14 * (0.5 * 1200.0 + 450.0)
    = -12501447.61 mm.³
```

Iteratively Solving for the Effective Bearing Length:
```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -818.7 * Y² + 11906.14 * Y + -0.1E+08 = 0
 Y  = 822.70 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (1200.0/2 - 822.7/3 - 327.1)
     = -1.33

 Denom = (Bplen / 2 - Y / 3 + f)
       = (1200.0/2 - 822.7/3 + 450.0)
       = 775.77
```

Total Bolt Tension Force [Tforce]:
```
  = - QO * Num / Denom
  = - 64.27 * -1.33/775.77
  = 0.11 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:
```
  = Tforce / (Stba * Nbt)
  = 0.11/( 300.0 * 2.0 )
  = 0.0018 cm²
```

Required Area of a Single Bolt [Bltarear]:
```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 0.4867, 0.0018]
  = 0.4867 cm²
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(64.27 + 0.11)/(822.7 * 170.0)
  = 9.21 bars
```

Distance from Baseplate Edge to the Web [ADIST]:
```
  = (Bplen - Weblngth) / 2
  = (1200.0 - 1149.2)/2
  = 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:
```
  = Tforce * Adist
  = 0.11 * 25.4
  = 2.81 N-m
```

Equivalent Bearing Pressure (f1):
```
  = fc * (Y - Adist) / Y
  = 9.21 * (822.7 - 25.4)/822.7
  = 8.92 bars
```

Overturning Moment due to Bearing Pressure [Mc]:
```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (25.4² * 170.0/6) * (8.92 + 2 * 9.21)
```

```
  = 49.99 N-m
```

Baseplate Required Thickness [Treq]:

```
  = (6 * max(Mt,Mc) / (Bpwid * Sba))½
  = (6 *max(2.81,49.99/(170.0 * 142.73))½
  = 3.5153 mm.
```

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      606.50  mm.
Stiffened Vessel Length per 4.15.6             L     6250.00  mm.
Distance from Saddle to Vessel tangent         a      850.00  mm.

Saddle Width                                   b      150.00  mm.
Saddle Bearing Angle                       theta      120.00  degrees

Wear Plate Width                              b1      260.00  mm.
Wear Plate Bearing Angle                  theta1      145.00  degrees
Wear Plate Thickness                          tr        10.0  mm.
Wear Plate Allowable Stress                   Sr      137.90  N./mm²

Inside Depth of Head                          h2      303.00  mm.

Shell Allowable Stress used in Calculation            196.73  N./mm²
Head Allowable Stress used in Calculation             196.73  N./mm²
Circumferential Efficiency in Plane of Saddle           1.00
Circumferential Efficiency at Mid-Span                  1.00

Distance from Saddle Base to Centerline        B     1200.00  mm.
Coefficient of Friction                       mu        0.30

Saddle Force Q, Test Case, no Ext. Forces              76.88  kN

Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                         N./mm² |       N./mm² |
----------------------------------------------------------------
Long. Stress at Top    of Midspan         17.28 |       196.73 |
Long. Stress at Bottom of Midspan         29.42 |       196.73 |
Long. Stress at Top    of Saddles         35.78 |       196.73 |
Long. Stress at Bottom of Saddles         16.46 |       196.73 |
----------------------------------------------------------------
Tangential Shear in Shell                 14.50 |       139.65 |
Circ. Stress at Horn of Saddle            25.58 |       295.10 |
Circ. Compressive Stress in Shell          3.32 |       196.73 |
----------------------------------------------------------------
```

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( 1.3/2 + 0 ) * 1200.0/1073.8717
 = 2.2 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

```
 = max( Fl, Friction Load, Sum of X Forces) * B / Ls
 = max( 0.52, 0.0, 0 ) * 1200.0/4953.3335
```

```
  = 0.1 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 75 + max( 0.1, 2, 0, 0 )
  = 76.9 kN
```

Longitudinal Wind Force [Fl]:
```
  = WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
  = 0.6 * 766.08( 1.584 + ( 1.539 * 1.2 ))
  = 1577.182 N
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		79.02	kN
Transverse Shear Load Saddle	Ft	0.65	kN
Longitudinal Shear Load Saddle		0.52	kN

Hydrostatic Test Pressure at center of Vessel 5.389 bars

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
```
  = min( 2( ShellID/2 + t + WearPadThickness )sin( theta/2 ), 2*Rm )
  = min( 2( 1200.0/2 + 10.0 + 10.0 )sin( 60.0/2 ), 2*606.5 )
  = 1073.872 mm.
```

The Computed K values from Table 4.15.1:
```
 K1  = 0.1066     K2  = 1.1707     K3  = 0.8799     K4  = 0.4011
 K5  = 0.7603     K6  = 0.0529     K7  = 0.0529     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0347
 K7p = 0.0347
```

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 + (Rm^2-h2^2)/(2a*L))/(1+(4h2)/3L)]
  = -77*850.0[1-(1-850.0/6250.0+(606.5^2-303.0^2)/
    (2*850.0*6250.0))/(1+(4*303.0)/(3*6250.0))]
  = -10724.8 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(Rm^2-h2^2)/(L^2))/(1+(4h2)/( 3L))-4a/L
  = 77*6250/4(1+2(607^2-303^2)/(6250^2))/(1+(4*303)/
    (3*6250))-4*850/6250
  = 49097.0 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm^2t)
  = 5.389 * 606.5/(2*7.0) - 49097.0/(pi*606.5^2*7.0)
  = 17.28 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7)   [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 5.389 * 606.5/(2 * 7.0) + 49097.0/(pi * 606.5² * 7.0 )
  = 29.42 N./mm²
```

Longitudinal Stress at Top of Shell at Support (4.15.10)   [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 5.389*606.5/(2*7.0)--10724.8/(0.1066*pi*606.5²*7.0)
  = 35.78 N./mm²
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11)   [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 5.389*606.5/(2*7.0)+-10724.8/(0.1923*pi*606.5²*7.0)
  = 16.46 N./mm²
```

Maximum Shear Force in the Saddle (4.15.5)   [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 77( 6250.0 - 2 * 850.0)/(6250.0 + ( 4 * 303.0/3))
  = 52.6 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14)   [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 52.57/( 606.5 * 7.0 )
  = 14.50 N./mm²
```

Decay Length (4.15.22)   [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 606.5 * 7.0 )
  = 50.823 mm.
```

Circumferential Stress in shell, no rings (4.15.23)   [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 77 * 0.1/( 7.0 * ( 150.0 + 50.82 + 50.82 ) )
  = -3.32 N./mm²
```

Effective reinforcing plate width (4.15.1)   [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a   )
  = min( 150.0 + 1.56 * sqrt( 606.5 * 7.0 ), 2 * 850.0 )
  = 251.65 mm.
```

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 ) )
  = - 0.7603 * 77 * 0.1/( 251.646( 7.0 + 1.0 * 10.0 ) )
  = -1.37 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27)   [sigma7,r]:
```
  = -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)
  = -77/(4(7.0 + 1.0 * 10.0)251.646) -
     3 * 0.053 * 77/(2(7.0 + 1.0 * 10.0)²)
  = -25.58 N./mm²
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1200.0000	mm.
Baseplate Thickness	Bpthk	15.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	15.0000	mm.
Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	585.0	mm.
Friction Coefficient	mu	0.300	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	361.4	7.0	3.5	25.3	8853.1	0.157E+05
Wearplate	260.0	10.0	12.0	26.0	31200.0	0.151E+05
Web	15.0	565.0	299.5	84.8	2538262.8	0.244E+05
BasePlate	170.0	15.0	589.5	25.5	1503225.0	0.289E+05
Totals	...	...	...	161.5	4081541.2	0.841E+05

Distance to Centroid [C1]:
= AY / A
= 1606.906/161.545
= 252.657 mm.

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120.0/2
= 120.0

Saddle Splitting Coefficient [K1]:
= $(1 + \cos(beta) - 0.5*\sin(beta)^2)/(pi - beta + \sin(beta)\cos(beta))$
= $(1 + \cos(120.0) - 0.5*\sin(120.0)^2)/(pi - 2.094 + \sin(120.0)\cos(120.0))$
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 76.878
= 15.6464 kN

Tension Stress, St = (Fh/As) = 1.1485 $N./mm^2$
Allowed Stress, Sa = 0.6 * Yield Str = 143.9676 $N./mm^2$

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 1200.0 - 603.0 * sin(120.0/2)/1.0472
= 701.323 mm.

Bending Moment, M = Fh * d = 10977.6348 N-m

```
Bending Stress, Sb = ( M * C1 / I  ) =          3.2966  N./mm²
Allowed Stress, Sa = 2/3 * Yield Str =        159.9640  N./mm²
```

Minimum Thickness of Baseplate per Moss:

```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(77 + 2)170.0/( 4 * 1200.0 * 159.964 ))½
  = 7.245 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:

```
  = 2 * cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )
  = 2 * cos( 90 - 120.0/2 )( 600.0 + 10.0 + 10.0 )
  = 1073.872 mm.
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1073.8716/( 4 - 1 )
  = 357.957 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 357.9572 * 170.0/2
  = 304.264 cm²
```

Bearing Pressure [Bp]:

```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 76.878/( 1200.0 * 170.0 )
  = 0.038 kN/cm²
```

Axial Load [P]:

```
  = Ap * Bp
  = 304.3 * 0.04
  = 11.466 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 20.25 + 26.847
  = 47.097 cm²
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 11.5/47.0968
  = 2.435 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	15.0	150.0	...	22.5	...	422.

Rib dimension [D]:

= Saddle Width - Web Thickness
= 150.0 - 15.0
= 135.000 mm.

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/47.097
= 0.000 mm.

Distance to Centroid [C1]:
= Saddle Width / 2
= 150.0/2
= 75.000 mm.

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(421.9/47.097)
= 29.929 mm.

Length of Outer Rib [L]:
= Saddle Height - cos(theta/2)(radius + shlthk + wpdthk) - bpthk
= 1200.0 - cos(120.0/2)(600.0 + 10.0 + 10.0) - 15.0
= 875.000 mm.

Intermediate Term [Cc]:
= $\mathrm{sqrt}(2 * pi^2 * \text{Elastic Modulus} / \text{Yield Stress})$
= $\mathrm{sqrt}(2 * pi^2 * 0.19994E+09/239.9)$
= 128.255

Slenderness ratio [KL/r]:
= KL/r
= 1 * 875.0/29.929
= 29.236

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 0.5/(2 * 1200.0) * 357.957 * 875.0/2
= 33.974 N-m

Compressive Allowable, KL/r < Cc (29.2356 < 128.2549) per AISC E2-1 [Sca]:
= $(1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$
= $(1-(29.24)^2/(2 * 128.25^2))240/$
$(5/3+3*(29.24)/(8* 128.25)-(29.24^3)/(8*128.25^3)$
= $133.5\ N./mm^2$

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 2.43/133.5 + (33.97 * 75.0/4218750)/159.96
= 0.022

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

B	D	Y	A	AY	Io

Rib	15.0	135.0	0.0	20.2	0.0	421.
Web	358.0	15.0	0.0	53.7	0.0	10.1
Totals	...	...	...	73.9	...	432.

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/73.944
= 0.000 mm.

Distance to Centroid [C1]:
= Saddle Width / 2
= 150.0/2
= 75.000 mm.

Length of Inner Rib [L]:
= Saddle Height - sqrt((Ro + Wpdthk)^2 - (Pitch/2)^2) - Bpthk
= 1200.0 - sqrt((620.0 + 10.0)^2 - (357.957/2)^2) - 15.0
= 591.395 mm.

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(431.5/73.944)
= 24.157 mm.

Slenderness ratio [KL/r]:
= KL/r
= 1 * 591.395/24.157
= 24.481

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 0.52/(2 * 1200.0)
= 0.000 kN/mm.

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 0. * 357.957 * 591.395
= 45.925 N-m

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 45.925/57536.086
= 0.798 N./mm^2

Compressive Allowable, KL/r < Cc (24.4809 < 128.2549) per AISC E2-1 [Sca]:
= (1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)
= (1-(24.48)^2/(2 * 128.25^2))240/
(5/3+3*(24.48)/(8* 128.25)-(24.48^3)/(8*128.25^3)
= 135.6 N./mm^2

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 3.14/135.59 + (45.92 * 75.0/431.52)/159.96
= 0.028

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	300.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	150.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	95.15	N./mm²
Area Available in a Single Bolt	BltArea	2.1705	cm²
Saddle Load QO (Weight)	QO	76.8	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.1	kN
Maximum Transverse Force	Ft	0.6	kN
Maximum Longitudinal Force	Fl	0.5	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
```
  = Fl / ( Bolt Area * Number of Bolts )
  = 0.5/( 2.17 * 4 )
  = 0.6 N./mm². Must be less than 180.0 N./mm².
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
```
  = Ft / ( Bolt Area * Number of Bolts )
  = 0.6/( 2.17 * 4 )
  = 0.7 N./mm². Must be less than 180.0 N./mm².
```

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 / ( BoltShearAllowable * Nbolts )
  = 0.52/(180.0 * 4.0)
  = 0.0072 cm²
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 1200.0 * 0.65 + 0.0
  = 779.44 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 779.44/76.84
  = 10.14 mm. < 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, 0.0072, 0.0]
  = 0.0072 cm²
```

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      606.50  mm.
Stiffened Vessel Length per 4.15.6               L     6250.00  mm.
Distance from Saddle to Vessel tangent           a      850.00  mm.

Saddle Width                                     b      150.00  mm.
Saddle Bearing Angle                         theta      120.00  degrees

Wear Plate Width                                b1      260.00  mm.
Wear Plate Bearing Angle                    theta1      145.00  degrees
Wear Plate Thickness                            tr       10.0   mm.
Wear Plate Allowable Stress                     Sr      137.90  N./mm²

Shell Allowable Stress used in Calculation              196.73  N./mm²
Head Allowable Stress used in Calculation               196.73  N./mm²
Circumferential Efficiency in Plane of Saddle             1.00
Circumferential Efficiency at Mid-Span                    1.00

Distance from Saddle Base to Centerline          B     1200.00  mm.
Coefficient of Friction                         mu        0.00

Saddle Force Q, Test Case, no Ext. Forces                89.81  kN

Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                         N./mm² |       N./mm² |
----------------------------------------------------------------
Long. Stress at Top    of Midspan         15.11 |       196.73 |
Long. Stress at Bottom of Midspan         31.59 |       196.73 |
Long. Stress at Top    of Saddles         32.32 |       196.73 |
Long. Stress at Bottom of Saddles         18.37 |       196.73 |
----------------------------------------------------------------
Tangential Shear in Shell                 18.03 |       139.65 |
Circ. Stress at Horn of Saddle            29.89 |       295.10 |
Circ. Compressive Stress in Shell          3.88 |       196.73 |
----------------------------------------------------------------
```

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( 1.3/2 + 0 ) * 1200.0/1073.8717
  = 2.2 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 0.52, 0.0, 0 ) * 1200.0/4953.3335
  = 0.1 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 88 + max( 0.1, 2, 0, 0 )
  = 89.8 kN
```

Longitudinal Wind Force [Fl]:

```
  = WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
  = 0.6 * 766.08( 1.584 + ( 1.539 * 1.2 ))
  = 1577.182 N
```

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)                91.95   kN
 Transverse Shear Load Saddle            Ft              0.65   kN
 Longitudinal Shear Load Saddle                          0.52   kN
```

Hydrostatic Test Pressure at center of Vessel 5.389 bars

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = min( 2( ShellID/2 + t + WearPadThickness )sin( theta/2 ), 2*Rm )
  = min( 2( 1200.0/2 + 10.0 + 10.0 )sin( 60.0/2 ), 2*606.5 )
  = 1073.872 mm.
```

The Computed K values from Table 4.15.1:

```
 K1  = 0.1066     K2  = 1.1707     K3  = 0.8799     K4  = 0.4011
 K5  = 0.7603     K6  = 0.0529     K7  = 0.0529     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0347
 K7p = 0.0347
```

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 + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -90*850.0[1-(1-850.0/6250.0+(606.5²-0.0²)/
    (2*850.0*6250.0))/(1+(4*0.0)/(3*6250.0))]
  = -7742.4 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 90*6250/4(1+2(607²-0²)/(6250²))/(1+(4*0)/
    (3*6250))-4*850/6250
  = 66660.4 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
```

```
  = 5.389 * 606.5/(2*7.0) - 66660.4/(pi*606.5²*7.0)
  = 15.11 N./mm²
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 5.389 * 606.5/(2 * 7.0) + 66660.4/(pi * 606.5² * 7.0 )
  = 31.59 N./mm²
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 5.389*606.5/(2*7.0)--7742.4/(0.1066*pi*606.5²*7.0)
  = 32.32 N./mm²
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 5.389*606.5/(2*7.0)+-7742.4/(0.1923*pi*606.5²*7.0)
  = 18.37 N./mm²
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 90( 6250.0 - 2 * 850.0)/(6250.0 + ( 4 * 0.0/3))
  = 65.4 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 65.38/( 606.5 * 7.0 )
  = 18.03 N./mm²
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 606.5 * 7.0 )
  = 50.823 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 90 * 0.1/( 7.0 * ( 150.0 + 50.82 + 50.82 ) )
  = -3.88 N./mm²
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 150.0 + 1.56 * sqrt( 606.5 * 7.0 ), 2 * 850.0 )
  = 251.65 mm.
```

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 ) )
  = - 0.7603 * 90 * 0.1/( 251.646( 7.0 + 1.0 * 10.0 ) )
  = -1.60 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27) [sigma7,r]:
```
  = -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)
  = -90/(4(7.0 + 1.0 * 10.0)251.646) -
     3 * 0.053 * 90/(2(7.0 + 1.0 * 10.0)²)
```

= -29.89 N./mm^2

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1200.0000	mm.
Baseplate Thickness	Bpthk	15.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	15.0000	mm.
Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	585.0	mm.
Friction Coefficient	mu	0.000	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	361.4	7.0	3.5	25.3	8853.1	0.157E+05
Wearplate	260.0	10.0	12.0	26.0	31200.0	0.151E+05
Web	15.0	565.0	299.5	84.8	2538262.8	0.244E+05
BasePlate	170.0	15.0	589.5	25.5	1503225.0	0.289E+05
Totals	...	...	...	161.5	4081541.2	0.841E+05

Distance to Centroid [C1]:
= AY / A
= 1606.906/161.545
= 252.657 mm.

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120.0/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)^2)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120.0) - 0.5*sin(120.0)^2)/(pi - 2.094 + sin(120.0)cos(120.0))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 89.811
= 18.2785 kN

Tension Stress, St = (Fh/As) = 1.3417 N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str = 143.9676 N./mm^2

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 1200.0 - 603.0 * sin(120.0/2)/1.0472
= 701.323 mm.

```
Bending Moment, M  = Fh * d          =      12824.3477  N-m

Bending Stress, Sb = ( M * C1 / I  ) =          3.8512  N./mm²
Allowed Stress, Sa = 2/3 * Yield Str =        159.9640  N./mm²
```

Minimum Thickness of Baseplate per Moss:

```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(90 + 2)170.0/( 4 * 1200.0 * 159.964 ))½
  = 7.815 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:

```
  = 2 * cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )
  = 2 * cos( 90 - 120.0/2 )( 600.0 + 10.0 + 10.0 )
  = 1073.872 mm.
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1073.8716/( 4 - 1 )
  = 357.957 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 357.9572 * 170.0/2
  = 304.264 cm²
```

Bearing Pressure [Bp]:

```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 89.811/( 1200.0 * 170.0 )
  = 0.044 kN/cm²
```

Axial Load [P]:

```
  = Ap * Bp
  = 304.3 * 0.04
  = 13.395 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 20.25 + 26.847
  = 47.097 cm²
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 13.4/47.0968
  = 2.844 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

```
                     B |            D |            Y |            A |           AY |           Io |
 ------------------------------------------------------------------------------------------
```

```
Rib+Web         15.0 |        150.0 |          ... |          22.5 |          ... |     422.      |
```

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 150.0 - 15.0
  = 135.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/47.097
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 150.0/2
  = 75.000 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 421.9/47.097 )
  = 29.929 mm.
```

Length of Outer Rib [L]:
```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 1200.0 - cos( 120.0/2 )( 600.0 + 10.0 + 10.0 ) - 15.0
  = 875.000 mm.
```

Intermediate Term [Cc]:
```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 0.19994E+09/239.9 )
  = 128.255
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 875.0/29.929
  = 29.236
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 0.5/( 2 * 1200.0 ) * 357.957 * 875.0/2
  = 33.974 N-m
```

Compressive Allowable, KL/r < Cc (29.2356 < 128.2549) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 29.24 )²/(2 * 128.25² ))240/
    ( 5/3+3*(29.24)/(8* 128.25)-( 29.24³)/(8*128.25³)
  = 133.5 N./mm²
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 2.84/133.5 + ( 33.97 * 75.0/4218750 )/159.96
  = 0.025
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	15.0	135.0	0.0	20.2	0.0	421.
Web	358.0	15.0	0.0	53.7	0.0	10.1
Totals	...	...	...	73.9	...	432.

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/73.944
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 150.0/2
  = 75.000 mm.
```

Length of Inner Rib [L]:
```
  = Saddle Height - sqrt( (Ro + Wpdthk)^2 - (Pitch/2)^2 ) - Bpthk
  = 1200.0 - sqrt( (620.0 + 10.0)^2 - (357.957/2)^2 ) - 15.0
  = 591.395 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 431.5/73.944 )
  = 24.157 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 591.395/24.157
  = 24.481
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 0.52/( 2 * 1200.0 )
  = 0.000 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0. * 357.957 * 591.395
  = 45.925 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 45.925/57536.086
  = 0.798 N./mm²
```

Compressive Allowable, KL/r < Cc (24.4809 < 128.2549) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 24.48 )²/(2 * 128.25² ))240/
    ( 5/3+3*(24.48)/(8* 128.25)-( 24.48³)/(8*128.25³)
  = 135.6 N./mm²
```

AISC Unity Check of Inside Ribs (must be <= 1)

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 3.66/135.59 + ( 45.92 * 75.0/431.52 )/159.96
  = 0.032
```

<u>Input Data for Base Plate Bolting Calculations:</u>

```
 Total Number of Bolts per BasePlate            Nbolts           4
 Total Number of Bolts in Tension/Baseplate        Nbt           2
 Bolt Material Specification                             SA-193 B7
 Bolt Allowable Stress                            Stba      300.00  N./mm²
 Bolt Corrosion Allowance                          Bca         0.0  mm.
 Distance from Bolts to Edge                   Edgedis       150.0  mm.
 Nominal Bolt Diameter                             Bnd     20.0000  mm.
 Thread Series                                  Series   TEMA Metric
 BasePlate Allowable Stress                          S       95.15  N./mm²
 Area Available in a Single Bolt               BltArea      2.1705  cm²
 Saddle Load QO (Weight)                            QO        89.8  kN
 Saddle Load QL (Wind/Seismic contribution)         QL         0.1  kN
 Maximum Transverse Force                           Ft         0.6  kN
 Maximum Longitudinal Force                         Fl         0.5  kN
 Saddle Bolted to Steel Foundation                             Yes
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

```
  = Ft / ( Bolt Area * Number of Bolts )
  = 0.6/( 2.17 * 4 )
  = 0.7 N./mm².  Must be less than 180.0 N./mm².
```

<u>Bolt Area Calculation per Dennis R. Moss</u>

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 / ( BoltShearAllowable * Nbolts )
  = 0.52/(180.0 * 4.0)
  = 0.0072 cm²
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 1200.0 * 0.65 + 0.0
  = 779.44 N-m
```

Eccentricity (e):

```
  = Rmom / QO
  = 779.44/89.77
  = 8.68 mm. < 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, 0.0072, 0.0]
  = 0.0072 cm²
```

Input, Nozzle Desc: N08 (1in) **From: 10**

```
Pressure for Reinforcement Calculations         P        4.135   bars
Temperature for Internal Pressure            Temp          234   °C
Design External Pressure                     Pext         1.03   bars
Temperature for External Pressure          Tempex          100   °C

Shell Material                                       SA-516 70
Shell Allowable Stress at Temperature          Sv       137.90   N./mm²
Shell Allowable Stress At Ambient             Sva       137.90   N./mm²

Inside Diameter of Elliptical Head              D      1200.00   mm.
Aspect Ratio of Elliptical Head                Ar         2.00
Head Finished (Minimum) Thickness               t      10.0000   mm.
Head Internal Corrosion Allowance               c       3.0000   mm.
Head External Corrosion Allowance              co       0.0000   mm.

Distance from Head Centerline                  L1     400.0000   mm.

User Entered Minimum Design Metal Temperature             5.00   °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                SA-105
Material UNS Number                                    K03504
Material Specification/Type                          Forgings
Allowable Stress at Temperature                Sn       136.43   N./mm²
Allowable Stress At Ambient                   Sna       137.90   N./mm²

Diameter Basis (for tr calc only)                           ID
Layout Angle                                            270.00   deg
Diameter                                                2.0000   in.

Size and Thickness Basis                                Actual
Actual Thickness                               tn      15.8500   mm.

Flange Material                                         SA-105
Flange Type                                    Long Weld Neck

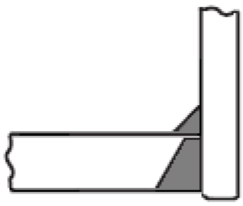
Corrosion Allowance                           can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle       E1         1.00
Joint Efficiency of Nozzle Neck                En         1.00

Outside Projection                             ho     150.0000   mm.
Weld leg size between Nozzle and Pad/Shell     Wo      10.0000   mm.
Groove weld depth between Nozzle and Vessel  Wgnv      10.0000   mm.
Inside Projection                               h       0.0000   mm.
Weld leg size, Inside Element to Shell         Wi       0.0000   mm.

Flange Class                                         150
Flange Grade                                         GR 1.1
Flange Series                              Series    =
```

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

Note : Checking Nozzle in the Meridional direction.

Reinforcement CALCULATION, Description: N08 (1in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation           2.000  in.
 Actual Thickness Used in Calculation                 0.624  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
   = (4.13*0.896*1206.0)/(2 *137.9*1.0-0.2*4.13)
   = 1.6202 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
   = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
   = (4.13*28.4)/(136*1.0-0.6*4.13)
   = 0.0862 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3393 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    124.3751   mm.
 Parallel to Vessel Wall, opening length              d     62.1876   mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000   mm.
```

Weld Strength Reduction Factor [fr1]:
```
   = min( 1, Sn/Sv )
   = min( 1, 136.4/137.9 )
   = 0.989
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
  = 0.989
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.989, 1.0 )
  = 0.989
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.012	0.986	NA
Area in Shell	A1	3.331	2.378	NA
Area in Nozzle Wall	A2	4.735	4.641	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.989	0.989	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	9.055	8.009	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  65.97   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(62.1876*3.1585*1+2*12.85*3.1585*1(1-0.99))
  = 0.986 cm²
```

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 )
  = 62.188( 1.0 * 7.0 - 1.0 * 3.159 ) - 2 * 12.85
    ( 1.0 * 7.0 - 1.0 * 3.1585 ) * ( 1 - 0.989 )
  = 2.378 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 17.5 )( 12.85 - 0.34 ) 0.9894/sin( 69.0 )
  = 4.641 cm²
```

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.62, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.231, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 4.13/19.60 = 0.211
```

Weld Size Calculations, Description: N08 (1in)

```
Intermediate Calc. for nozzle/shell Welds    Tmin       9.0000   mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
Nozzle Weld             6.0000 = Min per Code 7.0700 = 0.7 * Wo mm.
```

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,  ( 0.9864 - 2.3784 + 2 * 12.85 * 0.9894 *
    (1.0 * 7.0 - 3.1585 ) )138)
  = max( 0, -5.73) kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.6407 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 77.63 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.6407 + 0.0 + 0.9894 + ( 1.7799 ) ) * 138
  = 102.17 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.6407 + 0.0 + 0.9894 + 0.0 + ( 1.7799 ) ) * 138
  = 102.17 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 90.3253 * 10.0 * 0.49 * 136
  = 95. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 38.1282) * ( 15.85 - 3.0 ) * 0.7 * 136
  = 147. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 90.3253 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 101. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 95 + 147 ) = 242 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 95 + 0 + 101 + 0 ) = 196 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 95 + 101 + 0 ) = 196 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 241 kN , must exceed W = 0 kN  or W1 = 77 kN
 Path 2-2 = 196 kN , must exceed W = 0 kN  or W2 = 102 kN
 Path 3-3 = 196 kN , must exceed W = 0 kN  or W3 = 102 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1  bars
```

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: N08 (1in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.624  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)
  = (4.13*0.896*1206.0)/(2 *137.9*1.0-0.2*4.13)
  = 1.6202 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.13*28.4)/(136*1.0-0.6*4.13)
  = 0.0862 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3393 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)             Dl    113.6000  mm.
 Parallel to Vessel Wall, opening length               d     56.8000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad    Tlnp     17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.925	0.901	NA
Area in Shell	A1	3.041	2.171	NA
Area in Nozzle Wall	A2	4.420	4.332	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.989	0.989	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	8.450	7.493	NA

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(56.8*3.1585*1+2*12.85*3.1585*1(1-0.99))
  = 0.901 cm²
```

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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 3.159 ) - 2 * 12.85
    ( 1.0 * 7.0 - 1.0 * 3.1585 ) * ( 1 - 0.989 )
  = 2.171 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 12.85 - 0.34 ) 0.9894
  = 4.332 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

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

```
 Wall Thickness for Internal/External pressures       ta = 3.3393 mm.
```

```
Wall Thickness per UG16(b),                          tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 4.7969 mm.
Wall Thickness                   tb1 = max(trb1, tr16b) = 4.7969 mm.
Wall Thickness, shell/head, external pressure         trb2 = 3.4492 mm.
Wall Thickness                   tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                          tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 7.8, max( 4.7969, 4.5 ) ]
= 4.7969 mm.
```

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

```
= max( ta, tb )
= max( 3.3393, 4.7969 )
= 4.7969 mm.
```

Available Nozzle Neck Thickness = 15.8500 mm. --> OK

Weld Size Calculations, Description: N08 (1in)

```
Intermediate Calc. for nozzle/shell Welds    Tmin       9.0000   mm.
```

Results Per UW-16.1:

```
                          Required Thickness     Actual Thickness
Nozzle Weld             6.0000 = Min per Code 7.0700 = 0.7 * Wo mm.
```

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, ( 0.9013 - 2.1714 + 2 * 12.85 * 0.9894 *
  (1.0 * 7.0 - 3.1585 ) )138)
= max( 0, -4.04) kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 4.3322 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
= 73.38 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 4.3322 + 0.0 + 0.9894 + ( 1.7799 ) ) * 138
= 97.92 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 4.3322 + 0.0 + 0.9894 + 0.0 + ( 1.7799 ) ) * 138
= 97.92 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 82.5 * 10.0 * 0.49 * 136
  = 87. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 34.825) * ( 15.85 - 3.0 ) * 0.7 * 136
  = 134. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 82.5 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 93. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 87 + 134 ) = 221 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 87 + 0 + 93 + 0 ) = 179 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 87 + 93 + 0 ) = 179 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 220 kN , must exceed W = 0 kN  or W1 = 73 kN
 Path 2-2 = 179 kN , must exceed W = 0 kN  or W2 = 97 kN
 Path 3-3 = 179 kN , must exceed W = 0 kN  or W3 = 97 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 17.2963 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 178.0417 mm.

Input, Nozzle Desc: N02 (2in) **From: 20**

```
Pressure for Reinforcement Calculations          P        4.100   bars
Temperature for Internal Pressure              Temp         234   °C
Design External Pressure                       Pext        1.03   bars
Temperature for External Pressure            Tempex         100   °C

Shell Material                                         SA-516 70
Shell Allowable Stress at Temperature           Sv       137.90   N./mm²
Shell Allowable Stress At Ambient              Sva       137.90   N./mm²

Inside Diameter of Cylindrical Shell             D      1200.00   mm.
Design Length of Section                         L    3699.9998   mm.
Shell Finished (Minimum) Thickness               t      10.0000   mm.
Shell Internal Corrosion Allowance               c       3.0000   mm.
Shell External Corrosion Allowance              co       0.0000   mm.

Distance from Bottom/Left Tangent                        200.00   mm.

User Entered Minimum Design Metal Temperature              5.00   °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                SA-105
Material UNS Number                                    K03504
Material Specification/Type                          Forgings
Allowable Stress at Temperature                 Sn       136.43   N./mm²
Allowable Stress At Ambient                    Sna       137.90   N./mm²

Diameter Basis (for tr calc only)                            ID
Layout Angle                                             270.00   deg
Diameter                                                 2.0000   in.

Size and Thickness Basis                                Actual
Actual Thickness                                tn      15.8500   mm.

Flange Material                                         SA-105
Flange Type                                     Long Weld Neck

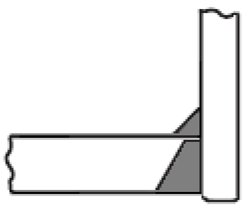
Corrosion Allowance                            can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     150.0000   mm.
Weld leg size between Nozzle and Pad/Shell      Wo      10.0000   mm.
Groove weld depth between Nozzle and Vessel   Wgnv      10.0000   mm.
Inside Projection                                h       0.0000   mm.
Weld leg size, Inside Element to Shell          Wi       0.0000   mm.

Flange Class                                           150
Flange Grade                                           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: N02 (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.000  in.
Actual Thickness Used in Calculation                    0.624  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3393 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    113.6000  mm.
Parallel to Vessel Wall, opening length              d     56.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
  = 0.989
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
```

```
 = 0.989
```

Weld Strength Reduction Factor [fr3]:

```
 = min( fr2, fr4 )
 = min( 0.989, 1.0 )
 = 0.989
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.025	1.775	NA
Area in Shell	A1	2.942	0.440	NA
Area in Nozzle Wall	A2	4.420	4.332	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.989	0.989	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	8.351	5.762	NA

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
 = 0.5(56.8*6.2213*1+2*12.85*6.2213*1(1-0.99))
 = 1.775 cm²
```

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 )
 = 56.8( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 12.85
   ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
 = 0.440 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
 = ( 2 * tlnp )( tn - trn )fr2
 = ( 2 * 17.5 )( 12.85 - 0.34 ) 0.9894
 = 4.332 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
 = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
 = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
 = 0.989 cm²
```

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

```
Wall Thickness for Internal/External pressures        ta = 3.3393 mm.
Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure      trb1 = 4.7961 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 4.7961 mm.
Wall Thickness, shell/head, external pressure      trb2 = 3.4524 mm.
```

```
Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                    tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.3393, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 15.8500 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
Sustained   :     12.0,  Allowable :    136.4 N./mm²  Passed
Expansion   :      0.0,  Allowable :    330.9 N./mm²  Passed
Occasional :       0.4,  Allowable :    181.5 N./mm²  Passed
Shear       :      3.1,  Allowable :     95.5 N./mm²  Passed
```

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

<u>Weld Size Calculations, Description: N02 (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
Nozzle Weld             4.9000 = 0.7 * tmin.   7.0700 = 0.7 * Wo mm.
```

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, (1.7753 - 0.4402 + 2 * 12.85 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 21.14 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.3322 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 73.38 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.3322 + 0.0 + 0.9894 + ( 1.7799 ) ) * 138
  = 97.92 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.3322 + 0.0 + 0.9894 + 0.0 + ( 1.7799 ) ) * 138
  = 97.92 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 82.5 * 10.0 * 0.49 * 136
  = 87. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 34.825) * ( 15.85 - 3.0 ) * 0.7 * 136
  = 134. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 82.5 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 93. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 87 + 134 ) = 221 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 87 + 0 + 93 + 0 ) = 179 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 87 + 93 + 0 ) = 179 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 220 kN , must exceed W = 21 kN  or W1 = 73 kN
 Path 2-2 = 179 kN , must exceed W = 21 kN  or W2 = 97 kN
 Path 3-3 = 179 kN , must exceed W = 21 kN  or W3 = 97 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case     16   bars
```

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

```
Nozzle is O.K. for the External Pressure            1   bars
```

The Drop for this Nozzle is : 1.4197 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 161.4197 mm.

Input Echo, WRC107/537 Item 1, Description: N02 (2in) :

```
Diameter Basis for Vessel                  Vbasis      ID
Cylindrical or Spherical Vessel            Cylsph      Cylindrical
Internal Corrosion Allowance                  Cas      3.0000   mm.
Vessel Diameter                                Dv    1200.000   mm.
Vessel Thickness                               Tv      10.000   mm.

Design Temperature                             T1       234.0   °C
Vessel Material                                      SA-516 70
Vessel UNS Number                                      K02700
Vessel Cold S.I. Allowable                    Smc      137.90   N./mm²
Vessel Hot  S.I. Allowable                    Smh      137.90   N./mm²
```

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

```
Attachment Type                               Type      Round

Diameter Basis for Nozzle                  Nbasis      ID
Corrosion Allowance for Nozzle                Can      3.0000   mm.
Nozzle Diameter                                Dn      50.800   mm.
Nozzle Thickness                               Tn      15.850   mm.
Nozzle Material                                        SA-105
Nozzle UNS Number                                      K03504
Nozzle Cold S.I. Allowable                   SNmc      137.90   N./mm²
Nozzle Hot  S.I. Allowable                   SNmh      136.43   N./mm²

Design Internal Pressure                       Dp       4.100   bars
Include Pressure Thrust                                    No
```

External Forces and Moments in WRC 107/537 Convention:

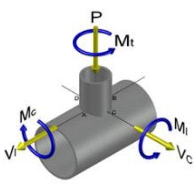
```
Radial Load             (SUS)                   P         2.8   kN
Longitudinal Shear      (SUS)                  Vl         2.8   kN
Circumferential Shear   (SUS)                  Vc        -2.1   kN
Circumferential Moment  (SUS)                  Mc      -280.0   N-m
Longitudinal Moment     (SUS)                  Ml      -360.0   N-m
Torsional Moment        (SUS)                  Mt      -420.0   N-m


Use Interactive Control                              No
```

```
WRC107 Version                          Version  March  1979

Include Pressure Stress Indices per Div. 2              No
Compute Pressure Stress per WRC-368                     No
Local Loads applied at end of Nozzle/Attachment         No
```

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 82.5 + 2 * 1.65 * sqrt( 606.5 ( 10.0 - 3.0 ) )
  = 297.520 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
Radial Load                                    P           2.8   kN
Circumferential Shear                          VC         -2.1   kN
Longitudinal Shear                             VL          2.8   kN
Circumferential Moment                         MC       -280.0   N-m
Longitudinal Moment                            ML       -360.0   N-m
Torsional Moment                               MT       -420.0   N-m

Dimensionless Parameters used :    Gamma =    86.64
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

```
-------------------------------------------------------------------
Curves read for 1979                  Beta  Figure     Value   Location
-------------------------------------------------------------------
N(PHI) / ( P/Rm )                    0.060   4C       15.037   (A,B)
N(PHI) / ( P/Rm )                    0.060   3C       14.463   (C,D)
M(PHI) / ( P )                       0.060   2C1       0.100   (A,B)
M(PHI) / ( P )                       0.060   1C        0.139   (C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )       0.060   3A        2.228   (A,B,C,D)
M(PHI) / ( MC/(Rm    * Beta) )       0.060   1A        0.096   (A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )       0.060   3B        7.820   (A,B,C,D)
M(PHI) / ( ML/(Rm    * Beta) )       0.060   1B        0.049   (A,B,C,D)

N(x)   / ( P/Rm )                    0.060   3C       14.463   (A,B)
N(x)   / ( P/Rm )                    0.060   4C       15.037   (C,D)
M(x)   / ( P )                       0.060   1C1       0.143   (A,B)
M(x)   / ( P )                       0.060   2C        0.101   (C,D)
N(x)   / ( MC/(Rm**2 * Beta) )       0.060   4A        3.056   (A,B,C,D)
M(x)   / ( MC/(Rm    * Beta) )       0.060   2A        0.057   (A,B,C,D)
N(x)   / ( ML/(Rm**2 * Beta) )       0.060   4B        2.219   (A,B,C,D)
```

```
M(x)    / ( ML/(Rm    * Beta) )    0.060    2B         0.080    (A,B,C,D)
```

Stress Concentration Factors: Kn = 1.00,   Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Memb.	P	-9.9	-9.9	-9.9	-9.9	-9.5	-9.5	-9.5	-9.5
Circ. Bend.	P	-34.4	34.4	-34.4	34.4	-47.7	47.7	-47.7	47.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	4.1	4.1	-4.1	-4.1
Circ. Memb.	MC	0.0	0.0	0.0	0.0	91.5	-91.5	-91.5	91.5
Circ. Memb.	ML	18.4	18.4	-18.4	-18.4	0.0	0.0	0.0	0.0
Circ. Bend.	ML	60.3	-60.3	-60.3	60.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.		34.3	-17.4	-123.1	66.5	38.3	-49.2	-152.8	125.6
Long. Memb.	P	-9.5	-9.5	-9.5	-9.5	-9.9	-9.9	-9.9	-9.9
Long. Bend.	P	-49.2	49.2	-49.2	49.2	-34.6	34.6	-34.6	34.6
Long. Memb.	MC	0.0	0.0	0.0	0.0	5.6	5.6	-5.6	-5.6
Long. Bend.	MC	0.0	0.0	0.0	0.0	53.8	-53.8	-53.8	53.8
Long. Memb.	ML	5.2	5.2	-5.2	-5.2	0.0	0.0	0.0	0.0
Long. Bend.	ML	97.2	-97.2	-97.2	97.2	0.0	0.0	0.0	0.0
Tot. Long. Str.		43.7	-52.3	-161.1	131.6	14.8	-23.5	-103.8	72.8
Shear	VC	-2.3	-2.3	2.3	2.3	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-3.1	-3.1	3.1	3.1
Shear	MT	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6
Tot. Shear		-7.9	-7.9	-3.3	-3.3	-8.7	-8.7	-2.5	-2.5
Str. Int.		48.2	54.0	161.4	131.8	41.1	51.9	152.9	125.7

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Pm	(SUS)	35.1	35.5	35.1	35.5	35.1	35.5	35.1	35.5
Circ. Pl	(SUS)	8.4	8.4	-28.3	-28.3	-5.5	-5.5	-13.6	-13.6
Circ. Q	(SUS)	25.9	-25.9	-94.8	94.8	43.7	-43.7	-139.2	139.2
Long. Pm	(SUS)	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6
Long. Pl	(SUS)	-4.3	-4.3	-14.8	-14.8	-4.3	-4.3	-15.5	-15.5
Long. Q	(SUS)	48.0	-48.0	-146.3	146.3	19.2	-19.2	-88.3	88.3

```
-------------------------------------------------------------------------------------------
Shear Pm (SUS) |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
Shear Pl (SUS) |     -2.3|     -2.3|      2.3|      2.3|     -3.1|     -3.1|      3.1|      3.1|
Shear Q  (SUS) |     -5.6|     -5.6|     -5.6|     -5.6|     -5.6|     -5.6|     -5.6|     -5.6|
Pm (SUS)       |     35.1|     35.5|     35.1|     35.5|     35.1|     35.5|     35.1|     35.5|
-------------------------------------------------------------------------------------------
Pm+Pl (SUS)    |     43.7|     44.1|      7.9|      8.2|     30.2|     30.6|     22.0|     22.4|
-------------------------------------------------------------------------------------------
Pm+Pl+Q (Total)|     74.3|     55.2|    143.7|    149.4|     75.1|     19.3|    117.9|    161.2|
```

Vessel Stress Summation Comparison (N./mm²):

```
Type of        |      Max. S.I.     S.I. Allowable      |       Result      |
Stress Int.    |                                        |                   |
--------------------------------------------------------------------------
Pm (SUS)       |         35.53            137.90        |      Passed       |
Pm+Pl (SUS)    |         44.15            206.85        |      Passed       |
Pm+Pl+Q (TOTAL)|        161.21            413.70        |      Passed       |
```

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: N12 (1in) From: 20

```
Pressure for Reinforcement Calculations        P        4.100   bars
Temperature for Internal Pressure           Temp          234   °C
Design External Pressure                    Pext         1.03   bars
Temperature for External Pressure         Tempex          100   °C

Shell Material                                       SA-516 70
Shell Allowable Stress at Temperature         Sv       137.90   N./mm²
Shell Allowable Stress At Ambient            Sva       137.90   N./mm²

Inside Diameter of Cylindrical Shell           D      1200.00   mm.
Design Length of Section                       L    3699.9998   mm.
Shell Finished (Minimum) Thickness             t      10.0000   mm.
Shell Internal Corrosion Allowance             c       3.0000   mm.
Shell External Corrosion Allowance            co       0.0000   mm.

Distance from Bottom/Left Tangent                      250.00   mm.

User Entered Minimum Design Metal Temperature            5.00   °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                SA-105
Material UNS Number                                    K03504
Material Specification/Type                          Forgings
Allowable Stress at Temperature               Sn       136.43   N./mm²
Allowable Stress At Ambient                  Sna       137.90   N./mm²

Diameter Basis (for tr calc only)                          ID
Layout Angle                                            90.00   deg
Diameter                                               1.0000   in.

Size and Thickness Basis                                Actual
Actual Thickness                              tn      12.8000   mm.

Flange Material                                         SA-105
Flange Type                                     Long Weld Neck

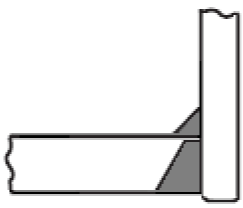
Corrosion Allowance                          can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle      E1         1.00
Joint Efficiency of Nozzle Neck               En         1.00

Outside Projection                            ho     150.0000   mm.
Weld leg size between Nozzle and Pad/Shell    Wo      10.0000   mm.
Groove weld depth between Nozzle and Vessel Wgnv      10.0000   mm.
Inside Projection                              h       0.0000   mm.
Weld leg size, Inside Element to Shell        Wi       0.0000   mm.

Flange Class                                         150
Flange Grade                                         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: N12 (1in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              1.000  in.
Actual Thickness Used in Calculation                    0.504  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
 = (4.1*603.0)/(138*1.0-0.6*4.1)
 = 1.7961 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
 = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
 = 15.7(exp([4.1/(136.43*1.0]-1)
 = 0.0473 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2571 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)              Dl     65.0000  mm.
Parallel to Vessel Wall                          Rn+tn+t     32.5000  mm.
Normal to Vessel Wall (Thickness Limit), no pad     Tlnp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
 = min( 1, Sn/Sv )
 = min( 1, 136.4/137.9 )
 = 0.989
```

Weld Strength Reduction Factor [fr2]:
```
 = min( 1, Sn/Sv )
 = min( 1, 136.4/137.9 )
```

```
  = 0.989
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.989, 1.0 )
  = 0.989
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.568	0.983	NA
Area in Shell	A1	1.738	0.260	NA
Area in Nozzle Wall	A2	3.377	3.305	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.900	0.900	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.015	4.465	NA

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(31.4*6.2213*1+2*9.8*6.2213*1(1-0.99))
  = 0.983 cm²
```

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 )
  = 33.6( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 9.8
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.260 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 9.8 - 0.26 ) 0.9894
  = 3.305 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
  = ( 10.0² - 0.09 ) * 0.9894 + ( 0.0² -0.0 ) * 0.9894
  = 0.900 cm²
```

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

```
 Wall Thickness for Internal/External pressures       ta = 3.2571 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure       trb1 = 4.7961 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure       trb2 = 3.4524 mm.
```

```
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                     tb3 = 6.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.42, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.2571, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 12.8000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

```
----------------------------------------------------------------------
```

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

<u>Weld Size Calculations, Description: N12 (1in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, ( 0.9832 - 0.26 + 2 * 9.8 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 12.05 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.3045 + 0.0 + 0.9003 - 0.0 * 0.99 ) * 138
  = 57.98 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.3045 + 0.0 + 0.9003 + ( 1.3574 ) ) * 138
  = 76.70 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.3045 + 0.0 + 0.9003 + 0.0 + ( 1.3574 ) ) * 138
  = 76.70 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 51.0 * 10.0 * 0.49 * 136
  = 54. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 20.6) * ( 12.8 - 3.0 ) * 0.7 * 136
  = 61. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 51.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 57. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 54 + 61 ) = 114 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 54 + 0 + 57 + 0 ) = 111 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 54 + 57 + 0 ) = 111 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 114 kN , must exceed W = 12 kN  or W1 = 57 kN
 Path 2-2 = 110 kN , must exceed W = 12 kN  or W2 = 76 kN
 Path 3-3 = 110 kN , must exceed W = 12 kN  or W3 = 76 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 0.5421 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 160.5421 mm.

Input, Nozzle Desc: M1 (24in) **From: 20**

Pressure for Reinforcement Calculations	P	4.100	bars
Temperature for Internal Pressure	Temp	234	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1200.00	mm.
Design Length of Section	L	3699.9998	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.

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

Physical Maximum for Diameter Limit	Dmax	920.0001	mm.
Distance from Bottom/Left Tangent		950.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

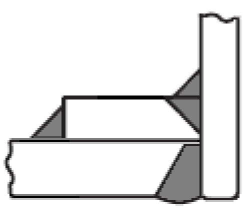
Material		SA-516 70	
Material UNS Number		K02700	
Material Specification/Type		Plate	
Allowable Stress at Temperature	Sn	137.90	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		24.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	10.0000	mm.
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	

```
Pad Allowable Stress at Temperature           Sp        137.90   N./mm²
Pad Allowable Stress At Ambient              Spa        137.90   N./mm²
Diameter of Pad along vessel surface          Dp      800.0000   mm.
Thickness of Pad                              te       10.0000   mm.
Weld leg size between Pad and Shell           Wp        8.0000   mm.
Groove weld depth between Pad and Nozzle    Wgpn       10.0000   mm.
Reinforcing Pad Width                                  95.2000   mm.
This is a Manway or Access Opening.

Flange Class                                          150
Flange Grade                                          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: M1 (24in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation          24.000   in.
Actual Thickness Used in Calculation                  0.394   in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

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)
  = (4.1*304.8)/(138*1.0+0.4*4.1)
  = 0.9052 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 1.0868 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    920.0001  mm.
Parallel to Vessel Wall, opening length              d    460.0000  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr4]:

```
  = min( 1, Sp/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1.0, 1.0 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	10.698	18.527	NA
Area in Shell	A1	16.881	2.526	NA
Area in Nozzle Wall	A2	2.133	2.070	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.577	1.577	NA
Area in Element	A5	19.040	19.040	NA
TOTAL AREA AVAILABLE	Atot	39.632	25.213	NA

The External 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:            733.1372    10.0000  mm.
Based on given Pad Diameter:             800.0001     6.4883  mm.
Based on Shell or Nozzle Thickness:      733.1372    10.0000  mm.
```

Area Required [A]:

```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(595.6*6.2213*1+2*7.0*6.2213*1(1-1.0))
  = 18.527 cm²
```

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 )
  = 324.4( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 7.0
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 1.0 )
  = 2.526 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 7.0 - 1.09 ) * 1.0
  = 2.070 cm²
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 1.0 + (0.0 ) * 1.0 + 203.2² * 1.0
  = 1.577 cm²
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 800.0 - 609.6 ) * 10.0 * 1.0
  = 19.040 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:B, Curve:A)

Govrn. thk, tg = 10.0, tr = 0.905, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.129, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A             -8 °C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                   -29 °C
```

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

Govrn. thk, tg = 10.0, tr = 0.905, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.129, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

Govrn. thk, tg = 10.0, tr = 0.905, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.129, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0

Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C

Gov. MDMT of the Nozzle                                 :  -104 °C
Gov. MDMT of the Reinforcement Pad                      :  -104 °C
Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)              Dl    893.4000  mm.
Parallel to Vessel Wall, opening length                d    446.7000  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  mm.
```

Reinforcement Areas for Large Nozzle (Per App 1-7(a)): (cm^2)

AREA AVAILABLE, A1 to A6		No Pad	With Pad
Area Required [External Pressure]	AR	12.352	12.352
Area Available in Shell	A1	2.319	2.319
Area Available in Nozzle Wall	A2	2.070	2.070
Area Available in Inward Nozzle	A3	0.000	0.000
Area Available in Welds	A4	1.000	1.577
Area Available in Pad	A5	0.000	19.040
Area Available in Hub	A6	0.000	0.000
TOTAL AREA AVAILABLE	Atot	5.389	25.006

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

Note: The Nozzle does not fall within the scope of the diameter requirements of App. 1-7(b). Therefore, the Membrane and Bending stress checks are not required.

Weld Size Calculations, Description: M1 (24in)

```
Intermediate Calc. for nozzle/shell Welds    Tmin       7.0000   mm.
Intermediate Calc. for pad/shell Welds     TminPad      7.0000   mm.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
 Nozzle Weld           4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
 Pad Weld              3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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, (18.527 - 2.5261 + 2 * 7.0 * 1.0 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 222.14 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.0696 + 19.04 + 1.5775 - 0.0 * 1.0 ) * 138
  = 312.83 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.0696 + 0.0 + 1. + ( 0.98 ) ) * 138
  = 55.84 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.0696 + 0.0 + 1.5775 + 19.04 + ( 0.98 ) ) * 138
  = 326.34 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 609.6 * 10.0 * 0.49 * 138
  = 647. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 800.0 * 8.0 * 0.49 * 138
  = 679. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 301.3) * ( 10.0 - 3.0 ) * 0.7 * 138
  = 640. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 609.6 * 10.0 * 0.74 * 138
  = 977. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 609.6 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 684. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 679 + 640 ) = 1319 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 647 + 977 + 684 + 0 ) = 2308 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 679 + 684 + 0 ) = 1363 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 1318 kN , must exceed W = 222 kN  or W1 = 312 kN
 Path 2-2 = 2307 kN , must exceed W = 222 kN  or W2 = 55 kN
 Path 3-3 = 1363 kN , must exceed W = 222 kN  or W3 = 326 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    11   bars

 Nozzle is O.K. for the External Pressure            1   bars
```

The Drop for this Nozzle is : 83.1858 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 243.1858 mm.

Percent Elongation Calculations:

```
 % Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro))   1.668 %
```

Input, Nozzle Desc: N07C (2in) **From: 20**

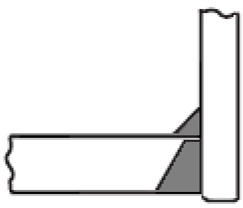
Pressure for Reinforcement Calculations	P	4.100	bars
Temperature for Internal Pressure	Temp	234	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1200.00	mm.
Design Length of Section	L	3699.9998	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		450.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	136.43	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	15.8500	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		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: N07C (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.000  in.
Actual Thickness Used in Calculation                    0.624  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
 = (4.1*603.0)/(138*1.0-0.6*4.1)
 = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
 = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
 = (4.1*28.4)/(136*1.0-0.6*4.1)
 = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3393 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)           Dl    113.6000  mm.
Parallel to Vessel Wall, opening length             d     56.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
 = min( 1, Sn/Sv )
 = min( 1, 136.4/137.9 )
 = 0.989
```

Weld Strength Reduction Factor [fr2]:
```
 = min( 1, Sn/Sv )
 = min( 1, 136.4/137.9 )
```

```
  = 0.989
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.989, 1.0 )
  = 0.989
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

```
 AREA AVAILABLE, A1 to A5      |    Design|  External|     Mapnc|
 ---------------------------------------------------------------
 Area Required               Ar |     1.025|     1.775|        NA|
 Area in Shell               A1 |     2.942|     0.440|        NA|
 Area in Nozzle Wall         A2 |     4.420|     4.332|        NA|
 Area in Inward Nozzle       A3 |     0.000|     0.000|        NA|
 Area in Welds     A41+A42+A43 |     0.989|     0.989|        NA|
 Area in Element             A5 |     0.000|     0.000|        NA|
 TOTAL AREA AVAILABLE      Atot |     8.351|     5.762|        NA|
```

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(56.8*6.2213*1+2*12.85*6.2213*1(1-0.99))
  = 1.775 cm²
```

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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 12.85
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.440 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 12.85 - 0.34 ) 0.9894
  = 4.332 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

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

```
 Wall Thickness for Internal/External pressures      ta = 3.3393 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 4.7961 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure     trb2 = 3.4524 mm.
```

```
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                     tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.3393, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 15.8500 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A               -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
Min Metal Temp. w/o impact per UG-20(f)                     -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

Weld Size Calculations, Description: N07C (2in)

```
Intermediate Calc. for nozzle/shell Welds    Tmin      7.0000   mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.7753 - 0.4402 + 2 * 12.85 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 21.14 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.3322 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 73.38 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.3322 + 0.0 + 0.9894 + ( 1.7799 ) ) * 138
  = 97.92 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.3322 + 0.0 + 0.9894 + 0.0 + ( 1.7799 ) ) * 138
  = 97.92 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 82.5 * 10.0 * 0.49 * 136
  = 87. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 34.825) * ( 15.85 - 3.0 ) * 0.7 * 136
  = 134. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 82.5 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 93. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 87 + 134 ) = 221 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 87 + 0 + 93 + 0 ) = 179 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 87 + 93 + 0 ) = 179 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 220 kN , must exceed W = 21 kN  or W1 = 73 kN
 Path 2-2 = 179 kN , must exceed W = 21 kN  or W2 = 97 kN
 Path 3-3 = 179 kN , must exceed W = 21 kN  or W3 = 97 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 1.4197 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 161.4197 mm.

Input, Nozzle Desc: N07B (2in) **From: 20**

```
Pressure for Reinforcement Calculations          P        4.100   bars
Temperature for Internal Pressure             Temp          234   °C
Design External Pressure                      Pext         1.03   bars
Temperature for External Pressure           Tempex          100   °C

Shell Material                                         SA-516 70
Shell Allowable Stress at Temperature           Sv       137.90   N./mm²
Shell Allowable Stress At Ambient              Sva       137.90   N./mm²

Inside Diameter of Cylindrical Shell             D      1200.00   mm.
Design Length of Section                         L    3699.9998   mm.
Shell Finished (Minimum) Thickness               t      10.0000   mm.
Shell Internal Corrosion Allowance               c       3.0000   mm.
Shell External Corrosion Allowance              co       0.0000   mm.

Distance from Bottom/Left Tangent                       1150.00   mm.

User Entered Minimum Design Metal Temperature              5.00   °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                  SA-105
Material UNS Number                                      K03504
Material Specification/Type                            Forgings
Allowable Stress at Temperature                 Sn       136.43   N./mm²
Allowable Stress At Ambient                    Sna       137.90   N./mm²

Diameter Basis (for tr calc only)                            ID
Layout Angle                                             270.00   deg
Diameter                                                 2.0000   in.

Size and Thickness Basis                                  Actual
Actual Thickness                                tn      15.8500   mm.

Flange Material                                           SA-105
Flange Type                                         Long Weld Neck

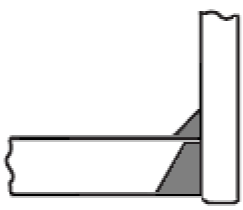
Corrosion Allowance                            can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     150.0000   mm.
Weld leg size between Nozzle and Pad/Shell      Wo      10.0000   mm.
Groove weld depth between Nozzle and Vessel Wgnv       10.0000   mm.
Inside Projection                                h       0.0000   mm.
Weld leg size, Inside Element to Shell          Wi       0.0000   mm.

Flange Class                                           150
Flange Grade                                           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: N07B (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.624  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3393 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    113.6000  mm.
 Parallel to Vessel Wall, opening length              d     56.8000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
  = 0.989
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
```

```
  = 0.989
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.989, 1.0 )
  = 0.989
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

```
 AREA AVAILABLE, A1 to A5       |    Design|  External|     Mapnc|
 ---------------------------------------------------------------
 Area Required              Ar |     1.025|     1.775|        NA|
 Area in Shell              A1 |     2.942|     0.440|        NA|
 Area in Nozzle Wall        A2 |     4.420|     4.332|        NA|
 Area in Inward Nozzle      A3 |     0.000|     0.000|        NA|
 Area in Welds     A41+A42+A43 |     0.989|     0.989|        NA|
 Area in Element            A5 |     0.000|     0.000|        NA|
 TOTAL AREA AVAILABLE     Atot |     8.351|     5.762|        NA|
```

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(56.8*6.2213*1+2*12.85*6.2213*1(1-0.99))
  = 1.775 cm²
```

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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 12.85
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.440 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 12.85 - 0.34 ) 0.9894
  = 4.332 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

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

```
 Wall Thickness for Internal/External pressures       ta = 3.3393 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 4.7961 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.4524 mm.
```

```
Wall Thickness                    tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                       tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.3393, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 15.8500 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

Weld Size Calculations, Description: N07B (2in)

```
Intermediate Calc. for nozzle/shell Welds    Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.7753 - 0.4402 + 2 * 12.85 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 21.14 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.3322 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 73.38 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.3322 + 0.0 + 0.9894 + ( 1.7799 ) ) * 138
  = 97.92 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.3322 + 0.0 + 0.9894 + 0.0 + ( 1.7799 ) ) * 138
  = 97.92 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 82.5 * 10.0 * 0.49 * 136
  = 87. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 34.825) * ( 15.85 - 3.0 ) * 0.7 * 136
  = 134. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 82.5 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 93. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 87 + 134 ) = 221 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 87 + 0 + 93 + 0 ) = 179 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 87 + 93 + 0 ) = 179 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 220 kN , must exceed W = 21 kN  or W1 = 73 kN
 Path 2-2 = 179 kN , must exceed W = 21 kN  or W2 = 97 kN
 Path 3-3 = 179 kN , must exceed W = 21 kN  or W3 = 97 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 1.4197 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 161.4197 mm.

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Input, Nozzle Desc: K9B (3in) From: 20

```
Pressure for Reinforcement Calculations        P        4.100  bars
Temperature for Internal Pressure           Temp          234  °C
Design External Pressure                    Pext         1.03  bars
Temperature for External Pressure         Tempex          100  °C

Shell Material                                     SA-516 70
Shell Allowable Stress at Temperature         Sv       137.90  N./mm²
Shell Allowable Stress At Ambient            Sva       137.90  N./mm²

Inside Diameter of Cylindrical Shell           D      1200.00  mm.
Design Length of Section                       L    3699.9998  mm.
Shell Finished (Minimum) Thickness             t      10.0000  mm.
Shell Internal Corrosion Allowance             c       3.0000  mm.
Shell External Corrosion Allowance            co       0.0000  mm.

Distance from Cylinder/Cone Centerline        L1     500.0000  mm.

Distance from Bottom/Left Tangent                      200.00  mm.

User Entered Minimum Design Metal Temperature            5.00  °C
```

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       117.90  N./mm²
Allowable Stress At Ambient                  Sna       117.90  N./mm²

Diameter Basis (for tr calc only)                          ID
Layout Angle                                           -55.05  deg
Diameter                                               3.0000  in.

Size and Thickness Basis                                Minimum
Nominal Thickness                             tn        80

Flange Material                                       SA-105
Flange Type                                  Weld Neck Flange

Corrosion Allowance                          can       3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle      E1         1.00
Joint Efficiency of Nozzle Neck               En         1.00

Outside Projection                            ho     300.0000  mm.
Weld leg size between Nozzle and Pad/Shell    Wo      10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv      10.0000  mm.
Inside Projection                              h       0.0000  mm.
Weld leg size, Inside Element to Shell        Wi       0.0000  mm.

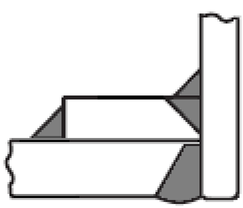
Pad Material                                       SA-516 70
Pad Allowable Stress at Temperature           Sp       137.90  N./mm²
Pad Allowable Stress At Ambient              Spa       137.90  N./mm²
```

```
Diameter of Pad along vessel surface         Dp     200.0000  mm.
Thickness of Pad                             te      10.0000  mm.
Weld leg size between Pad and Shell          Wp       8.0000  mm.
Groove weld depth between Pad and Nozzle   Wgpn      10.0000  mm.
Reinforcing Pad Width                                55.5500  mm.

Flange Class                                        300
Flange Grade                                        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: K9B (3in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          2.975  in.
Actual Thickness Used in Calculation                0.263  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*40.78)/(118*1.0-0.6*4.1)
  = 0.1421 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4726 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    294.0029  mm.
 Parallel to Vessel Wall, opening length              d    147.0015  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
   = min( 1, Sn/Sv )
   = min( 1, 117.9/137.9 )
   = 0.855
```

Weld Strength Reduction Factor [fr2]:

```
   = min( 1, Sn/Sv )
   = min( 1, 117.9/137.9 )
   = 0.855
```

Weld Strength Reduction Factor [fr4]:

```
   = min( 1, Sp/Sv )
   = min( 1, 137.9/137.9 )
   = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
   = min( fr2, fr4 )
   = min( 0.855, 1.0 )
   = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.659	4.606	NA
Area in Shell	A1	7.594	1.136	NA
Area in Nozzle Wall	A2	1.631	1.478	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.442	1.442	NA
Area in Element	A5	11.110	11.110	NA
TOTAL AREA AVAILABLE	Atot	21.777	15.166	NA

The External Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  33.70   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:               94.3965    10.0000   mm.
 Based on given Pad Diameter:               200.0000     0.4947   mm.
 Based on Shell or Nozzle Thickness:        168.4648     6.6675   mm.
```

Area Required [A]:

```
   = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
   = 0.5(147.0015*6.2213*1+2*3.6675*6.2213*1(1-0.86))
   = 4.606 cm²
```

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 )
  = 147.001( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 3.668
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.855 )
  = 1.136 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2/sin( alpha3 )
  = ( 2 * 17.5 ) * ( 3.67 - 0.47 ) * 0.855/sin( 40.3 )
  = 1.478 cm²
```

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 - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 0.86 + (0.0 ) * 0.86 + 203.2² * 1.0
  = 1.442 cm²
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 271.321 - 160.2211 ) * 10.0 * 1.0
  = 11.110 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:B, Curve:A)

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A            -8 °C
 Min Metal Temp. at Required thickness (UCS 66.1)        -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                  -29 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B           -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)        -104 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B           -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)        -104 °C
```

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

```
----------------------------------------------------------------------
```

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

```
----------------------------------------------------------------------
```

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C

Gov. MDMT of the Nozzle                              :   -104 °C
Gov. MDMT of the Reinforcement Pad                   :   -104 °C
Gov. MDMT of the nozzle to shell joint welded assembly :   -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

<u>Weld Size Calculations, Description: K9B (3in)</u>

```
Intermediate Calc. for nozzle/shell Welds    Tmin       3.6675  mm.
Intermediate Calc. for pad/shell Welds    TminPad       7.0000  mm.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
Nozzle Weld           2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
Pad Weld              3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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, (4.6058 - 1.1364 + 2 * 3.6675 * 0.855 *
     (1.0 * 7.0 - 6.2213 ) )138)
  = 48.51 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.4781 + 11.11 + 1.4416 - 0.0 * 0.86 ) * 138
  = 193.45 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.4781 + 0.0 + 0.8491 + ( 0.439 ) ) * 138
  = 38.14 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.4781 + 0.0 + 1.4416 + 11.11 + ( 0.439 ) ) * 138
  = 199.51 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 160.2211 * 10.0 * 0.49 * 118
  = 145. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 200.0 * 8.0 * 0.49 * 138
  = 170. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 76.8056) * ( 6.6675 - 3.0 ) * 0.7 * 118
  = 73. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 160.2211 * 10.0 * 0.74 * 138
  = 257. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 160.2211 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 180. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 170 + 73 ) = 243 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 145 + 257 + 180 + 0 ) = 582 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 170 + 180 + 0 ) = 350 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 242 kN , must exceed W = 48 kN  or W1 = 193 kN
 Path 2-2 = 581 kN , must exceed W = 48 kN  or W2 = 38 kN
 Path 3-3 = 349 kN , must exceed W = 48 kN  or W3 = 199 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    8  bars
```

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

```
Nozzle is O.K. for the External Pressure          1  bars
```

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

Reinforcement CALCULATION, Description: K9B (3in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.975  in.
Actual Thickness Used in Calculation                    0.263  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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*40.78)/(118*1.0-0.6*4.1)
  = 0.1421 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4726 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)             Dl    163.1300   mm.
Parallel to Vessel Wall, opening length               d     81.5650   mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000   mm.
```

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

Results of Nozzle Reinforcement Area Calculations: (cm²)

```
AREA AVAILABLE, A1 to A5      |     Design|  External|     Mapnc|
--------------------------------------------------------------
Area Required              Ar |     1.484|     2.570|        NA|
Area in Shell              A1 |     4.189|     0.627|        NA|
Area in Nozzle Wall        A2 |     1.055|     0.956|        NA|
Area in Inward Nozzle      A3 |     0.000|     0.000|        NA|
Area in Welds     A41+A42+A43 |     0.802|     0.802|        NA|
Area in Element            A5 |     7.423|     7.423|        NA|
TOTAL AREA AVAILABLE     Atot |    13.469|     9.807|        NA|
```

The External 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:              90.7578    10.0000   mm.
Based on given Pad Diameter:              200.0000     0.2503   mm.
```

```
 Based on Shell or Nozzle Thickness:       91.6863     6.6675  mm.
```

Area Required [A]:

```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(81.565*6.2213*1+2*3.6675*6.2213*1(1-0.86))
  = 2.570 cm²
```

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 )
  = 81.565( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 3.668
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.855 )
  = 0.627 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 3.67 - 0.47 ) * 0.855
  = 0.956 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 0.86 + (0.0 ) * 0.86 + 0.0² * 1.0
  = 0.802 cm²
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 163.13 - 88.9 ) * 10.0 * 1.0
  = 7.423 cm²
```

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

```
 Wall Thickness for Internal/External pressures      ta = 3.4726 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 4.7961 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.4524 mm.
 Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.4726, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 6.6675 mm. --> OK

<u>Weld Size Calculations, Description: K9B (3in)</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      3.6675  mm.
```

```
 Intermediate Calc. for pad/shell Welds    TminPad      7.0000   mm.
```

Results Per UW-16.1:

```
                              Required Thickness    Actual Thickness
 Nozzle Weld                 2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
 Pad Weld                    3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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, (2.5703 - 0.6269 + 2 * 3.6675 * 0.855 *
     (1.0 * 7.0 - 6.2213 ) )138)
   = 27.47 kN
```

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

Weld Load [W1]:

```
   = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
   = ( 0.9561 + 7.423 + 0.8016 - 0.0 * 0.86 ) * 138
   = 126.59 kN
```

Weld Load [W2]:

```
   = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
   = ( 0.9561 + 0.0 + 0.8491 + ( 0.439 ) ) * 138
   = 30.94 kN
```

Weld Load [W3]:

```
   = (A2+A3+A4+A5+(2*tn*t*fr1))*S
   = (  0.9561 + 0.0 + 0.8016 + 7.423 + ( 0.439 ) ) * 138
   = 132.64 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
   = (pi/2) * Dlo * Wo * 0.49 * Snw
   = ( 3.1416/2.0 ) * 88.9 * 10.0 * 0.49 * 118
   = 81. kN
```

Shear, Pad Element Weld [Spew]:

```
   = (pi/2) * DP * WP * 0.49 * SEW
   = ( 3.1416/2.0 ) * 200.0 * 8.0 * 0.49 * 138
   = 170. kN
```

Shear, Nozzle Wall [Snw]:

```
   = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
   = (3.1416 * 42.6162) * ( 6.6675 - 3.0 ) * 0.7 * 118
   = 41. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
   = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
   =  (3.1416/2 ) * 88.9 * 10.0 * 0.74 * 138
   = 142. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 88.9 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 100. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 170 + 41 ) = 210 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 81 + 142 + 100 + 0 ) = 323 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 170 + 100 + 0 ) = 270 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 210 kN , must exceed W = 27 kN  or W1 = 126 kN
 Path 2-2 = 322 kN , must exceed W = 27 kN  or W2 = 30 kN
 Path 3-3 = 269 kN , must exceed W = 27 kN  or W3 = 132 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    8   bars

 Nozzle is O.K. for the External Pressure            1   bars
```

The Drop for this Nozzle is : 79.5232 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 397.2889 mm.

Input, Nozzle Desc: K9A (3in) **From: 20**

```
Pressure for Reinforcement Calculations         P        4.100   bars
Temperature for Internal Pressure            Temp          234   °C
Design External Pressure                     Pext         1.03   bars
Temperature for External Pressure          Tempex          100   °C

Shell Material                                        SA-516 70
Shell Allowable Stress at Temperature          Sv       137.90   N./mm²
Shell Allowable Stress At Ambient             Sva       137.90   N./mm²

Inside Diameter of Cylindrical Shell            D      1200.00   mm.
Design Length of Section                        L    3699.9998   mm.
Shell Finished (Minimum) Thickness              t      10.0000   mm.
Shell Internal Corrosion Allowance              c       3.0000   mm.
Shell External Corrosion Allowance             co       0.0000   mm.

Distance from Cylinder/Cone Centerline         L1     500.0000   mm.

Distance from Bottom/Left Tangent                       200.00   mm.

User Entered Minimum Design Metal Temperature             5.00   °C
```

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       117.90   N./mm²
Allowable Stress At Ambient                   Sna       117.90   N./mm²

Diameter Basis (for tr calc only)                           ID
Layout Angle                                             55.05   deg
Diameter                                                3.0000   in.

Size and Thickness Basis                                  Minimum
Nominal Thickness                              tn         80

Flange Material                                           SA-105
Flange Type                                     Weld Neck Flange

Corrosion Allowance                           can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle       E1         1.00
Joint Efficiency of Nozzle Neck                En         1.00

Outside Projection                             ho     300.0000   mm.
Weld leg size between Nozzle and Pad/Shell     Wo      10.0000   mm.
Groove weld depth between Nozzle and Vessel Wgnv      10.0000   mm.
Inside Projection                               h       0.0000   mm.
Weld leg size, Inside Element to Shell         Wi       0.0000   mm.

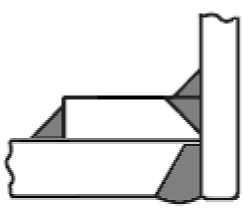
Pad Material                                          SA-516 70
Pad Allowable Stress at Temperature            Sp       137.90   N./mm²
Pad Allowable Stress At Ambient               Spa       137.90   N./mm²
```

```
Diameter of Pad along vessel surface          Dp     200.0000  mm.
Thickness of Pad                              te      10.0000  mm.
Weld leg size between Pad and Shell           Wp       8.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn      10.0000  mm.
Reinforcing Pad Width                                 55.5500  mm.

Flange Class                                         300
Flange Grade                                         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: K9A (3in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          2.975   in.
Actual Thickness Used in Calculation                0.263   in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*40.78)/(118*1.0-0.6*4.1)
  = 0.1421 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4726 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl   294.0029  mm.
 Parallel to Vessel Wall, opening length              d   147.0015  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
   = min( 1, Sn/Sv )
   = min( 1, 117.9/137.9 )
   = 0.855
```

Weld Strength Reduction Factor [fr2]:

```
   = min( 1, Sn/Sv )
   = min( 1, 117.9/137.9 )
   = 0.855
```

Weld Strength Reduction Factor [fr4]:

```
   = min( 1, Sp/Sv )
   = min( 1, 137.9/137.9 )
   = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
   = min( fr2, fr4 )
   = min( 0.855, 1.0 )
   = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.659	4.606	NA
Area in Shell	A1	7.594	1.136	NA
Area in Nozzle Wall	A2	1.631	1.478	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.442	1.442	NA
Area in Element	A5	11.110	11.110	NA
TOTAL AREA AVAILABLE	Atot	21.777	15.166	NA

The External Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  33.70   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:               94.3965    10.0000   mm.
 Based on given Pad Diameter:               200.0000     0.4947   mm.
 Based on Shell or Nozzle Thickness:        168.4648     6.6675   mm.
```

Area Required [A]:

```
   = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
   = 0.5(147.0015*6.2213*1+2*3.6675*6.2213*1(1-0.86))
   = 4.606 cm²
```

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 )
  = 147.001( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 3.668
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.855 )
  = 1.136 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2/sin( alpha3 )
  = ( 2 * 17.5 ) * ( 3.67 - 0.47 ) * 0.855/sin( 40.3 )
  = 1.478 cm²
```

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 - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 0.86 + (0.0 ) * 0.86 + 203.2² * 1.0
  = 1.442 cm²
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 271.321 - 160.2211 ) * 10.0 * 1.0
  = 11.110 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:B, Curve:A)

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B           -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -104 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B           -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -104 °C

Gov. MDMT of the Nozzle                             :   -104 °C
Gov. MDMT of the Reinforcement Pad                  :   -104 °C
Gov. MDMT of the nozzle to shell joint welded assembly : -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

<u>Weld Size Calculations, Description: K9A (3in)</u>

```
Intermediate Calc. for nozzle/shell Welds    Tmin       3.6675  mm.
Intermediate Calc. for pad/shell Welds      TminPad     7.0000  mm.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
Nozzle Weld           2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
Pad Weld              3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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, (4.6058 - 1.1364 + 2 * 3.6675 * 0.855 *
   (1.0 * 7.0 - 6.2213 ) )138)
 = 48.51 kN
```

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

Weld Load [W1]:

```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 1.4781 + 11.11 + 1.4416 - 0.0 * 0.86 ) * 138
 = 193.45 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.4781 + 0.0 + 0.8491 + ( 0.439 ) ) * 138
  = 38.14 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.4781 + 0.0 + 1.4416 + 11.11 + ( 0.439 ) ) * 138
  = 199.51 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 160.2211 * 10.0 * 0.49 * 118
  = 145. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 200.0 * 8.0 * 0.49 * 138
  = 170. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 76.8056) * ( 6.6675 - 3.0 ) * 0.7 * 118
  = 73. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 160.2211 * 10.0 * 0.74 * 138
  = 257. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 160.2211 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 180. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 170 + 73 ) = 243 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 145 + 257 + 180 + 0 ) = 582 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 170 + 180 + 0 ) = 350 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 242 kN , must exceed W = 48 kN  or W1 = 193 kN
 Path 2-2 = 581 kN , must exceed W = 48 kN  or W2 = 38 kN
 Path 3-3 = 349 kN , must exceed W = 48 kN  or W3 = 199 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    8  bars
```

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

```
Nozzle is O.K. for the External Pressure           1  bars
```

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

Reinforcement CALCULATION, Description: K9A (3in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation            2.975  in.
Actual Thickness Used in Calculation                  0.263  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)
 = (4.1*603.0)/(138*1.0-0.6*4.1)
 = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
 = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
 = (4.1*40.78)/(118*1.0-0.6*4.1)
 = 0.1421 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4726 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)             Dl    163.1300  mm.
Parallel to Vessel Wall, opening length               d     81.5650  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  mm.
```

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

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |     Design|  External|     Mapnc|
---------------------------------------------------------------
Area Required              Ar |      1.484|     2.570|        NA|
Area in Shell              A1 |      4.189|     0.627|        NA|
Area in Nozzle Wall        A2 |      1.055|     0.956|        NA|
Area in Inward Nozzle      A3 |      0.000|     0.000|        NA|
Area in Welds     A41+A42+A43 |      0.802|     0.802|        NA|
Area in Element            A5 |      7.423|     7.423|        NA|
TOTAL AREA AVAILABLE     Atot |     13.469|     9.807|        NA|
```

The External 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:              90.7578    10.0000  mm.
Based on given Pad Diameter:              200.0000     0.2503  mm.
```

```
 Based on Shell or Nozzle Thickness:       91.6863     6.6675  mm.
```

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(81.565*6.2213*1+2*3.6675*6.2213*1(1-0.86))
  = 2.570 cm²
```

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 )
  = 81.565( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 3.668
     ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.855 )
  = 0.627 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 3.67 - 0.47 ) * 0.855
  = 0.956 cm²
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 0.86 + (0.0 ) * 0.86 + 0.0² * 1.0
  = 0.802 cm²
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 163.13 - 88.9 ) * 10.0 * 1.0
  = 7.423 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures       ta = 3.4726 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 4.7961 mm.
 Wall Thickness                tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.4524 mm.
 Wall Thickness                tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.4726, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 6.6675 mm. --> OK

Weld Size Calculations, Description: K9A (3in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      3.6675  mm.
```

```
Intermediate Calc. for pad/shell Welds   TminPad      7.0000  mm.
```

Results Per UW-16.1:

```
                         Required Thickness    Actual Thickness
Nozzle Weld             2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
Pad Weld                3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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, (2.5703 - 0.6269 + 2 * 3.6675 * 0.855 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 27.47 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.9561 + 7.423 + 0.8016 - 0.0 * 0.86 ) * 138
  = 126.59 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.9561 + 0.0 + 0.8491 + ( 0.439 ) ) * 138
  = 30.94 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.9561 + 0.0 + 0.8016 + 7.423 + ( 0.439 ) ) * 138
  = 132.64 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 88.9 * 10.0 * 0.49 * 118
  = 81. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 200.0 * 8.0 * 0.49 * 138
  = 170. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 42.6162) * ( 6.6675 - 3.0 ) * 0.7 * 118
  = 41. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 88.9 * 10.0 * 0.74 * 138
  = 142. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 88.9 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 100. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 170 + 41 ) = 210 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 81 + 142 + 100 + 0 ) = 323 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 170 + 100 + 0 ) = 270 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 210 kN , must exceed W = 27 kN  or W1 = 126 kN
 Path 2-2 = 322 kN , must exceed W = 27 kN  or W2 = 30 kN
 Path 3-3 = 269 kN , must exceed W = 27 kN  or W3 = 132 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    8   bars

 Nozzle is O.K. for the External Pressure            1   bars
```

The Drop for this Nozzle is : 79.5232 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 397.2889 mm.

Input, Nozzle Desc: K10A (2in) **From: 20**

```
Pressure for Reinforcement Calculations          P       4.100  bars
Temperature for Internal Pressure             Temp         234  °C
Design External Pressure                      Pext        1.03  bars
Temperature for External Pressure           Tempex         100  °C

Shell Material                                        SA-516 70
Shell Allowable Stress at Temperature           Sv      137.90  N./mm²
Shell Allowable Stress At Ambient              Sva      137.90  N./mm²

Inside Diameter of Cylindrical Shell             D     1200.00  mm.
Design Length of Section                         L   3699.9998  mm.
Shell Finished (Minimum) Thickness               t     10.0000  mm.
Shell Internal Corrosion Allowance               c      3.0000  mm.
Shell External Corrosion Allowance              co      0.0000  mm.

Distance from Cylinder/Cone Centerline          L1    222.0000  mm.

Distance from Bottom/Left Tangent                       450.00  mm.

User Entered Minimum Design Metal Temperature             5.00  °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                 SA-105
Material UNS Number                                     K03504
Material Specification/Type                           Forgings
Allowable Stress at Temperature                 Sn      136.43  N./mm²
Allowable Stress At Ambient                    Sna      137.90  N./mm²

Diameter Basis (for tr calc only)                           ID
Layout Angle                                            -21.34  deg
Diameter                                                2.0000  in.

Size and Thickness Basis                                 Actual
Actual Thickness                                tn     16.6000  mm.

Flange Material                                          SA-105
Flange Type                                      Long Weld Neck

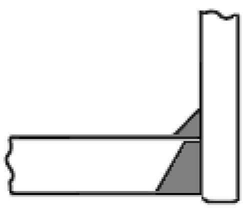
Corrosion Allowance                            can      3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1        1.00
Joint Efficiency of Nozzle Neck                 En        1.00

Outside Projection                              ho    150.0000  mm.
Weld leg size between Nozzle and Pad/Shell      Wo     10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv     10.0000  mm.
Inside Projection                                h      0.0000  mm.
Weld leg size, Inside Element to Shell          Wi      0.0000  mm.

Flange Class                                          300
Flange Grade                                          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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K10A (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.000  in.
Actual Thickness Used in Calculation                    0.654  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3430 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    122.1596   mm.
Parallel to Vessel Wall, opening length              d     61.0798   mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000   mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |     Design|  External|      Mapnc|
---------------------------------------------------------------
```

```
Area Required              Ar |      0.551|      1.909|          NA|
Area in Shell              A1 |      3.709|      0.473|          NA|
Area in Nozzle Wall        A2 |      4.952|      4.858|          NA|
Area in Inward Nozzle      A3 |      0.000|      0.000|          NA|
Area in Welds     A41+A42+A43 |      0.989|      0.989|          NA|
Area in Element            A5 |      0.000|      0.000|          NA|
TOTAL AREA AVAILABLE     Atot |      9.651|      6.321|          NA|
```

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  68.42   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(61.0798*6.2213*1+2*13.6*6.2213*1(1-0.99))
  = 1.909 cm²
```

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 )
  = 61.08( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 13.6
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.473 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 17.5 )( 13.6 - 0.34 ) 0.9894/sin( 70.9 )
  = 4.858 cm²
```

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A               -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
Min Metal Temp. w/o impact per UG-20(f)                     -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)       -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)        -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

<u>Weld Size Calculations, Description: K10A (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds    Tmin       7.0000   mm.
```

Results Per UW-16.1:

```
                           Required Thickness    Actual Thickness
Nozzle Weld               4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.909 - 0.4734 + 2 * 13.6 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 22.68 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.858 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 80.63 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.858 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 106.60 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.858 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 106.60 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 90.3293 * 10.0 * 0.49 * 136
  = 95. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 37.8523) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 154. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 90.3293 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 101. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 95 + 154 ) = 249 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 95 + 0 + 101 + 0 ) = 196 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 95 + 101 + 0 ) = 196 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 249 kN , must exceed W = 22 kN  or W1 = 80 kN
 Path 2-2 = 196 kN , must exceed W = 22 kN  or W2 = 106 kN
 Path 3-3 = 196 kN , must exceed W = 22 kN  or W3 = 106 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1  bars
```

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

Reinforcement CALCULATION, Description: K10A (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation            2.000  in.
 Actual Thickness Used in Calculation                  0.654  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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3430 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)          Dl    113.6000  mm.
 Parallel to Vessel Wall, opening length            d     56.8000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

```
AREA AVAILABLE, A1 to A5      |    Design|  External|      Mapnc|
--------------------------------------------------------------
Area Required              Ar |     1.025|     1.776|         NA|
Area in Shell              A1 |     2.941|     0.440|         NA|
Area in Nozzle Wall        A2 |     4.680|     4.591|         NA|
Area in Inward Nozzle      A3 |     0.000|     0.000|         NA|
Area in Welds     A41+A42+A43 |     0.989|     0.989|         NA|
Area in Element            A5 |     0.000|     0.000|         NA|
TOTAL AREA AVAILABLE     Atot |     8.610|     6.020|         NA|
```

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(56.8*6.2213*1+2*13.6*6.2213*1(1-0.99))
  = 1.776 cm²
```

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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 13.6
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.440 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 13.6 - 0.34 ) 0.9894
  = 4.591 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 3.3430 mm.
Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 4.7961 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 4.7961 mm.
Wall Thickness, shell/head, external pressure     trb2 = 3.4524 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                     tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.343, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Weld Size Calculations, Description: K10A (2in)

```
 Intermediate Calc. for nozzle/shell Welds    Tmin       7.0000   mm.
```

Results Per UW-16.1:

```
                           Required Thickness    Actual Thickness
 Nozzle Weld             4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.7758 - 0.4401 + 2 * 13.6 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 21.31 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.5906 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 76.94 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.5906 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 102.92 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.5906 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 102.92 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 136
  = 88. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:

```
 = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
 = ( 3.1416/2.0 ) * 84.0 * ( 10.0 - 3.0 ) * 0.74 * 138
 = 94. kN
```

Strength of Failure Paths:

```
 PATH11 = ( SONW + SNW ) = ( 88 + 144 ) = 232 kN
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
        = ( 88 + 0 + 94 + 0 ) = 182 kN
 PATH33 = ( Sonw + Tngw + Sinw )
        = ( 88 + 94 + 0 ) = 182 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 231 kN , must exceed W = 21 kN  or W1 = 76 kN
Path 2-2 = 182 kN , must exceed W = 21 kN  or W2 = 102 kN
Path 3-3 = 182 kN , must exceed W = 21 kN  or W3 = 102 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 18.6204 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 179.3703 mm.

Input, Nozzle Desc: K10B (2in) **From: 20**

```
Pressure for Reinforcement Calculations          P        4.100   bars
Temperature for Internal Pressure             Temp          234   °C
Design External Pressure                      Pext         1.03   bars
Temperature for External Pressure           Tempex          100   °C

Shell Material                                         SA-516 70
Shell Allowable Stress at Temperature           Sv       137.90   N./mm²
Shell Allowable Stress At Ambient              Sva       137.90   N./mm²

Inside Diameter of Cylindrical Shell             D      1200.00   mm.
Design Length of Section                         L    3699.9998   mm.
Shell Finished (Minimum) Thickness               t      10.0000   mm.
Shell Internal Corrosion Allowance               c       3.0000   mm.
Shell External Corrosion Allowance              co       0.0000   mm.

Distance from Cylinder/Cone Centerline          L1     478.0000   mm.

Distance from Bottom/Left Tangent                        450.00   mm.

User Entered Minimum Design Metal Temperature              5.00   °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                  SA-105
Material UNS Number                                     K03504
Material Specification/Type                           Forgings
Allowable Stress at Temperature                 Sn       136.43   N./mm²
Allowable Stress At Ambient                    Sna       137.90   N./mm²

Diameter Basis (for tr calc only)                            ID
Layout Angle                                             -51.59   deg
Diameter                                                 2.0000   in.

Size and Thickness Basis                                  Actual
Actual Thickness                                tn      16.6000   mm.

Flange Material                                           SA-105
Flange Type                                       Long Weld Neck

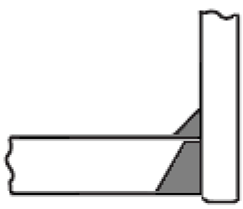
Corrosion Allowance                            can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     300.0000   mm.
Weld leg size between Nozzle and Pad/Shell      Wo      10.0000   mm.
Groove weld depth between Nozzle and Vessel Wgnv        10.0000   mm.
Inside Projection                                h       0.0000   mm.
Weld leg size, Inside Element to Shell          Wi       0.0000   mm.

Flange Class                                           300
Flange Grade                                           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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K10B (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation             2.000  in.
Actual Thickness Used in Calculation                   0.654  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4569 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    185.8421  mm.
Parallel to Vessel Wall, opening length              d     92.9211  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |     Design|  External|      Mapnc|
---------------------------------------------------------------
```

```
Area Required              Ar |     0.837|     2.899|         NA|
Area in Shell              A1 |     5.652|     0.721|         NA|
Area in Nozzle Wall        A2 |     7.038|     6.844|         NA|
Area in Inward Nozzle      A3 |     0.000|     0.000|         NA|
Area in Welds     A41+A42+A43 |     0.989|     0.989|         NA|
Area in Element            A5 |     0.000|     0.000|         NA|
TOTAL AREA AVAILABLE     Atot |    13.679|     8.555|         NA|
```

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  37.68   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(92.9211*6.2213*1+2*13.6*6.2213*1(1-0.99))
  = 2.899 cm²
```

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 )
  = 92.921( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 13.6
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.721 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 17.5 )( 13.6 - 0.46 ) 0.9894/sin( 41.7 )
  = 6.844 cm²
```

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A             -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
Min Metal Temp. w/o impact per UG-20(f)                   -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

Weld Size Calculations, Description: K10B (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
Nozzle Weld             4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (2.8994 - 0.7213 + 2 * 13.6 * 0.9894 *
     (1.0 * 7.0 - 6.2213 ) )138)
  = 32.92 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 6.8443 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 108.02 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 6.8443 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 133.99 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 6.8443 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 133.99 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 137.4185 * 10.0 * 0.49 * 136
  = 144. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 57.5849) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 235. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 137.4185 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 154. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 144 + 235 ) = 379 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 144 + 0 + 154 + 0 ) = 298 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 144 + 154 + 0 ) = 298 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 379 kN , must exceed W = 32 kN  or W1 = 108 kN
 Path 2-2 = 298 kN , must exceed W = 32 kN  or W2 = 133 kN
 Path 3-3 = 298 kN , must exceed W = 32 kN  or W3 = 133 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

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

Reinforcement CALCULATION, Description: K10B (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation            2.000  in.
 Actual Thickness Used in Calculation                  0.654  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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4569 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)           Dl    113.6000  mm.
 Parallel to Vessel Wall, opening length             d     56.8000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.025	1.776	NA
Area in Shell	A1	2.941	0.440	NA
Area in Nozzle Wall	A2	4.680	4.551	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.989	0.989	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	8.610	5.981	NA

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(56.8*6.2213*1+2*13.6*6.2213*1(1-0.99))
  = 1.776 cm²
```

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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 13.6
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.440 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 13.6 - 0.46 ) 0.9894
  = 4.551 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures       ta = 3.4569 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 4.7961 mm.
 Wall Thickness                    tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.4524 mm.
 Wall Thickness                    tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( 3.4569, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

<u>Weld Size Calculations, Description: K10B (2in)</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000   mm.
```

Results Per UW-16.1:

```
                         Required Thickness    Actual Thickness
 Nozzle Weld            4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.7758 - 0.4401 + 2 * 13.6 * 0.9894 *
     (1.0 * 7.0 - 6.2213 ) )138)
  = 21.31 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.5512 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 76.40 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.5512 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 102.37 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.5512 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 102.37 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 136
  = 88. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 94. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 88 + 144 ) = 232 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 88 + 0 + 94 + 0 ) = 182 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 88 + 94 + 0 ) = 182 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 231 kN , must exceed W = 21 kN  or W1 = 76 kN
 Path 2-2 = 182 kN , must exceed W = 21 kN  or W2 = 102 kN
 Path 3-3 = 182 kN , must exceed W = 21 kN  or W3 = 102 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 63.3188 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 379.6345 mm.

Input, Nozzle Desc: K11A (2in) From: 20

```
Pressure for Reinforcement Calculations          P        4.100  bars
Temperature for Internal Pressure             Temp          234  °C
Design External Pressure                      Pext         1.03  bars
Temperature for External Pressure           Tempex          100  °C

Shell Material                                          SA-516 70
Shell Allowable Stress at Temperature           Sv       137.90  N./mm²
Shell Allowable Stress At Ambient              Sva       137.90  N./mm²

Inside Diameter of Cylindrical Shell             D      1200.00  mm.
Design Length of Section                         L    3699.9998  mm.
Shell Finished (Minimum) Thickness               t      10.0000  mm.
Shell Internal Corrosion Allowance               c       3.0000  mm.
Shell External Corrosion Allowance              co       0.0000  mm.

Distance from Cylinder/Cone Centerline          L1     222.0000  mm.

Distance from Bottom/Left Tangent                        600.00  mm.

User Entered Minimum Design Metal Temperature              5.00  °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                   SA-105
Material UNS Number                                      K03504
Material Specification/Type                            Forgings
Allowable Stress at Temperature                 Sn       136.43  N./mm²
Allowable Stress At Ambient                    Sna       137.90  N./mm²

Diameter Basis (for tr calc only)                            ID
Layout Angle                                              21.34  deg
Diameter                                                 2.0000  in.

Size and Thickness Basis                                   Actual
Actual Thickness                                tn      16.6000  mm.

Flange Material                                            SA-105
Flange Type                                        Long Weld Neck

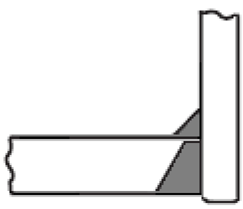
Corrosion Allowance                            can       3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     150.0000  mm.
Weld leg size between Nozzle and Pad/Shell      Wo      10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv        10.0000  mm.
Inside Projection                                h       0.0000  mm.
Weld leg size, Inside Element to Shell          Wi       0.0000  mm.

Flange Class                                            300
Flange Grade                                            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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K11A (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation             2.000  in.
Actual Thickness Used in Calculation                   0.654  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
 = (4.1*603.0)/(138*1.0-0.6*4.1)
 = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
 = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
 = (4.1*28.4)/(136*1.0-0.6*4.1)
 = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3430 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    122.1596   mm.
Parallel to Vessel Wall, opening length              d     61.0798   mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000   mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |     Design|  External|      Mapnc|
---------------------------------------------------------------
```

```
Area Required               Ar |      0.551|      1.909|         NA|
Area in Shell               A1 |      3.709|      0.473|         NA|
Area in Nozzle Wall         A2 |      4.952|      4.858|         NA|
Area in Inward Nozzle       A3 |      0.000|      0.000|         NA|
Area in Welds     A41+A42+A43 |      0.989|      0.989|         NA|
Area in Element             A5 |      0.000|      0.000|         NA|
TOTAL AREA AVAILABLE      Atot |      9.651|      6.321|         NA|
```

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  68.42   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(61.0798*6.2213*1+2*13.6*6.2213*1(1-0.99))
  = 1.909 cm²
```

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 )
  = 61.08( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 13.6
     ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.473 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 17.5 )( 13.6 - 0.34 ) 0.9894/sin( 70.9 )
  = 4.858 cm²
```

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

Weld Size Calculations, Description: K11A (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin       7.0000  mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
Nozzle Weld             4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.909 - 0.4734 + 2 * 13.6 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 22.68 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.858 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 80.63 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.858 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 106.60 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.858 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 106.60 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 90.3293 * 10.0 * 0.49 * 136
  = 95. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 37.8523) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 154. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 90.3293 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 101. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 95 + 154 ) = 249 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 95 + 0 + 101 + 0 ) = 196 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 95 + 101 + 0 ) = 196 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 249 kN , must exceed W = 22 kN  or W1 = 80 kN
 Path 2-2 = 196 kN , must exceed W = 22 kN  or W2 = 106 kN
 Path 3-3 = 196 kN , must exceed W = 22 kN  or W3 = 106 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1  bars
```

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

Reinforcement CALCULATION, Description: K11A (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation            2.000  in.
 Actual Thickness Used in Calculation                  0.654  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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3430 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    113.6000  mm.
 Parallel to Vessel Wall, opening length              d     56.8000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |    Design|  External|     Mapnc|
--------------------------------------------------------------
Area Required             Ar |     1.025|     1.776|        NA|
Area in Shell             A1 |     2.941|     0.440|        NA|
Area in Nozzle Wall       A2 |     4.680|     4.591|        NA|
Area in Inward Nozzle     A3 |     0.000|     0.000|        NA|
Area in Welds     A41+A42+A43 |     0.989|     0.989|        NA|
Area in Element           A5 |     0.000|     0.000|        NA|
TOTAL AREA AVAILABLE    Atot |     8.610|     6.020|        NA|
```

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(56.8*6.2213*1+2*13.6*6.2213*1(1-0.99))
  = 1.776 cm²
```

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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 13.6
   ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.440 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 13.6 - 0.34 ) 0.9894
  = 4.591 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures       ta = 3.3430 mm.
Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure      trb1 = 4.7961 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 4.7961 mm.
Wall Thickness, shell/head, external pressure      trb2 = 3.4524 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( 3.343, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Weld Size Calculations, Description: K11A (2in)

```
 Intermediate Calc. for nozzle/shell Welds    Tmin       7.0000   mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
 Nozzle Weld            4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.7758 - 0.4401 + 2 * 13.6 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 21.31 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.5906 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 76.94 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.5906 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 102.92 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.5906 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 102.92 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 136
  = 88. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 94. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 88 + 144 ) = 232 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 88 + 0 + 94 + 0 ) = 182 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 88 + 94 + 0 ) = 182 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 231 kN , must exceed W = 21 kN  or W1 = 76 kN
 Path 2-2 = 182 kN , must exceed W = 21 kN  or W2 = 102 kN
 Path 3-3 = 182 kN , must exceed W = 21 kN  or W3 = 102 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 18.6204 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 179.3703 mm.

Input, Nozzle Desc: K11B (2in) From: 20

```
Pressure for Reinforcement Calculations         P        4.100   bars
Temperature for Internal Pressure            Temp          234   °C
Design External Pressure                     Pext         1.03   bars
Temperature for External Pressure          Tempex          100   °C

Shell Material                                         SA-516 70
Shell Allowable Stress at Temperature          Sv       137.90   N./mm²
Shell Allowable Stress At Ambient             Sva       137.90   N./mm²

Inside Diameter of Cylindrical Shell            D      1200.00   mm.
Design Length of Section                        L    3699.9998   mm.
Shell Finished (Minimum) Thickness              t      10.0000   mm.
Shell Internal Corrosion Allowance              c       3.0000   mm.
Shell External Corrosion Allowance             co       0.0000   mm.
```

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

```
Physical Maximum for Diameter Limit          Dmax      90.0000   mm.

Distance from Cylinder/Cone Centerline         L1     478.0000   mm.

Distance from Bottom/Left Tangent                       600.00   mm.

User Entered Minimum Design Metal Temperature             5.00   °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                SA-105
Material UNS Number                                     K03504
Material Specification/Type                           Forgings
Allowable Stress at Temperature                Sn       136.43   N./mm²
Allowable Stress At Ambient                   Sna       137.90   N./mm²

Diameter Basis (for tr calc only)                           ID
Layout Angle                                             51.59   deg
Diameter                                                2.0000   in.

Size and Thickness Basis                                Actual
Actual Thickness                               tn      16.6000   mm.

Flange Material                                         SA-105
Flange Type                                    Long Weld Neck

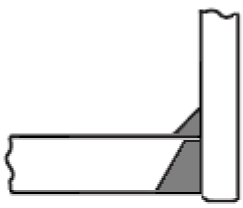
Corrosion Allowance                           can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle       E1         1.00
Joint Efficiency of Nozzle Neck                En         1.00

Outside Projection                             ho     300.0000   mm.
Weld leg size between Nozzle and Pad/Shell     Wo      10.0000   mm.
Groove weld depth between Nozzle and Vessel Wgnv      10.0000   mm.
Inside Projection                               h       0.0000   mm.
Weld leg size, Inside Element to Shell         Wi       0.0000   mm.
```

```
Flange Class                                        300
Flange Grade                                        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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K11B (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation            2.000  in.
Actual Thickness Used in Calculation                  0.654  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4569 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    147.2341   mm.
Parallel to Vessel Wall, opening length              d     73.6170   mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000   mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.837	2.899	NA
Area in Shell	A1	3.296	0.421	NA
Area in Nozzle Wall	A2	7.038	6.844	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.989	0.989	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.324	8.254	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  37.68   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(92.9211*6.2213*1+2*13.6*6.2213*1(1-0.99))
  = 2.899 cm²
```

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 )
  = 54.313( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 13.6
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.421 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 17.5 )( 13.6 - 0.46 ) 0.9894/sin( 41.7 )
  = 6.844 cm²
```

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

```
Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

Weld Size Calculations, Description: K11B (2in)

```
Intermediate Calc. for nozzle/shell Welds    Tmin       7.0000   mm.
```

Results Per UW-16.1:

```
                          Required Thickness     Actual Thickness
Nozzle Weld             4.9000 = 0.7 * tmin.   7.0700 = 0.7 * Wo mm.
```

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, (2.8994 - 0.4207 + 2 * 13.6 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 37.07 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 6.8443 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 108.02 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 6.8443 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 133.99 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 6.8443 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 133.99 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 137.4185 * 10.0 * 0.49 * 136
  = 144. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 57.5849) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 235. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 137.4185 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 154. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 144 + 235 ) = 379 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 144 + 0 + 154 + 0 ) = 298 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 144 + 154 + 0 ) = 298 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 379 kN , must exceed W = 37 kN  or W1 = 108 kN
 Path 2-2 = 298 kN , must exceed W = 37 kN  or W2 = 133 kN
 Path 3-3 = 298 kN , must exceed W = 37 kN  or W3 = 133 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

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

Reinforcement CALCULATION, Description: K11B (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.654  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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4569 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    90.0000  mm.
 Parallel to Vessel Wall, opening length              d    45.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.025	1.776	NA
Area in Shell	A1	1.713	0.256	NA
Area in Nozzle Wall	A2	4.680	4.551	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.505	0.505	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.897	5.312	NA

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(56.8*6.2213*1+2*13.6*6.2213*1(1-0.99))
= 1.776 cm²
```

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 )
= 33.2( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 13.6
  ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
= 0.256 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 17.5 )( 13.6 - 0.46 ) 0.9894
= 4.551 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
= ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
= ( 10.0² - 0.49 ) * 0.9894 + ( 0.0² -0.0 ) * 0.9894
= 0.505 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures       ta = 3.4569 mm.
Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure      trb1 = 4.7961 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 4.7961 mm.
Wall Thickness, shell/head, external pressure      trb2 = 3.4524 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
= min[ tb3, max( tb1,tb2) ]
= min[ 7.8, max( 4.7961, 4.5 ) ]
= 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.4569, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

<u>Weld Size Calculations, Description: K11B (2in)</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
 Nozzle Weld            4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.7758 - 0.2563 + 2 * 13.6 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 23.84 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.5512 + 0.0 + 0.5046 - 0.0 * 0.99 ) * 138
  = 69.71 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.5512 + 0.0 + 0.5046 + ( 1.8838 ) ) * 138
  = 95.69 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.5512 + 0.0 + 0.5046 + 0.0 + ( 1.8838 ) ) * 138
  = 95.69 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 136
  = 88. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 94. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 88 + 144 ) = 232 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 88 + 0 + 94 + 0 ) = 182 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 88 + 94 + 0 ) = 182 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 231 kN , must exceed W = 23 kN  or W1 = 69 kN
 Path 2-2 = 182 kN , must exceed W = 23 kN  or W2 = 95 kN
 Path 3-3 = 182 kN , must exceed W = 23 kN  or W3 = 95 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 63.3188 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 379.6345 mm.

Input, Nozzle Desc: K7A (3in) **From: 20**

```
Pressure for Reinforcement Calculations          P        4.100  bars
Temperature for Internal Pressure             Temp          234  °C
Design External Pressure                      Pext         1.03  bars
Temperature for External Pressure           Tempex          100  °C

Shell Material                                          SA-516 70
Shell Allowable Stress at Temperature           Sv       137.90  N./mm²
Shell Allowable Stress At Ambient              Sva       137.90  N./mm²

Inside Diameter of Cylindrical Shell             D      1200.00  mm.
Design Length of Section                         L    3699.9998  mm.
Shell Finished (Minimum) Thickness               t      10.0000  mm.
Shell Internal Corrosion Allowance               c       3.0000  mm.
Shell External Corrosion Allowance              co       0.0000  mm.

Distance from Cylinder/Cone Centerline          L1      50.0000  mm.

Distance from Bottom/Left Tangent                       1250.00  mm.

User Entered Minimum Design Metal Temperature              5.00  °C
```

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       117.90  N./mm²
Allowable Stress At Ambient                    Sna       117.90  N./mm²

Diameter Basis (for tr calc only)                            ID
Layout Angle                                               4.70  deg
Diameter                                                 3.0000  in.

Size and Thickness Basis                                  Minimum
Nominal Thickness                               tn        80

Flange Material                                           SA-105
Flange Type                                    Weld Neck Flange

Corrosion Allowance                            can       3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     200.0000  mm.
Weld leg size between Nozzle and Pad/Shell      Wo      10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv        10.0000  mm.
Inside Projection                                h       0.0000  mm.
Weld leg size, Inside Element to Shell          Wi       0.0000  mm.

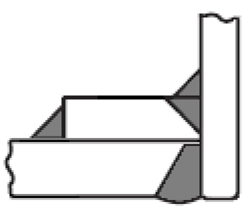
Pad Material                                            SA-516 70
Pad Allowable Stress at Temperature             Sp       137.90  N./mm²
Pad Allowable Stress At Ambient                Spa       137.90  N./mm²
```

```
Diameter of Pad along vessel surface          Dp      200.0000  mm.
Thickness of Pad                              te       10.0000  mm.
Weld leg size between Pad and Shell           Wp        8.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn       10.0000  mm.
Reinforcing Pad Width                                   55.5500  mm.

Flange Class                                          300
Flange Grade                                          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: K7A (3in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          2.975   in.
Actual Thickness Used in Calculation                0.263   in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*40.78)/(118*1.0-0.6*4.1)
  = 0.1421 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3989 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    163.8150  mm.
Parallel to Vessel Wall, opening length              d     81.9075  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  mm.
```

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

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr4]:

```
  = min( 1, Sp/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.855, 1.0 )
  = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.490	2.581	NA
Area in Shell	A1	4.207	0.630	NA
Area in Nozzle Wall	A2	1.055	0.978	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.802	0.802	NA
Area in Element	A5	7.454	7.454	NA
TOTAL AREA AVAILABLE	Atot	13.518	9.864	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  84.76  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:	90.6140	10.0000	mm.
Based on given Pad Diameter:	200.0000	0.2299	mm.
Based on Shell or Nozzle Thickness:	91.8440	6.6675	mm.

Area Required [A]:

```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(81.9075*6.2213*1+2*3.6675*6.2213*1(1-0.86))
```

```
  = 2.581 cm²
```

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 )
  = 81.908( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 3.668
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.855 )
  = 0.630 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2/sin( alpha3 )
  = ( 2 * 17.5 ) * ( 3.67 - 0.4 ) * 0.855/sin( 88.6 )
  = 0.978 cm²
```

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 - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 0.86 + (0.0 ) * 0.86 + 0.0² * 1.0
  = 0.802 cm²
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 163.815 - 89.2733 ) * 10.0 * 1.0
  = 7.454 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:B, Curve:A)

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C

Gov. MDMT of the Nozzle                                :  -104 °C
Gov. MDMT of the Reinforcement Pad                     :  -104 °C
Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

<u>Weld Size Calculations, Description: K7A (3in)</u>

```
Intermediate Calc. for nozzle/shell Welds    Tmin       3.6675  mm.
Intermediate Calc. for pad/shell Welds    TminPad       7.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
Pad Weld             3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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, (2.5809 - 0.6295 + 2 * 3.6675 * 0.855 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 27.58 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.9784 + 7.4542 + 0.8016 - 0.0 * 0.86 ) * 138
  = 127.33 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.9784 + 0.0 + 0.8491 + ( 0.439 ) ) * 138
  = 31.25 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.9784 + 0.0 + 0.8016 + 7.4542 + ( 0.439 ) ) * 138
  = 133.38 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 89.2733 * 10.0 * 0.49 * 118
  = 81. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 200.0 * 8.0 * 0.49 * 138
  = 170. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 42.7952) * ( 6.6675 - 3.0 ) * 0.7 * 118
  = 41. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 89.2733 * 10.0 * 0.74 * 138
  = 143. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 89.2733 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 100. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 170 + 41 ) = 211 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 81 + 143 + 100 + 0 ) = 324 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 170 + 100 + 0 ) = 270 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 210 kN , must exceed W = 27 kN  or W1 = 127 kN
 Path 2-2 = 324 kN , must exceed W = 27 kN  or W2 = 31 kN
 Path 3-3 = 269 kN , must exceed W = 27 kN  or W3 = 133 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case    8  bars
```

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

```
Nozzle is O.K. for the External Pressure          1  bars
```

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

Reinforcement CALCULATION, Description: K7A (3in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          2.975  in.
Actual Thickness Used in Calculation                0.263  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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*40.78)/(118*1.0-0.6*4.1)
  = 0.1421 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3989 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    163.1300  mm.
Parallel to Vessel Wall, opening length              d     81.5650  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  mm.
```

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

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |     Design|  External|     Mapnc|
---------------------------------------------------------------
Area Required              Ar |      1.484|     2.570|        NA|
Area in Shell              A1 |      4.189|     0.627|        NA|
Area in Nozzle Wall        A2 |      1.055|     0.978|        NA|
Area in Inward Nozzle      A3 |      0.000|     0.000|        NA|
Area in Welds     A41+A42+A43 |      0.802|     0.802|        NA|
Area in Element            A5 |      7.423|     7.423|        NA|
TOTAL AREA AVAILABLE     Atot |     13.469|     9.830|        NA|
```

The External 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:             90.5371    10.0000   mm.
Based on given Pad Diameter:             200.0000     0.2206   mm.
```

```
 Based on Shell or Nozzle Thickness:       91.3554     6.6675  mm.
```

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(81.565*6.2213*1+2*3.6675*6.2213*1(1-0.86))
  = 2.570 cm²
```

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 )
  = 81.565( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 3.668
     ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.855 )
  = 0.627 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 3.67 - 0.4 ) * 0.855
  = 0.978 cm²
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 0.86 + (0.0 ) * 0.86 + 0.0² * 1.0
  = 0.802 cm²
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 163.13 - 88.9 ) * 10.0 * 1.0
  = 7.423 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures       ta = 3.3989 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 4.7961 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.4524 mm.
 Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.3989, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 6.6675 mm. --> OK

Weld Size Calculations, Description: K7A (3in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      3.6675  mm.
```

```
 Intermediate Calc. for pad/shell Welds   TminPad      7.0000  mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
 Nozzle Weld             2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
 Pad Weld                3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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, (2.5703 - 0.6269 + 2 * 3.6675 * 0.855 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 27.47 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.9781 + 7.423 + 0.8016 - 0.0 * 0.86 ) * 138
  = 126.89 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.9781 + 0.0 + 0.8491 + ( 0.439 ) ) * 138
  = 31.25 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.9781 + 0.0 + 0.8016 + 7.423 + ( 0.439 ) ) * 138
  = 132.95 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 88.9 * 10.0 * 0.49 * 118
  = 81. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 200.0 * 8.0 * 0.49 * 138
  = 170. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 42.6162) * ( 6.6675 - 3.0 ) * 0.7 * 118
  = 41. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 88.9 * 10.0 * 0.74 * 138
  = 142. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 88.9 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 100. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 170 + 41 ) = 210 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 81 + 142 + 100 + 0 ) = 323 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 170 + 100 + 0 ) = 270 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 210 kN , must exceed W = 27 kN  or W1 = 126 kN
 Path 2-2 = 322 kN , must exceed W = 27 kN  or W2 = 31 kN
 Path 3-3 = 269 kN , must exceed W = 27 kN  or W3 = 132 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    8   bars
```

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

```
 Nozzle is O.K. for the External Pressure            1   bars
```

The Drop for this Nozzle is : 5.3937 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 215.4280 mm.

Input, Nozzle Desc: K7B (3in) From: 20

```
Pressure for Reinforcement Calculations          P        4.100   bars
Temperature for Internal Pressure             Temp          234   °C
Design External Pressure                      Pext         1.03   bars
Temperature for External Pressure           Tempex          100   °C

Shell Material                                         SA-516 70
Shell Allowable Stress at Temperature           Sv       137.90   N./mm²
Shell Allowable Stress At Ambient              Sva       137.90   N./mm²

Inside Diameter of Cylindrical Shell             D      1200.00   mm.
Design Length of Section                         L    3699.9998   mm.
Shell Finished (Minimum) Thickness               t      10.0000   mm.
Shell Internal Corrosion Allowance               c       3.0000   mm.
Shell External Corrosion Allowance              co       0.0000   mm.

Distance from Cylinder/Cone Centerline          L1     350.0000   mm.

Distance from Bottom/Left Tangent                       1250.00   mm.

User Entered Minimum Design Metal Temperature              5.00   °C
```

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       117.90   N./mm²
Allowable Stress At Ambient                    Sna       117.90   N./mm²

Diameter Basis (for tr calc only)                            ID
Layout Angle                                             -35.01   deg
Diameter                                                 3.0000   in.

Size and Thickness Basis                                  Minimum
Nominal Thickness                               tn        80

Flange Material                                           SA-105
Flange Type                                     Weld Neck Flange

Corrosion Allowance                            can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     250.0000   mm.
Weld leg size between Nozzle and Pad/Shell      Wo      10.0000   mm.
Groove weld depth between Nozzle and Vessel   Wgnv      10.0000   mm.
Inside Projection                                h       0.0000   mm.
Weld leg size, Inside Element to Shell          Wi       0.0000   mm.

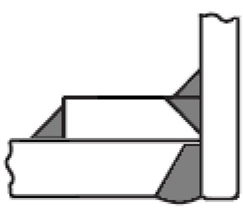
Pad Material                                           SA-516 70
Pad Allowable Stress at Temperature             Sp       137.90   N./mm²
Pad Allowable Stress At Ambient                Spa       137.90   N./mm²
```

```
Diameter of Pad along vessel surface          Dp     200.0000  mm.
Thickness of Pad                              te      10.0000  mm.
Weld leg size between Pad and Shell           Wp       8.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn      10.0000  mm.
Reinforcing Pad Width                                 55.5500  mm.

Flange Class                                         300
Flange Grade                                         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: K7B (3in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          2.975   in.
Actual Thickness Used in Calculation                0.263   in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*40.78)/(118*1.0-0.6*4.1)
  = 0.1421 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4399 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    200.3822  mm.
Parallel to Vessel Wall, opening length              d    100.1911  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr4]:

```
  = min( 1, Sp/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.855, 1.0 )
  = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.819	3.150	NA
Area in Shell	A1	5.158	0.772	NA
Area in Nozzle Wall	A2	1.232	1.128	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.802	0.802	NA
Area in Element	A5	9.118	9.118	NA
TOTAL AREA AVAILABLE	Atot	16.310	11.820	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                 54.50   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:               93.3801    10.0000   mm.
Based on given Pad Diameter:               200.0000     0.4913   mm.
Based on Shell or Nozzle Thickness:        115.9204     6.6675   mm.
```

Area Required [A]:

```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(100.1911*6.2213*1+2*3.6675*6.2213*1(1-0.86))
  = 3.150 cm²
```

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 )
  = 100.191( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 3.668
     ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.855 )
  = 0.772 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2/sin( alpha3 )
  = ( 2 * 17.5 ) * ( 3.67 - 0.44 ) * 0.855/sin( 58.9 )
  = 1.128 cm²
```

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 - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 0.86 + (0.0 ) * 0.86 + 0.0² * 1.0
  = 0.802 cm²
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 200.3822 - 109.2011 ) * 10.0 * 1.0
  = 9.118 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:B, Curve:A)

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A            -8 °C
 Min Metal Temp. at Required thickness (UCS 66.1)        -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                  -29 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B           -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)        -104 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B           -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)        -104 °C
```

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C

Gov. MDMT of the Nozzle                              :    -104 °C
Gov. MDMT of the Reinforcement Pad                   :    -104 °C
Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

<u>Weld Size Calculations, Description: K7B (3in)</u>

```
Intermediate Calc. for nozzle/shell Welds    Tmin       3.6675  mm.
Intermediate Calc. for pad/shell Welds    TminPad       7.0000  mm.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
Nozzle Weld            2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
Pad Weld               3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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, (3.1497 - 0.7719 + 2 * 3.6675 * 0.855 *
   (1.0 * 7.0 - 6.2213 ) )138)
 = 33.46 kN
```

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

Weld Load [W1]:
```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 1.1282 + 9.1181 + 0.8016 - 0.0 * 0.86 ) * 138
 = 152.34 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.1282 + 0.0 + 0.8491 + ( 0.439 ) ) * 138
  = 33.32 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.1282 + 0.0 + 0.8016 + 9.1181 + ( 0.439 ) ) * 138
  = 158.39 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 109.2011 * 10.0 * 0.49 * 118
  = 99. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 200.0 * 8.0 * 0.49 * 138
  = 170. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 52.3481) * ( 6.6675 - 3.0 ) * 0.7 * 118
  = 50. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 109.2011 * 10.0 * 0.74 * 138
  = 175. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 109.2011 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 123. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 170 + 50 ) = 220 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 99 + 175 + 123 + 0 ) = 397 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 170 + 123 + 0 ) = 292 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 219 kN , must exceed W = 33 kN  or W1 = 152 kN
 Path 2-2 = 396 kN , must exceed W = 33 kN  or W2 = 33 kN
 Path 3-3 = 292 kN , must exceed W = 33 kN  or W3 = 158 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    8   bars
```

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

```
Nozzle is O.K. for the External Pressure          1  bars
```

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

Reinforcement CALCULATION, Description: K7B (3in)

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```
Actual Inside Diameter Used in Calculation             2.975  in.
Actual Thickness Used in Calculation                   0.263  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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*40.78)/(118*1.0-0.6*4.1)
  = 0.1421 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4399 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    163.1300  mm.
Parallel to Vessel Wall, opening length              d     81.5650  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  mm.
```

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

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.484	2.570	NA
Area in Shell	A1	4.189	0.627	NA
Area in Nozzle Wall	A2	1.055	0.966	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.802	0.802	NA
Area in Element	A5	7.423	7.423	NA
TOTAL AREA AVAILABLE	Atot	13.469	9.817	NA

The External 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:              90.6597    10.0000  mm.
Based on given Pad Diameter:              200.0000     0.2371  mm.
```

```
 Based on Shell or Nozzle Thickness:       91.5392     6.6675  mm.
```

Area Required [A]:

```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(81.565*6.2213*1+2*3.6675*6.2213*1(1-0.86))
  = 2.570 cm²
```

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 )
  = 81.565( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 3.668
     ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.855 )
  = 0.627 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 3.67 - 0.44 ) * 0.855
  = 0.966 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 0.86 + (0.0 ) * 0.86 + 0.0² * 1.0
  = 0.802 cm²
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 163.13 - 88.9 ) * 10.0 * 1.0
  = 7.423 cm²
```

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

```
 Wall Thickness for Internal/External pressures      ta = 3.4399 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 4.7961 mm.
 Wall Thickness                tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure     trb2 = 3.4524 mm.
 Wall Thickness                tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                     tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.4399, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 6.6675 mm. --> OK

Weld Size Calculations, Description: K7B (3in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      3.6675  mm.
```

```
Intermediate Calc. for pad/shell Welds   TminPad      7.0000  mm.
```

Results Per UW-16.1:

```
                         Required Thickness    Actual Thickness
Nozzle Weld             2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
Pad Weld                3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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, (2.5703 - 0.6269 + 2 * 3.6675 * 0.855 *
     (1.0 * 7.0 - 6.2213 ) )138)
  = 27.47 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.9659 + 7.423 + 0.8016 - 0.0 * 0.86 ) * 138
  = 126.73 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.9659 + 0.0 + 0.8491 + ( 0.439 ) ) * 138
  = 31.08 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.9659 + 0.0 + 0.8016 + 7.423 + ( 0.439 ) ) * 138
  = 132.78 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 88.9 * 10.0 * 0.49 * 118
  = 81. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 200.0 * 8.0 * 0.49 * 138
  = 170. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 42.6162) * ( 6.6675 - 3.0 ) * 0.7 * 118
  = 41. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 88.9 * 10.0 * 0.74 * 138
  = 142. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 88.9 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 100. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 170 + 41 ) = 210 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 81 + 142 + 100 + 0 ) = 323 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 170 + 100 + 0 ) = 270 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 210 kN , must exceed W = 27 kN  or W1 = 126 kN
 Path 2-2 = 322 kN , must exceed W = 27 kN  or W2 = 31 kN
 Path 3-3 = 269 kN , must exceed W = 27 kN  or W3 = 132 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    8   bars
```

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

```
 Nozzle is O.K. for the External Pressure            1   bars
```

The Drop for this Nozzle is : 35.2234 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 297.4835 mm.

Input, Nozzle Desc: N05 (2in) **From: 20**

```
Pressure for Reinforcement Calculations          P        4.100   bars
Temperature for Internal Pressure             Temp          234   °C
Design External Pressure                      Pext         1.03   bars
Temperature for External Pressure           Tempex          100   °C

Shell Material                                          SA-516 70
Shell Allowable Stress at Temperature           Sv       137.90   N./mm²
Shell Allowable Stress At Ambient              Sva       137.90   N./mm²

Inside Diameter of Cylindrical Shell             D      1200.00   mm.
Design Length of Section                         L    3699.9998   mm.
Shell Finished (Minimum) Thickness               t      10.0000   mm.
Shell Internal Corrosion Allowance               c       3.0000   mm.
Shell External Corrosion Allowance              co       0.0000   mm.

Distance from Bottom/Left Tangent                       1415.00   mm.

User Entered Minimum Design Metal Temperature              5.00   °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                   SA-105
Material UNS Number                                      K03504
Material Specification/Type                            Forgings
Allowable Stress at Temperature                 Sn       136.43   N./mm²
Allowable Stress At Ambient                    Sna       137.90   N./mm²

Diameter Basis (for tr calc only)                            ID
Layout Angle                                             270.00   deg
Diameter                                                 2.0000   in.

Size and Thickness Basis                                   Actual
Actual Thickness                                tn      15.8500   mm.

Flange Material                                            SA-105
Flange Type                                          Long Weld Neck

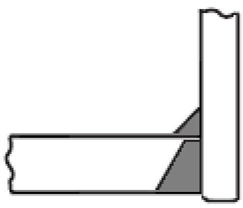
Corrosion Allowance                            can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     150.0000   mm.
Weld leg size between Nozzle and Pad/Shell      Wo      10.0000   mm.
Groove weld depth between Nozzle and Vessel Wgnv        10.0000   mm.
Inside Projection                                h       0.0000   mm.
Weld leg size, Inside Element to Shell          Wi       0.0000   mm.

Flange Class                                           150
Flange Grade                                           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: N05 (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.000  in.
Actual Thickness Used in Calculation                    0.624  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3393 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)             Dl    113.6000  mm.
Parallel to Vessel Wall, opening length               d     56.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad    Tlnp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
  = 0.989
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
```

```
  = 0.989
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.989, 1.0 )
  = 0.989
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.025	1.775	NA
Area in Shell	A1	2.942	0.440	NA
Area in Nozzle Wall	A2	4.420	4.332	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.989	0.989	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	8.351	5.762	NA

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(56.8*6.2213*1+2*12.85*6.2213*1(1-0.99))
  = 1.775 cm²
```

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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 12.85
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.440 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 12.85 - 0.34 ) 0.9894
  = 4.332 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

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

```
 Wall Thickness for Internal/External pressures       ta = 3.3393 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 4.7961 mm.
 Wall Thickness                   tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.4524 mm.
```

```
Wall Thickness                     tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                        tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.3393, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 15.8500 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
Sustained   :     12.0,  Allowable :    136.4 N./mm²  Passed
Expansion   :      0.0,  Allowable :    330.9 N./mm²  Passed
Occasional  :      0.4,  Allowable :    181.5 N./mm²  Passed
Shear       :      3.1,  Allowable :     95.5 N./mm²  Passed
```

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

<u>Weld Size Calculations, Description: N05 (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
Nozzle Weld              4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.7753 - 0.4402 + 2 * 12.85 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 21.14  kN
```

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

Weld Load [W1]:
```
  =  (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  =  ( 4.3322 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  =  73.38  kN
```

Weld Load [W2]:
```
  =  (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  =  ( 4.3322 + 0.0 + 0.9894 + ( 1.7799 ) ) * 138
  =  97.92  kN
```

Weld Load [W3]:
```
  =  (A2+A3+A4+A5+(2*tn*t*fr1))*S
  =  ( 4.3322 + 0.0 + 0.9894 + 0.0 + ( 1.7799 ) ) * 138
  =  97.92  kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  =  (pi/2) * Dlo * Wo * 0.49 * Snw
  =  ( 3.1416/2.0 ) * 82.5 * 10.0 * 0.49 * 136
  =  87.  kN
```

Shear, Nozzle Wall [Snw]:
```
  =  (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  =  (3.1416 * 34.825) * ( 15.85 - 3.0 ) * 0.7 * 136
  =  134.  kN
```

Tension, Shell Groove Weld [Tngw]:
```
  =  (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  =  ( 3.1416/2.0 ) * 82.5 * ( 10.0 - 3.0 ) * 0.74 * 138
  =  93.  kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 87 + 134 ) = 221 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 87 + 0 + 93 + 0 ) = 179 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 87 + 93 + 0 ) = 179 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 220 kN , must exceed W = 21 kN  or W1 = 73 kN
 Path 2-2 = 179 kN , must exceed W = 21 kN  or W2 = 97 kN
 Path 3-3 = 179 kN , must exceed W = 21 kN  or W3 = 97 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 1.4197 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 161.4197 mm.

Input Echo, WRC107/537 Item 1, Description: N05 (2in) :

```
 Diameter Basis for Vessel                 Vbasis      ID
 Cylindrical or Spherical Vessel           Cylsph      Cylindrical
 Internal Corrosion Allowance                 Cas      3.0000   mm.
 Vessel Diameter                               Dv    1200.000   mm.
 Vessel Thickness                              Tv      10.000   mm.

 Design Temperature                            T1       234.0   °C
 Vessel Material                                     SA-516 70
 Vessel UNS Number                                     K02700
 Vessel Cold S.I. Allowable                   Smc      137.90   N./mm²
 Vessel Hot  S.I. Allowable                   Smh      137.90   N./mm²
```

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

```
 Attachment Type                             Type      Round

 Diameter Basis for Nozzle                 Nbasis      ID
 Corrosion Allowance for Nozzle               Can      3.0000   mm.
 Nozzle Diameter                               Dn      50.800   mm.
 Nozzle Thickness                              Tn      15.850   mm.
 Nozzle Material                                       SA-105
 Nozzle UNS Number                                     K03504
 Nozzle Cold S.I. Allowable                  SNmc      137.90   N./mm²
 Nozzle Hot  S.I. Allowable                  SNmh      136.43   N./mm²

 Design Internal Pressure                      Dp       4.100   bars
 Include Pressure Thrust                                   No
```

External Forces and Moments in WRC 107/537 Convention:

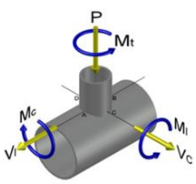
```
 Radial Load             (SUS)                  P         2.8   kN
 Longitudinal Shear      (SUS)                 Vl         2.8   kN
 Circumferential Shear   (SUS)                 Vc        -2.1   kN
 Circumferential Moment  (SUS)                 Mc      -280.0   N-m
 Longitudinal Moment     (SUS)                 Ml      -360.0   N-m
 Torsional Moment        (SUS)                 Mt      -420.0   N-m


 Use Interactive Control                           No
```

```
WRC107 Version                           Version  March  1979

Include Pressure Stress Indices per Div. 2                No
Compute Pressure Stress per WRC-368                       No
Local Loads applied at end of Nozzle/Attachment           No
```

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 82.5 + 2 * 1.65 * sqrt( 606.5 ( 10.0 - 3.0 ) )
  = 297.520 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	2.8	kN
Circumferential Shear	VC	-2.1	kN
Longitudinal Shear	VL	2.8	kN
Circumferential Moment	MC	-280.0	N-m
Longitudinal Moment	ML	-360.0	N-m
Torsional Moment	MT	-420.0	N-m

Dimensionless Parameters used :   Gamma =   86.64

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.060	4C	15.037	(A,B)
N(PHI) / (P/Rm)	0.060	3C	14.463	(C,D)
M(PHI) / (P)	0.060	2C1	0.100	(A,B)
M(PHI) / (P)	0.060	1C	0.139	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.060	3A	2.228	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.060	1A	0.096	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.060	3B	7.820	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.060	1B	0.049	(A,B,C,D)
N(x) / (P/Rm)	0.060	3C	14.463	(A,B)
N(x) / (P/Rm)	0.060	4C	15.037	(C,D)
M(x) / (P)	0.060	1C1	0.143	(A,B)
M(x) / (P)	0.060	2C	0.101	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.060	4A	3.056	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.060	2A	0.057	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.060	4B	2.219	(A,B,C,D)

```
M(x)    / ( ML/(Rm    * Beta) )   0.060   2B        0.080   (A,B,C,D)
```

Stress Concentration Factors: Kn = 1.00,   Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-9.9	-9.9	-9.9	-9.9	-9.5	-9.5	-9.5	-9.5
Circ. Bend.	P	-34.4	34.4	-34.4	34.4	-47.7	47.7	-47.7	47.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	4.1	4.1	-4.1	-4.1
Circ. Memb.	MC	0.0	0.0	0.0	0.0	91.5	-91.5	-91.5	91.5
Circ. Memb.	ML	18.4	18.4	-18.4	-18.4	0.0	0.0	0.0	0.0
Circ. Bend.	ML	60.3	-60.3	-60.3	60.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.		34.3	-17.4	-123.1	66.5	38.3	-49.2	-152.8	125.6
Long. Memb.	P	-9.5	-9.5	-9.5	-9.5	-9.9	-9.9	-9.9	-9.9
Long. Bend.	P	-49.2	49.2	-49.2	49.2	-34.6	34.6	-34.6	34.6
Long. Memb.	MC	0.0	0.0	0.0	0.0	5.6	5.6	-5.6	-5.6
Long. Bend.	MC	0.0	0.0	0.0	0.0	53.8	-53.8	-53.8	53.8
Long. Memb.	ML	5.2	5.2	-5.2	-5.2	0.0	0.0	0.0	0.0
Long. Bend.	ML	97.2	-97.2	-97.2	97.2	0.0	0.0	0.0	0.0
Tot. Long. Str.		43.7	-52.3	-161.1	131.6	14.8	-23.5	-103.8	72.8
Shear	VC	-2.3	-2.3	2.3	2.3	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-3.1	-3.1	3.1	3.1
Shear	MT	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6
Tot. Shear		-7.9	-7.9	-3.3	-3.3	-8.7	-8.7	-2.5	-2.5
Str. Int.		48.2	54.0	161.4	131.8	41.1	51.9	152.9	125.7

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	35.1	35.5	35.1	35.5	35.1	35.5	35.1	35.5
Circ. Pl	(SUS)	8.4	8.4	-28.3	-28.3	-5.5	-5.5	-13.6	-13.6
Circ. Q	(SUS)	25.9	-25.9	-94.8	94.8	43.7	-43.7	-139.2	139.2
Long. Pm	(SUS)	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6
Long. Pl	(SUS)	-4.3	-4.3	-14.8	-14.8	-4.3	-4.3	-15.5	-15.5
Long. Q	(SUS)	48.0	-48.0	-146.3	146.3	19.2	-19.2	-88.3	88.3

```
-------------------------------------------------------------------------------------------------
Shear Pm (SUS) |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
Shear Pl (SUS) |     -2.3|     -2.3|      2.3|      2.3|     -3.1|     -3.1|      3.1|      3.1|
Shear Q  (SUS) |     -5.6|     -5.6|     -5.6|     -5.6|     -5.6|     -5.6|     -5.6|     -5.6|
Pm (SUS)       |     35.1|     35.5|     35.1|     35.5|     35.1|     35.5|     35.1|     35.5|
-------------------------------------------------------------------------------------------------
Pm+Pl (SUS)    |     43.7|     44.1|      7.9|      8.2|     30.2|     30.6|     22.0|     22.4|
-------------------------------------------------------------------------------------------------
Pm+Pl+Q (Total)|     74.3|     55.2|    143.7|    149.4|     75.1|     19.3|    117.9|    161.2|
```

Vessel Stress Summation Comparison (N./mm²):

```
Type of        |      Max. S.I.     S.I. Allowable      |       Result     |
Stress Int.    |                                        |                  |
--------------------------------------------------------------------------
Pm (SUS)       |          35.53            137.90       |       Passed     |
Pm+Pl (SUS)    |          44.15            206.85       |       Passed     |
Pm+Pl+Q (TOTAL)|         161.21            413.70       |       Passed     |
```

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: K2B (2in) From: 30

```
Pressure for Reinforcement Calculations         P        4.100  bars
Temperature for Internal Pressure            Temp          234  °C
Design External Pressure                     Pext         1.03  bars
Temperature for External Pressure          Tempex          100  °C

Shell Material                                        SA-516 70
Shell Allowable Stress at Temperature          Sv       137.90  N./mm²
Shell Allowable Stress At Ambient             Sva       137.90  N./mm²

Inside Diameter of Cylindrical Shell            D      1200.00  mm.
Design Length of Section                        L    3699.9998  mm.
Shell Finished (Minimum) Thickness              t      10.0000  mm.
Shell Internal Corrosion Allowance              c       3.0000  mm.
Shell External Corrosion Allowance             co       0.0000  mm.

Distance from Cylinder/Cone Centerline         L1     228.0000  mm.

Distance from Bottom/Left Tangent                      2200.00  mm.

User Entered Minimum Design Metal Temperature             5.00  °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                 SA-105
Material UNS Number                                     K03504
Material Specification/Type                           Forgings
Allowable Stress at Temperature                Sn       136.43  N./mm²
Allowable Stress At Ambient                   Sna       137.90  N./mm²

Diameter Basis (for tr calc only)                           ID
Layout Angle                                            -21.95  deg
Diameter                                                2.0000  in.

Size and Thickness Basis                                 Actual
Actual Thickness                               tn      16.6000  mm.

Flange Material                                          SA-105
Flange Type                                      Long Weld Neck

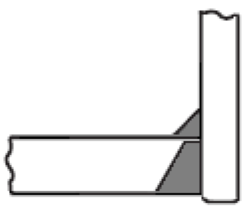
Corrosion Allowance                           can       3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle       E1         1.00
Joint Efficiency of Nozzle Neck                En         1.00

Outside Projection                             ho     150.0000  mm.
Weld leg size between Nozzle and Pad/Shell     Wo      10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv      10.0000  mm.
Inside Projection                               h       0.0000  mm.
Weld leg size, Inside Element to Shell         Wi       0.0000  mm.

Flange Class                                          300
Flange Grade                                          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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K2B (2in)

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```
Actual Inside Diameter Used in Calculation              2.000  in.
Actual Thickness Used in Calculation                    0.654  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3430 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    122.6836   mm.
Parallel to Vessel Wall, opening length              d     61.3418   mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000   mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |     Design|  External|      Mapnc|
---------------------------------------------------------------
```

```
Area Required               Ar |      0.553|      1.917|         NA|
Area in Shell               A1 |      3.725|      0.475|         NA|
Area in Nozzle Wall         A2 |      4.971|      4.876|         NA|
Area in Inward Nozzle       A3 |      0.000|      0.000|         NA|
Area in Welds     A41+A42+A43 |      0.989|      0.989|         NA|
Area in Element             A5 |      0.000|      0.000|         NA|
TOTAL AREA AVAILABLE      Atot |      9.685|      6.341|         NA|
```

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  67.81   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(61.3418*6.2213*1+2*13.6*6.2213*1(1-0.99))
  = 1.917 cm²
```

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 )
  = 61.342( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 13.6
     ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.475 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 17.5 )( 13.6 - 0.34 ) 0.9894/sin( 70.3 )
  = 4.876 cm²
```

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

<u>Weld Size Calculations, Description: K2B (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                         Required Thickness    Actual Thickness
Nozzle Weld             4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.9171 - 0.4754 + 2 * 13.6 * 0.9894 *
     (1.0 * 7.0 - 6.2213 ) )138)
  = 22.77 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.8759 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 80.88 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.8759 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 106.85 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.8759 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 106.85 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 90.7167 * 10.0 * 0.49 * 136
  = 95. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 38.0146) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 155. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 90.7167 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 102. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 95 + 155 ) = 250 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 95 + 0 + 102 + 0 ) = 197 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 95 + 102 + 0 ) = 197 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 250 kN , must exceed W = 22 kN  or W1 = 80 kN
 Path 2-2 = 197 kN , must exceed W = 22 kN  or W2 = 106 kN
 Path 3-3 = 197 kN , must exceed W = 22 kN  or W3 = 106 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

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

Reinforcement CALCULATION, Description: K2B (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation            2.000  in.
 Actual Thickness Used in Calculation                  0.654  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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3430 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    113.6000  mm.
 Parallel to Vessel Wall, opening length              d     56.8000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |    Design|  External|      Mapnc|
-----------------------------------------------------------------
Area Required             Ar |     1.025|     1.776|         NA|
Area in Shell             A1 |     2.941|     0.440|         NA|
Area in Nozzle Wall       A2 |     4.680|     4.591|         NA|
Area in Inward Nozzle     A3 |     0.000|     0.000|         NA|
Area in Welds     A41+A42+A43 |     0.989|     0.989|         NA|
Area in Element           A5 |     0.000|     0.000|         NA|
TOTAL AREA AVAILABLE    Atot |     8.610|     6.020|         NA|
```

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(56.8*6.2213*1+2*13.6*6.2213*1(1-0.99))
  = 1.776 cm²
```

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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 13.6
     ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.440 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 13.6 - 0.34 ) 0.9894
  = 4.591 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 3.3430 mm.
Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 4.7961 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 4.7961 mm.
Wall Thickness, shell/head, external pressure     trb2 = 3.4524 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                     tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
```

```
  = max( 3.343, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Weld Size Calculations, Description: K2B (2in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000   mm.
```

Results Per UW-16.1:

```
                         Required Thickness    Actual Thickness
 Nozzle Weld            4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.7758 - 0.4401 + 2 * 13.6 * 0.9894 *
     (1.0 * 7.0 - 6.2213 ) )138)
  = 21.31 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.5906 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 76.94 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.5906 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 102.92 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.5906 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 102.92 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 136
  = 88. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 94. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 88 + 144 ) = 232 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 88 + 0 + 94 + 0 ) = 182 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 88 + 94 + 0 ) = 182 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 231 kN , must exceed W = 21 kN  or W1 = 76 kN
Path 2-2 = 182 kN , must exceed W = 21 kN  or W2 = 102 kN
Path 3-3 = 182 kN , must exceed W = 21 kN  or W3 = 102 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 19.1747 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 179.9709 mm.

Input, Nozzle Desc: K2A (2in) From: 30

```
Pressure for Reinforcement Calculations        P        4.100   bars
Temperature for Internal Pressure           Temp          234   °C
Design External Pressure                    Pext         1.03   bars
Temperature for External Pressure         Tempex          100   °C

Shell Material                                    SA-516 70
Shell Allowable Stress at Temperature         Sv       137.90   N./mm²
Shell Allowable Stress At Ambient            Sva       137.90   N./mm²

Inside Diameter of Cylindrical Shell           D      1200.00   mm.
Design Length of Section                       L    3699.9998   mm.
Shell Finished (Minimum) Thickness             t      10.0000   mm.
Shell Internal Corrosion Allowance             c       3.0000   mm.
Shell External Corrosion Allowance            co       0.0000   mm.

Distance from Cylinder/Cone Centerline        L1      28.0000   mm.

Distance from Bottom/Left Tangent                     2200.00   mm.

User Entered Minimum Design Metal Temperature            5.00   °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                              SA-105
Material UNS Number                                 K03504
Material Specification/Type                       Forgings
Allowable Stress at Temperature               Sn       136.43   N./mm²
Allowable Stress At Ambient                  Sna       137.90   N./mm²

Diameter Basis (for tr calc only)                        ID
Layout Angle                                             2.63   deg
Diameter                                               2.0000   in.

Size and Thickness Basis                              Actual
Actual Thickness                              tn      16.6000   mm.

Flange Material                                       SA-105
Flange Type                                     Long Weld Neck

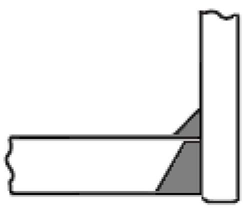
Corrosion Allowance                          can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle      E1         1.00
Joint Efficiency of Nozzle Neck               En         1.00

Outside Projection                            ho     150.0000   mm.
Weld leg size between Nozzle and Pad/Shell    Wo      10.0000   mm.
Groove weld depth between Nozzle and Vessel Wgnv      10.0000   mm.
Inside Projection                              h       0.0000   mm.
Weld leg size, Inside Element to Shell        Wi       0.0000   mm.

Flange Class                                      300
Flange Grade                                      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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K2A (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation             2.000  in.
Actual Thickness Used in Calculation                   0.654  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3430 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    113.7635   mm.
 Parallel to Vessel Wall, opening length              d     56.8818   mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000   mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

```
 AREA AVAILABLE, A1 to A5      |     Design|  External|      Mapnc|
 ---------------------------------------------------------------
```

Area Required	Ar	0.513	1.778	NA
Area in Shell	A1	3.453	0.441	NA
Area in Nozzle Wall	A2	4.680	4.591	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.989	0.989	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	9.123	6.021	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 86.93 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(56.8818*6.2213*1+2*13.6*6.2213*1(1-0.99))
= 1.778 cm^2

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)
= 56.882(1.0 * 7.0 - 1.0 * 6.221) - 2 * 13.6
(1.0 * 7.0 - 1.0 * 6.2213) * (1 - 0.989)
= 0.441 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 17.5)(13.6 - 0.34) 0.9894/sin(89.5)
= 4.591 cm^2

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo^2 * fr2 + (Wi-can/0.707 $)^2$ * fr2
= 10.0^2 * 0.9894 + (0.0 $)^2$ * 0.9894
= 0.989 cm^2

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve A	-8	°C
Min Metal Temp. at Required thickness (UCS 66.1)	-104	°C
Min Metal Temp. w/o impact per UG-20(f)	-29	°C

Gov. MDMT of the nozzle to shell joint welded assembly : -104 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

Weld Size Calculations, Description: K2A (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                         Required Thickness    Actual Thickness
Nozzle Weld             4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.7784 - 0.4407 + 2 * 13.6 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 21.33 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.5908 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 76.94 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.5908 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 102.92 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.5908 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 102.92 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.1209 * 10.0 * 0.49 * 136
  = 88. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2507) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.1209 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 94. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 88 + 144 ) = 232 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 88 + 0 + 94 + 0 ) = 183 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 88 + 94 + 0 ) = 183 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 232 kN , must exceed W = 21 kN  or W1 = 76 kN
 Path 2-2 = 182 kN , must exceed W = 21 kN  or W2 = 102 kN
 Path 3-3 = 182 kN , must exceed W = 21 kN  or W3 = 102 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

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

Reinforcement CALCULATION, Description: K2A (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation             2.000  in.
 Actual Thickness Used in Calculation                   0.654  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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3430 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    113.6000  mm.
 Parallel to Vessel Wall, opening length              d     56.8000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |    Design|  External|     Mapnc|
---------------------------------------------------------------
Area Required             Ar  |     1.025|     1.776|        NA|
Area in Shell             A1  |     2.941|     0.440|        NA|
Area in Nozzle Wall       A2  |     4.680|     4.591|        NA|
Area in Inward Nozzle     A3  |     0.000|     0.000|        NA|
Area in Welds     A41+A42+A43 |     0.989|     0.989|        NA|
Area in Element           A5  |     0.000|     0.000|        NA|
TOTAL AREA AVAILABLE    Atot  |     8.610|     6.020|        NA|
```

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(56.8*6.2213*1+2*13.6*6.2213*1(1-0.99))
  = 1.776 cm²
```

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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 13.6
   ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.440 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 13.6 - 0.34 ) 0.9894
  = 4.591 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

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

```
 Wall Thickness for Internal/External pressures       ta = 3.3430 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 4.7961 mm.
 Wall Thickness                    tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.4524 mm.
 Wall Thickness                    tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
```

```
  = max( 3.343, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Weld Size Calculations, Description: K2A (2in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000   mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
 Nozzle Weld             4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.7758 - 0.4401 + 2 * 13.6 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 21.31 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.5906 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 76.94 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.5906 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 102.92 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.5906 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 102.92 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 136
  = 88. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 94. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 88 + 144 ) = 232 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 88 + 0 + 94 + 0 ) = 182 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 88 + 94 + 0 ) = 182 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 231 kN , must exceed W = 21 kN  or W1 = 76 kN
Path 2-2 = 182 kN , must exceed W = 21 kN  or W2 = 102 kN
Path 3-3 = 182 kN , must exceed W = 21 kN  or W3 = 102 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 3.4436 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 163.4544 mm.

Input, Nozzle Desc: K3A (3in) **From: 30**

```
Pressure for Reinforcement Calculations         P       4.100   bars
Temperature for Internal Pressure            Temp         234   °C
Design External Pressure                     Pext        1.03   bars
Temperature for External Pressure          Tempex         100   °C

Shell Material                                      SA-516 70
Shell Allowable Stress at Temperature          Sv      137.90   N./mm²
Shell Allowable Stress At Ambient             Sva      137.90   N./mm²

Inside Diameter of Cylindrical Shell            D     1200.00   mm.
Design Length of Section                        L   3699.9998   mm.
Shell Finished (Minimum) Thickness              t     10.0000   mm.
Shell Internal Corrosion Allowance              c      3.0000   mm.
Shell External Corrosion Allowance             co      0.0000   mm.

Distance from Cylinder/Cone Centerline         L1    400.0000   mm.

Distance from Bottom/Left Tangent                     2450.00   mm.

User Entered Minimum Design Metal Temperature            5.00   °C
```

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      117.90   N./mm²
Allowable Stress At Ambient                   Sna      117.90   N./mm²

Diameter Basis (for tr calc only)                          ID
Layout Angle                                            40.98   deg
Diameter                                               3.0000   in.

Size and Thickness Basis                                 Minimum
Nominal Thickness                              tn        80

Flange Material                                          SA-105
Flange Type                                    Weld Neck Flange

Corrosion Allowance                           can      3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle       E1        1.00
Joint Efficiency of Nozzle Neck                En        1.00

Outside Projection                             ho    250.0000   mm.
Weld leg size between Nozzle and Pad/Shell     Wo     10.0000   mm.
Groove weld depth between Nozzle and Vessel  Wgnv     10.0000   mm.
Inside Projection                               h      0.0000   mm.
Weld leg size, Inside Element to Shell         Wi      0.0000   mm.

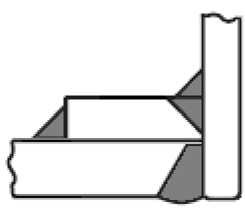
Pad Material                                        SA-516 70
Pad Allowable Stress at Temperature            Sp      137.90   N./mm²
Pad Allowable Stress At Ambient               Spa      137.90   N./mm²
```

```
Diameter of Pad along vessel surface         Dp      200.0000   mm.
Thickness of Pad                             te       10.0000   mm.
Weld leg size between Pad and Shell          Wp        8.0000   mm.
Groove weld depth between Pad and Nozzle    Wgpn      10.0000   mm.
Reinforcing Pad Width                                 55.5500   mm.

Flange Class                                         300
Flange Grade                                         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: K3A (3in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.975   in.
Actual Thickness Used in Calculation                    0.263   in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*40.78)/(118*1.0-0.6*4.1)
  = 0.1421 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4399 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    218.1052  mm.
Parallel to Vessel Wall, opening length              d    109.0526  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr4]:

```
  = min( 1, Sp/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.855, 1.0 )
  = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.978	3.425	NA
Area in Shell	A1	5.620	0.841	NA
Area in Nozzle Wall	A2	1.317	1.206	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.802	0.802	NA
Area in Element	A5	9.925	9.925	NA
TOTAL AREA AVAILABLE	Atot	17.663	12.773	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  48.41   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:              94.6694    10.0000   mm.
Based on given Pad Diameter:              200.0000     0.5813   mm.
Based on Shell or Nozzle Thickness:       127.5125     6.6675   mm.
```

Area Required [A]:

```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(109.0526*6.2213*1+2*3.6675*6.2213*1(1-0.86))
  = 3.425 cm²
```

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 )
  = 109.053( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 3.668
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.855 )
  = 0.841 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2/sin( alpha3 )
  = ( 2 * 17.5 ) * ( 3.67 - 0.44 ) * 0.855/sin( 53.2 )
  = 1.206 cm²
```

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 - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 0.86 + (0.0 ) * 0.86 + 0.0² * 1.0
  = 0.802 cm²
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 218.1052 - 118.8595 ) * 10.0 * 1.0
  = 9.925 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:B, Curve:A)

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A             -8 °C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                   -29 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

```
---------------------------------------------------------------------
```

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B           -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -104 °C
```

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

```
---------------------------------------------------------------------
```

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B           -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -104 °C

Gov. MDMT of the Nozzle                              :  -104 °C
Gov. MDMT of the Reinforcement Pad                   :  -104 °C
Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

<u>Weld Size Calculations, Description: K3A (3in)</u>

```
Intermediate Calc. for nozzle/shell Welds    Tmin       3.6675   mm.
Intermediate Calc. for pad/shell Welds    TminPad       7.0000   mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
Pad Weld             3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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, (3.4253 - 0.8409 + 2 * 3.6675 * 0.855 *
   (1.0 * 7.0 - 6.2213 ) )138)
 = 36.31 kN
```

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

Weld Load [W1]:

```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 1.2059 + 9.9246 + 0.8016 - 0.0 * 0.86 ) * 138
 = 164.53 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.2059 + 0.0 + 0.8491 + ( 0.439 ) ) * 138
  = 34.39 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.2059 + 0.0 + 0.8016 + 9.9246 + ( 0.439 ) ) * 138
  = 170.58 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 118.8595 * 10.0 * 0.49 * 118
  = 108. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 200.0 * 8.0 * 0.49 * 138
  = 170. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 56.978) * ( 6.6675 - 3.0 ) * 0.7 * 118
  = 54. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 118.8595 * 10.0 * 0.74 * 138
  = 191. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 118.8595 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 133. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 170 + 54 ) = 224 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 108 + 191 + 133 + 0 ) = 432 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 170 + 133 + 0 ) = 303 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 223 kN , must exceed W = 36 kN  or W1 = 164 kN
 Path 2-2 = 431 kN , must exceed W = 36 kN  or W2 = 34 kN
 Path 3-3 = 303 kN , must exceed W = 36 kN  or W3 = 170 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    8  bars
```

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

```
Nozzle is O.K. for the External Pressure          1  bars
```

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

Reinforcement CALCULATION, Description: K3A (3in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation             2.975  in.
Actual Thickness Used in Calculation                   0.263  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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*40.78)/(118*1.0-0.6*4.1)
  = 0.1421 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4399 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    163.1300  mm.
Parallel to Vessel Wall, opening length              d     81.5650  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  mm.
```

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

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5     |     Design|  External|      Mapnc|
---------------------------------------------------------------
Area Required             Ar |     1.484|     2.570|         NA|
Area in Shell             A1 |     4.189|     0.627|         NA|
Area in Nozzle Wall       A2 |     1.055|     0.966|         NA|
Area in Inward Nozzle     A3 |     0.000|     0.000|         NA|
Area in Welds    A41+A42+A43 |     0.802|     0.802|         NA|
Area in Element           A5 |     7.423|     7.423|         NA|
TOTAL AREA AVAILABLE    Atot |    13.469|     9.817|         NA|
```

The External 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:              90.6597    10.0000   mm.
Based on given Pad Diameter:              200.0000     0.2371   mm.
```

```
 Based on Shell or Nozzle Thickness:       91.5392     6.6675  mm.
```

Area Required [A]:

```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(81.565*6.2213*1+2*3.6675*6.2213*1(1-0.86))
  = 2.570 cm²
```

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 )
  = 81.565( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 3.668
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.855 )
  = 0.627 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 3.67 - 0.44 ) * 0.855
  = 0.966 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 0.86 + (0.0 ) * 0.86 + 0.0² * 1.0
  = 0.802 cm²
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 163.13 - 88.9 ) * 10.0 * 1.0
  = 7.423 cm²
```

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

```
 Wall Thickness for Internal/External pressures      ta = 3.4399 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 4.7961 mm.
 Wall Thickness                tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure     trb2 = 3.4524 mm.
 Wall Thickness                tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                     tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.4399, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 6.6675 mm. --> OK

<u>Weld Size Calculations, Description: K3A (3in)</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      3.6675  mm.
```

```
Intermediate Calc. for pad/shell Welds   TminPad      7.0000  mm.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
Nozzle Weld           2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
Pad Weld              3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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, (2.5703 - 0.6269 + 2 * 3.6675 * 0.855 *
     (1.0 * 7.0 - 6.2213 ) )138)
  = 27.47 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.9659 + 7.423 + 0.8016 - 0.0 * 0.86 ) * 138
  = 126.73 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.9659 + 0.0 + 0.8491 + ( 0.439 ) ) * 138
  = 31.08 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.9659 + 0.0 + 0.8016 + 7.423 + ( 0.439 ) ) * 138
  = 132.78 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 88.9 * 10.0 * 0.49 * 118
  = 81. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 200.0 * 8.0 * 0.49 * 138
  = 170. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 42.6162) * ( 6.6675 - 3.0 ) * 0.7 * 118
  = 41. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 88.9 * 10.0 * 0.74 * 138
  = 142. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 88.9 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 100. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 170 + 41 ) = 210 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 81 + 142 + 100 + 0 ) = 323 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 170 + 100 + 0 ) = 270 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 210 kN , must exceed W = 27 kN  or W1 = 126 kN
 Path 2-2 = 322 kN , must exceed W = 27 kN  or W2 = 31 kN
 Path 3-3 = 269 kN , must exceed W = 27 kN  or W3 = 132 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    8   bars
```

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

```
 Nozzle is O.K. for the External Pressure            1   bars
```

The Drop for this Nozzle is : 44.1451 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 307.4748 mm.

Input, Nozzle Desc: K3B (3in) From: 30

```
Pressure for Reinforcement Calculations          P        4.100   bars
Temperature for Internal Pressure             Temp          234   °C
Design External Pressure                      Pext         1.03   bars
Temperature for External Pressure           Tempex          100   °C

Shell Material                                          SA-516 70
Shell Allowable Stress at Temperature           Sv       137.90   N./mm²
Shell Allowable Stress At Ambient              Sva       137.90   N./mm²

Inside Diameter of Cylindrical Shell             D      1200.00   mm.
Design Length of Section                         L    3699.9998   mm.
Shell Finished (Minimum) Thickness               t      10.0000   mm.
Shell Internal Corrosion Allowance               c       3.0000   mm.
Shell External Corrosion Allowance              co       0.0000   mm.

Distance from Cylinder/Cone Centerline          L1     200.0000   mm.

Distance from Bottom/Left Tangent                       2450.00   mm.

User Entered Minimum Design Metal Temperature              5.00   °C
```

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       117.90   N./mm²
Allowable Stress At Ambient                    Sna       117.90   N./mm²

Diameter Basis (for tr calc only)                             ID
Layout Angle                                             -19.14   deg
Diameter                                                 3.0000   in.

Size and Thickness Basis                                    Minimum
Nominal Thickness                               tn          80

Flange Material                                             SA-105
Flange Type                                       Weld Neck Flange

Corrosion Allowance                            can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     200.0000   mm.
Weld leg size between Nozzle and Pad/Shell      Wo      10.0000   mm.
Groove weld depth between Nozzle and Vessel Wgnv       10.0000   mm.
Inside Projection                                h       0.0000   mm.
Weld leg size, Inside Element to Shell          Wi       0.0000   mm.

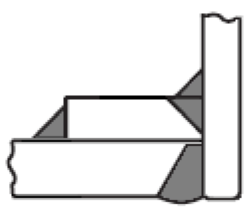
Pad Material                                            SA-516 70
Pad Allowable Stress at Temperature             Sp       137.90   N./mm²
Pad Allowable Stress At Ambient                Spa       137.90   N./mm²
```

```
Diameter of Pad along vessel surface        Dp      200.0000  mm.
Thickness of Pad                            te       10.0000  mm.
Weld leg size between Pad and Shell         Wp        8.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn     10.0000  mm.
Reinforcing Pad Width                                55.5500  mm.

Flange Class                                        300
Flange Grade                                        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: K3B (3in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation           2.975   in.
Actual Thickness Used in Calculation                 0.263   in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
 = (4.1*603.0)/(138*1.0-0.6*4.1)
 = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
 = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
 = (4.1*40.78)/(118*1.0-0.6*4.1)
 = 0.1421 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3989 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl   173.0097  mm.
Parallel to Vessel Wall, opening length              d    86.5048  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp    17.5000  mm.
```

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

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 117.9/137.9 )
= 0.855
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 117.9/137.9 )
= 0.855
```

Weld Strength Reduction Factor [fr4]:

```
= min( 1, Sp/Sv )
= min( 1, 137.9/137.9 )
= 1.000
```

Weld Strength Reduction Factor [fr3]:

```
= min( fr2, fr4 )
= min( 0.855, 1.0 )
= 0.855
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.573	2.724	NA
Area in Shell	A1	4.446	0.665	NA
Area in Nozzle Wall	A2	1.096	1.016	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.802	0.802	NA
Area in Element	A5	7.873	7.873	NA
TOTAL AREA AVAILABLE	Atot	14.216	10.356	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  70.54  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:	91.3093	10.0000	mm.
Based on given Pad Diameter:	200.0000	0.3060	mm.
Based on Shell or Nozzle Thickness:	97.8975	6.6675	mm.

Area Required [A]:

```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(86.5048*6.2213*1+2*3.6675*6.2213*1(1-0.86))
```

```
  = 2.724 cm²
```

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 )
  = 86.505( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 3.668
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.855 )
  = 0.665 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2/sin( alpha3 )
  = ( 2 * 17.5 ) * ( 3.67 - 0.4 ) * 0.855/sin( 74.3 )
  = 1.016 cm²
```

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 - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 0.86 + (0.0 ) * 0.86 + 0.0² * 1.0
  = 0.802 cm²
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 173.0097 - 94.2841 ) * 10.0 * 1.0
  = 7.873 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:B, Curve:A)

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A             -8 °C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                   -29 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

```
---------------------------------------------------------------------
```

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

```
---------------------------------------------------------------------
```

Govrn. thk, tg = 6.668, tr = 0.142, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.039, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C

Gov. MDMT of the Nozzle                              :   -104 °C
Gov. MDMT of the Reinforcement Pad                   :   -104 °C
Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

<u>Weld Size Calculations, Description: K3B (3in)</u>

```
Intermediate Calc. for nozzle/shell Welds    Tmin       3.6675  mm.
Intermediate Calc. for pad/shell Welds    TminPad       7.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
Pad Weld             3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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, (2.7239 - 0.6653 + 2 * 3.6675 * 0.855 *
     (1.0 * 7.0 - 6.2213 ) )138)
  = 29.06 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.0161 + 7.8726 + 0.8016 - 0.0 * 0.86 ) * 138
  = 133.62 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.0161 + 0.0 + 0.8491 + ( 0.439 ) ) * 138
  = 31.77 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.0161 + 0.0 + 0.8016 + 7.8726 + ( 0.439 ) ) * 138
  = 139.67 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 94.2841 * 10.0 * 0.49 * 118
  = 86. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 200.0 * 8.0 * 0.49 * 138
  = 170. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 45.1972) * ( 6.6675 - 3.0 ) * 0.7 * 118
  = 43. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 94.2841 * 10.0 * 0.74 * 138
  = 151. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 94.2841 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 106. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 170 + 43 ) = 213 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 86 + 151 + 106 + 0 ) = 342 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 170 + 106 + 0 ) = 276 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 212 kN , must exceed W = 29 kN  or W1 = 133 kN
 Path 2-2 = 342 kN , must exceed W = 29 kN  or W2 = 31 kN
 Path 3-3 = 275 kN , must exceed W = 29 kN  or W3 = 139 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    8  bars
```

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

```
Nozzle is O.K. for the External Pressure          1  bars
```

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

Reinforcement CALCULATION, Description: K3B (3in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.975  in.
Actual Thickness Used in Calculation                    0.263  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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*40.78)/(118*1.0-0.6*4.1)
  = 0.1421 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3989 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    163.1300  mm.
Parallel to Vessel Wall, opening length              d     81.5650  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  mm.
```

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

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |     Design|  External|      Mapnc|
-----------------------------------------------------------------
Area Required              Ar |      1.484|     2.570|         NA|
Area in Shell              A1 |      4.189|     0.627|         NA|
Area in Nozzle Wall        A2 |      1.055|     0.978|         NA|
Area in Inward Nozzle      A3 |      0.000|     0.000|         NA|
Area in Welds     A41+A42+A43 |      0.802|     0.802|         NA|
Area in Element            A5 |      7.423|     7.423|         NA|
TOTAL AREA AVAILABLE     Atot |     13.469|     9.830|         NA|
```

The External 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:              90.5371    10.0000  mm.
Based on given Pad Diameter:              200.0000     0.2206  mm.
```

```
Based on Shell or Nozzle Thickness:       91.3554     6.6675  mm.
```

Area Required [A]:

```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(81.565*6.2213*1+2*3.6675*6.2213*1(1-0.86))
  = 2.570 cm²
```

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 )
  = 81.565( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 3.668
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.855 )
  = 0.627 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 3.67 - 0.4 ) * 0.855
  = 0.978 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 0.86 + (0.0 ) * 0.86 + 0.0² * 1.0
  = 0.802 cm²
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 163.13 - 88.9 ) * 10.0 * 1.0
  = 7.423 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 3.3989 mm.
Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 4.7961 mm.
Wall Thickness                tb1 = max(trb1, tr16b) = 4.7961 mm.
Wall Thickness, shell/head, external pressure     trb2 = 3.4524 mm.
Wall Thickness                tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                     tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.3989, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 6.6675 mm. --> OK

<u>Weld Size Calculations, Description: K3B (3in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      3.6675  mm.
```

```
Intermediate Calc. for pad/shell Welds    TminPad      7.0000  mm.
```

Results Per UW-16.1:

```
                         Required Thickness    Actual Thickness
Nozzle Weld             2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
Pad Weld                3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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, (2.5703 - 0.6269 + 2 * 3.6675 * 0.855 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 27.47 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.9781 + 7.423 + 0.8016 - 0.0 * 0.86 ) * 138
  = 126.89 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.9781 + 0.0 + 0.8491 + ( 0.439 ) ) * 138
  = 31.25 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.9781 + 0.0 + 0.8016 + 7.423 + ( 0.439 ) ) * 138
  = 132.95 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 88.9 * 10.0 * 0.49 * 118
  = 81. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 200.0 * 8.0 * 0.49 * 138
  = 170. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 42.6162) * ( 6.6675 - 3.0 ) * 0.7 * 118
  = 41. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 88.9 * 10.0 * 0.74 * 138
  = 142. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 88.9 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 100. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 170 + 41 ) = 210 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 81 + 142 + 100 + 0 ) = 323 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 170 + 100 + 0 ) = 270 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 210 kN , must exceed W = 27 kN  or W1 = 126 kN
 Path 2-2 = 322 kN , must exceed W = 27 kN  or W2 = 31 kN
 Path 3-3 = 269 kN , must exceed W = 27 kN  or W3 = 132 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case    8  bars
```

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

```
 Nozzle is O.K. for the External Pressure            1  bars
```

The Drop for this Nozzle is : 17.7400 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 228.3358 mm.

Input, Nozzle Desc: N11 (1in) From: 30

```
Pressure for Reinforcement Calculations         P        4.100   bars
Temperature for Internal Pressure            Temp          234   °C
Design External Pressure                     Pext         1.03   bars
Temperature for External Pressure          Tempex          100   °C

Shell Material                                       SA-516 70
Shell Allowable Stress at Temperature          Sv       137.90   N./mm²
Shell Allowable Stress At Ambient             Sva       137.90   N./mm²

Inside Diameter of Cylindrical Shell            D      1200.00   mm.
Design Length of Section                        L    3699.9998   mm.
Shell Finished (Minimum) Thickness              t      10.0000   mm.
Shell Internal Corrosion Allowance              c       3.0000   mm.
Shell External Corrosion Allowance             co       0.0000   mm.

Distance from Bottom/Left Tangent                      1750.00   mm.

User Entered Minimum Design Metal Temperature             5.00   °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                SA-105
Material UNS Number                                     K03504
Material Specification/Type                           Forgings
Allowable Stress at Temperature                Sn       136.43   N./mm²
Allowable Stress At Ambient                   Sna       137.90   N./mm²

Diameter Basis (for tr calc only)                           ID
Layout Angle                                             90.00   deg
Diameter                                                1.0000   in.

Size and Thickness Basis                                Actual
Actual Thickness                               tn      12.8000   mm.

Flange Material                                         SA-105
Flange Type                                     Long Weld Neck

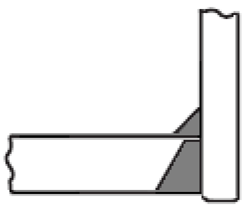
Corrosion Allowance                           can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle       E1         1.00
Joint Efficiency of Nozzle Neck                En         1.00

Outside Projection                             ho     150.0000   mm.
Weld leg size between Nozzle and Pad/Shell     Wo       8.0000   mm.
Groove weld depth between Nozzle and Vessel  Wgnv      10.0000   mm.
Inside Projection                               h       0.0000   mm.
Weld leg size, Inside Element to Shell         Wi       0.0000   mm.

Flange Class                                         150
Flange Grade                                         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: N11 (1in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              1.000  in.
Actual Thickness Used in Calculation                    0.504  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 15.7(exp([4.1/(136.43*1.0]-1)
  = 0.0473 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2571 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl     65.0000  mm.
Parallel to Vessel Wall                        Rn+tn+t     32.5000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
  = 0.989
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
```

```
  = 0.989
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.989, 1.0 )
  = 0.989
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.568	0.983	NA
Area in Shell	A1	1.738	0.260	NA
Area in Nozzle Wall	A2	3.377	3.305	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.623	0.623	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	5.738	4.188	NA

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(31.4*6.2213*1+2*9.8*6.2213*1(1-0.99))
  = 0.983 cm²
```

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 )
  = 33.6( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 9.8
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.260 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 9.8 - 0.26 ) 0.9894
  = 3.305 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
  = ( 8.0² - 0.01 ) * 0.9894 + ( 0.0² -0.0 ) * 0.9894
  = 0.623 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures       ta = 3.2571 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure       trb1 = 4.7961 mm.
 Wall Thickness                    tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure       trb2 = 3.4524 mm.
```

```
Wall Thickness                     tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                        tb3 = 6.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.42, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.2571, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 12.8000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

<u>Weld Size Calculations, Description: N11 (1in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
Nozzle Weld            4.9000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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, ( 0.9832 - 0.26 + 2 * 9.8 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 12.05 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.3045 + 0.0 + 0.6233 - 0.0 * 0.99 ) * 138
  = 54.16 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.3045 + 0.0 + 0.6233 + ( 1.3574 ) ) * 138
  = 72.88 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.3045 + 0.0 + 0.6233 + 0.0 + ( 1.3574 ) ) * 138
  = 72.88 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 51.0 * 8.0 * 0.49 * 136
  = 43. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 20.6) * ( 12.8 - 3.0 ) * 0.7 * 136
  = 61. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 51.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 57. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 43 + 61 ) = 103 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 43 + 0 + 57 + 0 ) = 100 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 43 + 57 + 0 ) = 100 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 103 kN , must exceed W = 12 kN  or W1 = 54 kN
 Path 2-2 = 100 kN , must exceed W = 12 kN  or W2 = 72 kN
 Path 3-3 = 100 kN , must exceed W = 12 kN  or W3 = 72 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 0.5421 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 160.5421 mm.

Input, Nozzle Desc: M2 (24in) **From: 30**

```
Pressure for Reinforcement Calculations          P        4.100   bars
Temperature for Internal Pressure             Temp          234   °C
Design External Pressure                      Pext         1.03   bars
Temperature for External Pressure           Tempex          100   °C

Shell Material                                        SA-516 70
Shell Allowable Stress at Temperature           Sv       137.90   N./mm²
Shell Allowable Stress At Ambient              Sva       137.90   N./mm²

Inside Diameter of Cylindrical Shell             D      1200.00   mm.
Design Length of Section                         L    3699.9998   mm.
Shell Finished (Minimum) Thickness               t      10.0000   mm.
Shell Internal Corrosion Allowance               c       3.0000   mm.
Shell External Corrosion Allowance              co       0.0000   mm.
```

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

```
Physical Maximum for Diameter Limit         Dmax    1000.0000   mm.

Distance from Bottom/Left Tangent                     3050.00   mm.

User Entered Minimum Design Metal Temperature            5.00   °C
```

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       137.90   N./mm²
Allowable Stress At Ambient                    Sna       137.90   N./mm²

Diameter Basis (for tr calc only)                            OD
Layout Angle                                               0.00   deg
Diameter                                                24.0000   in.

Size and Thickness Basis                                 Actual
Actual Thickness                                tn      10.0000   mm.

Flange Material                                          SA-105
Flange Type                                     Weld Neck Flange

Corrosion Allowance                            can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     150.0000   mm.
Weld leg size between Nozzle and Pad/Shell      Wo      10.0000   mm.
Groove weld depth between Nozzle and Vessel   Wgnv      10.0000   mm.
Inside Projection                                h       0.0000   mm.
Weld leg size, Inside Element to Shell          Wi       0.0000   mm.

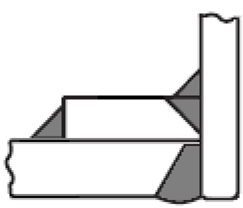
Pad Material                                          SA-516 70
```

```
Pad Allowable Stress at Temperature          Sp       137.90  N./mm²
Pad Allowable Stress At Ambient             Spa       137.90  N./mm²
Diameter of Pad along vessel surface         Dp     800.0000  mm.
Thickness of Pad                             te      10.0000  mm.
Weld leg size between Pad and Shell          Wp       8.0000  mm.
Groove weld depth between Pad and Nozzle   Wgpn      10.0000  mm.
Reinforcing Pad Width                                95.2000  mm.
This is a Manway or Access Opening.

Flange Class                                        150
Flange Grade                                        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: M2 (24in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation          24.000  in.
Actual Thickness Used in Calculation                  0.394  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

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)
  = (4.1*304.8)/(138*1.0+0.4*4.1)
  = 0.9052 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 1.0868 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl   1000.0000  mm.
Parallel to Vessel Wall, opening length              d    500.0000  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 137.9/137.9 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 137.9/137.9 )
= 1.000
```

Weld Strength Reduction Factor [fr4]:

```
= min( 1, Sp/Sv )
= min( 1, 137.9/137.9 )
= 1.000
```

Weld Strength Reduction Factor [fr3]:

```
= min( fr2, fr4 )
= min( 1.0, 1.0 )
= 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	10.698	18.527	NA
Area in Shell	A1	21.044	3.149	NA
Area in Nozzle Wall	A2	2.133	2.070	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.577	1.577	NA
Area in Element	A5	19.040	19.040	NA
TOTAL AREA AVAILABLE	Atot	43.795	25.836	NA

The External 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:            726.9075    10.0000   mm.
Based on given Pad Diameter:             800.0001     6.1611   mm.
Based on Shell or Nozzle Thickness:      726.9075    10.0000   mm.
```

Area Required [A]:

```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(595.6*6.2213*1+2*7.0*6.2213*1(1-1.0))
= 18.527 cm²
```

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 )
  = 404.4( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 7.0
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 1.0 )
  = 3.149 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 7.0 - 1.09 ) * 1.0
  = 2.070 cm²
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 1.0 + (0.0 ) * 1.0 + 203.2² * 1.0
  = 1.577 cm²
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 800.0 - 609.6 ) * 10.0 * 1.0
  = 19.040 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 10.0, tr = 0.905, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.129, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

Govrn. thk, tg = 10.0, tr = 0.905, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.129, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

Govrn. thk, tg = 10.0, tr = 0.905, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.129, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C

Gov. MDMT of the Nozzle                              :   -104 °C
Gov. MDMT of the Reinforcement Pad                   :   -104 °C
Gov. MDMT of the nozzle to shell joint welded assembly : -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)    -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)     -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)             Dl    893.4000  mm.
Parallel to Vessel Wall, opening length               d    446.7000  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp      17.5000  mm.
```

Reinforcement Areas for Large Nozzle (Per App 1-7(a)): (cm^2)

AREA AVAILABLE, A1 to A6		No Pad	With Pad
Area Required [External Pressure]	AR	12.352	12.352
Area Available in Shell	A1	2.319	2.319
Area Available in Nozzle Wall	A2	2.070	2.070
Area Available in Inward Nozzle	A3	0.000	0.000
Area Available in Welds	A4	1.000	1.577
Area Available in Pad	A5	0.000	19.040
Area Available in Hub	A6	0.000	0.000
TOTAL AREA AVAILABLE	Atot	5.389	25.006

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

Note: The Nozzle does not fall within the scope of the diameter requirements of App. 1-7(b). Therefore, the Membrane and Bending stress checks are not required.

Weld Size Calculations, Description: M2 (24in)

```
Intermediate Calc. for nozzle/shell Welds    Tmin        7.0000   mm.
Intermediate Calc. for pad/shell Welds       TminPad     7.0000   mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld         4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
 Pad Weld            3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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, (18.527 - 3.1491 + 2 * 7.0 * 1.0 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 213.55 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.0696 + 19.04 + 1.5775 - 0.0 * 1.0 ) * 138
  = 312.83 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.0696 + 0.0 + 1. + ( 0.98 ) ) * 138
  = 55.84 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.0696 + 0.0 + 1.5775 + 19.04 + ( 0.98 ) ) * 138
  = 326.34 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 609.6 * 10.0 * 0.49 * 138
  = 647. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 800.0 * 8.0 * 0.49 * 138
  = 679. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 301.3) * ( 10.0 - 3.0 ) * 0.7 * 138
  = 640. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 609.6 * 10.0 * 0.74 * 138
  = 977. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
```

```
= ( 3.1416/2.0 ) * 609.6 * ( 10.0 - 3.0 ) * 0.74 * 138
= 684. kN
```

Strength of Failure Paths:

```
PATH11 = ( SPEW + SNW ) = ( 679 + 640 ) = 1319 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 647 + 977 + 684 + 0 ) = 2308 kN
PATH33 = ( Spew + Tngw + Sinw )
       = ( 679 + 684 + 0 ) = 1363 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 1318 kN , must exceed W = 213 kN  or W1 = 312 kN
Path 2-2 = 2307 kN , must exceed W = 213 kN  or W2 = 55 kN
Path 3-3 = 1363 kN , must exceed W = 213 kN  or W3 = 326 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   11  bars

Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 83.1858 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 243.1858 mm.

Percent Elongation Calculations:

```
% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro))  1.668 %
```

Input, Nozzle Desc: K8 (2in) From: 30

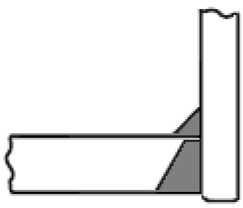
Pressure for Reinforcement Calculations	P	4.100	bars
Temperature for Internal Pressure	Temp	234	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1200.00	mm.
Design Length of Section	L	3699.9998	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1747.40	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	136.43	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		0.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		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: K8 (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation             2.000  in.
Actual Thickness Used in Calculation                   0.654  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
= (4.1*603.0)/(138*1.0-0.6*4.1)
= 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
= (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
= (4.1*28.4)/(136*1.0-0.6*4.1)
= 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3862 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)             Dl    113.6000  mm.
Parallel to Vessel Wall, opening length               d     56.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad    Tlnp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
= min( 1, Sn/Sv )
= min( 1, 136.4/137.9 )
= 0.989
```

Weld Strength Reduction Factor [fr2]:
```
= min( 1, Sn/Sv )
= min( 1, 136.4/137.9 )
```

```
  = 0.989
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.989, 1.0 )
  = 0.989
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.025	1.776	NA
Area in Shell	A1	2.941	0.440	NA
Area in Nozzle Wall	A2	4.680	4.576	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.989	0.989	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	8.610	6.005	NA

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(56.8*6.2213*1+2*13.6*6.2213*1(1-0.99))
  = 1.776 cm²
```

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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 6.221 ) - 2 * 13.6
    ( 1.0 * 7.0 - 1.0 * 6.2213 ) * ( 1 - 0.989 )
  = 0.440 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 13.6 - 0.39 ) 0.9894
  = 4.576 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

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

```
Wall Thickness for Internal/External pressures        ta = 3.3862 mm.
Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure       trb1 = 4.7961 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 4.7961 mm.
Wall Thickness, shell/head, external pressure       trb2 = 3.4524 mm.
```

```
Wall Thickness                   tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.3862, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

<u>Weld Size Calculations, Description: K8 (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.7758 - 0.4401 + 2 * 13.6 * 0.9894 *
    (1.0 * 7.0 - 6.2213 ) )138)
  = 21.31 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.5757 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 76.74 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.5757 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 102.71 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.5757 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 102.71 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 136
  = 88. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 94. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 88 + 144 ) = 232 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 88 + 0 + 94 + 0 ) = 182 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 88 + 94 + 0 ) = 182 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 231 kN , must exceed W = 21 kN  or W1 = 76 kN
 Path 2-2 = 182 kN , must exceed W = 21 kN  or W2 = 102 kN
 Path 3-3 = 182 kN , must exceed W = 21 kN  or W3 = 102 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 1.4718 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 211.4718 mm.

Input, Nozzle Desc: N04 (6in) **From: 40**

Pressure for Reinforcement Calculations	P	4.100	bars
Temperature for Internal Pressure	Temp	234	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1200.00	mm.
Design Length of Section	L	2649.9998	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		4550.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

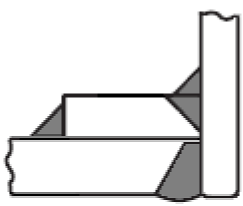
Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm²
Diameter of Pad along vessel surface	Dp	300.0000	mm.
Thickness of Pad	te	10.0000	mm.

```
Weld leg size between Pad and Shell           Wp      6.0000   mm.
Groove weld depth between Pad and Nozzle     Wgpn    10.0000   mm.
Reinforcing Pad Width                                65.8625   mm.

Flange Class                                    150
Flange Grade                                    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: N04 (6in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              5.869   in.
Actual Thickness Used in Calculation                    0.378   in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*77.54)/(118*1.0-0.6*4.1)
  = 0.2702 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5131 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    310.1452   mm.
Parallel to Vessel Wall, opening length             d     155.0726   mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000   mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr4]:
```
  = min( 1, Sp/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

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

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.820	4.234	NA
Area in Shell	A1	7.970	2.460	NA
Area in Nozzle Wall	A2	1.895	1.822	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.896	0.896	NA
Area in Element	A5	13.173	13.173	NA
TOTAL AREA AVAILABLE	Atot	23.934	18.351	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                 90.00   Degs.
```

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

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(155.0726*5.3937*1+2*6.6012*5.3937*1(1-0.86))
  = 4.234 cm²
```

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 )
  = 155.073( 1.0 * 7.0 - 1.0 * 5.394 ) - 2 * 6.601
    ( 1.0 * 7.0 - 1.0 * 5.3937 ) * ( 1 - 0.855 )
  = 2.460 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 6.6 - 0.51 ) * 0.855
  = 1.822 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Trapfr4
  = ( 0.6375 ) * 0.86 + (0.0 ) * 0.86 + 35.1399² * 1.0
  = 0.896 cm²
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 300.0 - 168.275 ) * 10.0 * 1.0
  = 13.173 cm²
```

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

```
 Wall Thickness for Internal/External pressures      ta = 3.5131 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 4.7961 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure     trb2 = 3.4524 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                     tb3 = 9.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.22, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.5131, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 9.6012 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 9.601, tr = 0.27, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.041, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

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

Govrn. thk, tg = 9.601, tr = 0.27, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.041, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

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

```
----------------------------------------------------------------------
```

Govrn. thk, tg = 9.601, tr = 0.27, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.041, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

```
----------------------------------------------------------------------
```

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

```
----------------------------------------------------------------------
```

Govrn. thk, tg = 9.601, tr = 0.27, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.041, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C

Gov. MDMT of the Nozzle                               :  -104 °C
Gov. MDMT of the Reinforcement Pad                    :  -104 °C
Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

Weld Size Calculations, Description: N04 (6in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin       6.6012  mm.
Intermediate Calc. for pad/shell Welds    TminPad      7.0000  mm.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
Nozzle Weld           4.6208 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
Pad Weld              3.5000 = 0.5*TminPad  4.2420 = 0.7 * Wp mm.
```

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, (4.2337 - 2.4602 + 2 * 6.6012 * 0.855 *
    (1.0 * 7.0 - 5.3937 ) )138)
  = 26.96 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.8218 + 13.1725 + 0.8965 - 0.0 * 0.86 ) * 138
  = 219.12 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.8218 + 0.0 + 0.5472 + ( 0.7902 ) ) * 138
  = 43.56 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.8218 + 0.0 + 0.8965 + 13.1725 + ( 0.7902 ) ) * 138
  = 230.01 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 168.275 * 8.0 * 0.49 * 118
  = 122. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 300.0 * 6.0 * 0.49 * 138
  = 191. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 80.8369) * ( 9.6012 - 3.0 ) * 0.7 * 118
  = 138. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 168.275 * 10.0 * 0.74 * 138
  = 270. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 168.275 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 189. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 191 + 138 ) = 329 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 122 + 270 + 189 + 0 ) = 581 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 191 + 189 + 0 ) = 380 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 329 kN , must exceed W = 26 kN  or W1 = 219 kN
Path 2-2 = 580 kN , must exceed W = 26 kN  or W2 = 43 kN
Path 3-3 = 379 kN , must exceed W = 26 kN  or W3 = 230 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 5.9286 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 165.9286 mm.

Input, Nozzle Desc: K1B (2in) From: 40

```
Pressure for Reinforcement Calculations          P        4.100  bars
Temperature for Internal Pressure             Temp          234  °C
Design External Pressure                      Pext         1.03  bars
Temperature for External Pressure           Tempex          100  °C

Shell Material                                          SA-516 70
Shell Allowable Stress at Temperature           Sv       137.90  N./mm²
Shell Allowable Stress At Ambient              Sva       137.90  N./mm²

Inside Diameter of Cylindrical Shell             D      1200.00  mm.
Design Length of Section                         L    2649.9998  mm.
Shell Finished (Minimum) Thickness               t      10.0000  mm.
Shell Internal Corrosion Allowance               c       3.0000  mm.
Shell External Corrosion Allowance              co       0.0000  mm.

Distance from Bottom/Left Tangent                       5400.00  mm.

User Entered Minimum Design Metal Temperature              5.00  °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                  SA-105
Material UNS Number                                     K03504
Material Specification/Type                           Forgings
Allowable Stress at Temperature                 Sn       136.43  N./mm²
Allowable Stress At Ambient                    Sna       137.90  N./mm²

Diameter Basis (for tr calc only)                            ID
Layout Angle                                              90.00  deg
Diameter                                                 2.0000  in.

Size and Thickness Basis                                 Actual
Actual Thickness                                tn      16.6000  mm.

Flange Material                                          SA-105
Flange Type                                      Long Weld Neck

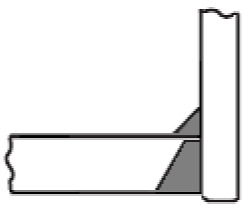
Corrosion Allowance                            can       3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     150.0000  mm.
Weld leg size between Nozzle and Pad/Shell      Wo      10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv       10.0000  mm.
Inside Projection                                h       0.0000  mm.
Weld leg size, Inside Element to Shell          Wi       0.0000  mm.

Flange Class                                            300
Flange Grade                                            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: K1B (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.000  in.
Actual Thickness Used in Calculation                    0.654  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3430 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    113.6000  mm.
Parallel to Vessel Wall, opening length              d     56.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
  = 0.989
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
```

```
  = 0.989
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.989, 1.0 )
  = 0.989
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

```
 AREA AVAILABLE, A1 to A5      |    Design|  External|     Mapnc|
 ---------------------------------------------------------------
 Area Required              Ar |     1.025|     1.540|        NA|
 Area in Shell              A1 |     2.941|     0.908|        NA|
 Area in Nozzle Wall        A2 |     4.680|     4.591|        NA|
 Area in Inward Nozzle      A3 |     0.000|     0.000|        NA|
 Area in Welds     A41+A42+A43 |     0.989|     0.989|        NA|
 Area in Element            A5 |     0.000|     0.000|        NA|
 TOTAL AREA AVAILABLE     Atot |     8.610|     6.488|        NA|
```

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(56.8*5.3937*1+2*13.6*5.3937*1(1-0.99))
  = 1.540 cm²
```

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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 5.394 ) - 2 * 13.6
    ( 1.0 * 7.0 - 1.0 * 5.3937 ) * ( 1 - 0.989 )
  = 0.908 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 13.6 - 0.34 ) 0.9894
  = 4.591 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

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

```
 Wall Thickness for Internal/External pressures        ta = 3.3430 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure       trb1 = 4.7961 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure       trb2 = 3.4524 mm.
```

```
Wall Thickness                tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                    tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.343, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A             -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
Min Metal Temp. w/o impact per UG-20(f)                   -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)    -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)     -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

Weld Size Calculations, Description: K1B (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.5396 - 0.9077 + 2 * 13.6 * 0.9894 *
    (1.0 * 7.0 - 5.3937 ) )138)
  = 14.67 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.5906 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 76.94 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.5906 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 102.92 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.5906 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 102.92 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 136
  = 88. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 94. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 88 + 144 ) = 232 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 88 + 0 + 94 + 0 ) = 182 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 88 + 94 + 0 ) = 182 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 231 kN , must exceed W = 14 kN  or W1 = 76 kN
 Path 2-2 = 182 kN , must exceed W = 14 kN  or W2 = 102 kN
 Path 3-3 = 182 kN , must exceed W = 14 kN  or W3 = 102 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 1.4718 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 161.4718 mm.

Input, Nozzle Desc: N07A (2in) From: 40

```
Pressure for Reinforcement Calculations        P         4.100   bars
Temperature for Internal Pressure              Temp        234   °C
Design External Pressure                       Pext       1.03   bars
Temperature for External Pressure              Tempex      100   °C

Shell Material                                         SA-516 70
Shell Allowable Stress at Temperature          Sv       137.90   N./mm²
Shell Allowable Stress At Ambient              Sva      137.90   N./mm²

Inside Diameter of Cylindrical Shell           D       1200.00   mm.
Design Length of Section                       L     2649.9998   mm.
Shell Finished (Minimum) Thickness             t       10.0000   mm.
Shell Internal Corrosion Allowance             c        3.0000   mm.
Shell External Corrosion Allowance             co       0.0000   mm.

Distance from Bottom/Left Tangent                      4550.00   mm.

User Entered Minimum Design Metal Temperature             5.00   °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                 SA-105
Material UNS Number                                    K03504
Material Specification/Type                          Forgings
Allowable Stress at Temperature                Sn       136.43   N./mm²
Allowable Stress At Ambient                    Sna      137.90   N./mm²

Diameter Basis (for tr calc only)                           ID
Layout Angle                                            270.00   deg
Diameter                                                2.0000   in.

Size and Thickness Basis                                 Actual
Actual Thickness                               tn      15.8500   mm.

Flange Material                                          SA-105
Flange Type                                       Long Weld Neck

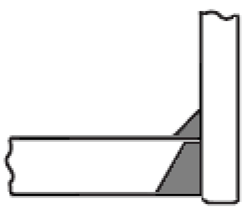
Corrosion Allowance                            can      3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle       E1         1.00
Joint Efficiency of Nozzle Neck                En         1.00

Outside Projection                             ho     150.0000   mm.
Weld leg size between Nozzle and Pad/Shell     Wo      10.0000   mm.
Groove weld depth between Nozzle and Vessel Wgnv       10.0000   mm.
Inside Projection                              h        0.0000   mm.
Weld leg size, Inside Element to Shell         Wi       0.0000   mm.

Flange Class                                           150
Flange Grade                                           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: N07A (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.000  in.
Actual Thickness Used in Calculation                    0.624  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3393 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    113.6000  mm.
Parallel to Vessel Wall, opening length              d     56.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
  = 0.989
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
```

```
  = 0.989
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.989, 1.0 )
  = 0.989
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.025	1.539	NA
Area in Shell	A1	2.942	0.908	NA
Area in Nozzle Wall	A2	4.420	4.332	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.989	0.989	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	8.351	6.230	NA

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(56.8*5.3937*1+2*12.85*5.3937*1(1-0.99))
  = 1.539 cm²
```

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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 5.394 ) - 2 * 12.85
    ( 1.0 * 7.0 - 1.0 * 5.3937 ) * ( 1 - 0.989 )
  = 0.908 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 12.85 - 0.34 ) 0.9894
  = 4.332 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

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

```
 Wall Thickness for Internal/External pressures       ta = 3.3393 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure       trb1 = 4.7961 mm.
 Wall Thickness                    tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure       trb2 = 3.4524 mm.
```

```
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                    tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.3393, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 15.8500 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), min(Curve:A, Curve:B)
```
----------------------------------------------------------------------
```
Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

<u>Weld Size Calculations, Description: N07A (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000   mm.
```

Results Per UW-16.1:
```
                         Required Thickness    Actual Thickness
Nozzle Weld             4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.5392 - 0.908 + 2 * 12.85 * 0.9894 *
     (1.0 * 7.0 - 5.3937 ) )138)
  = 14.34 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.3322 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 73.38 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.3322 + 0.0 + 0.9894 + ( 1.7799 ) ) * 138
  = 97.92 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.3322 + 0.0 + 0.9894 + 0.0 + ( 1.7799 ) ) * 138
  = 97.92 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 82.5 * 10.0 * 0.49 * 136
  = 87. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 34.825) * ( 15.85 - 3.0 ) * 0.7 * 136
  = 134. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 82.5 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 93. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 87 + 134 ) = 221 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 87 + 0 + 93 + 0 ) = 179 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 87 + 93 + 0 ) = 179 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 220 kN , must exceed W = 14 kN  or W1 = 73 kN
 Path 2-2 = 179 kN , must exceed W = 14 kN  or W2 = 97 kN
 Path 3-3 = 179 kN , must exceed W = 14 kN  or W3 = 97 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 1.4197 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 161.4197 mm.

Input, Nozzle Desc: N09A (1.5in) **From: 40**

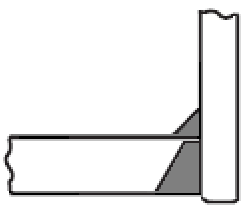
Pressure for Reinforcement Calculations	P	4.100	bars
Temperature for Internal Pressure	Temp	234	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1200.00	mm.
Design Length of Section	L	2649.9998	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Cylinder/Cone Centerline	L1	200.0000	mm.
Distance from Bottom/Left Tangent		3750.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	136.43	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		289.14	deg
Diameter		1.5000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	14.4500	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: N09A (1.5in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              1.500  in.
Actual Thickness Used in Calculation                    0.569  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
= (4.1*603.0)/(138*1.0-0.6*4.1)
= 1.7961 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
= R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
= 22.05(exp([4.1/(136.43*1.0]-1)
= 0.0664 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3000 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)             Dl     93.4727  mm.
Parallel to Vessel Wall, opening length               d     46.7364  mm.
Normal to Vessel Wall (Thickness Limit), no pad    Tlnp     17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |     Design|  External|     Mapnc|
---------------------------------------------------------------
```

```
Area Required                  Ar |     0.422|     1.267|        NA|
Area in Shell                  A1 |     2.837|     0.747|        NA|
Area in Nozzle Wall            A2 |     4.134|     4.050|        NA|
Area in Inward Nozzle          A3 |     0.000|     0.000|        NA|
Area in Welds         A41+A42+A43 |     0.989|     0.989|        NA|
Area in Element                A5 |     0.000|     0.000|        NA|
TOTAL AREA AVAILABLE         Atot |     7.961|     5.786|        NA|
```

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                 70.66   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(46.7364*5.3937*1+2*11.45*5.3937*1(1-0.99))
  = 1.267 cm²
```

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 )
  = 46.736( 1.0 * 7.0 - 1.0 * 5.394 ) - 2 * 11.45
    ( 1.0 * 7.0 - 1.0 * 5.3937 ) * ( 1 - 0.989 )
  = 0.747 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 17.5 )( 11.45 - 0.3 ) 0.9894/sin( 72.4 )
  = 4.050 cm²
```

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

<u>Weld Size Calculations, Description: N09A (1.5in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin       7.0000   mm.
```

Results Per UW-16.1:

```
                     Required Thickness    Actual Thickness
Nozzle Weld         4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.267 - 0.7468 + 2 * 11.45 * 0.9894 *
     (1.0 * 7.0 - 5.3937 ) )138)
  = 12.19 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.0495 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 69.48 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.0495 + 0.0 + 0.9894 + ( 1.586 ) ) * 138
  = 91.35 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.0495 + 0.0 + 0.9894 + 0.0 + ( 1.586 ) ) * 138
  = 91.35 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 71.0054 * 10.0 * 0.49 * 136
  = 75. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 29.4354) * ( 14.45 - 3.0 ) * 0.7 * 136
  = 101. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 71.0054 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 80. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 75 + 101 ) = 176 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 75 + 0 + 80 + 0 ) = 154 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 75 + 80 + 0 ) = 154 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 175 kN , must exceed W = 12 kN  or W1 = 69 kN
 Path 2-2 = 154 kN , must exceed W = 12 kN  or W2 = 91 kN
 Path 3-3 = 154 kN , must exceed W = 12 kN  or W3 = 91 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1  bars
```

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

Reinforcement CALCULATION, Description: N09A (1.5in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation             1.500  in.
 Actual Thickness Used in Calculation                   0.569  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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 22.05(exp([4.1/(136.43*1.0]-1)
  = 0.0664 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3000 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl     88.2000  mm.
 Parallel to Vessel Wall, opening length              d     44.1000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |    Design|  External|     Mapnc|
---------------------------------------------------------------
Area Required              Ar |     0.796|     1.196|        NA|
Area in Shell              A1 |     2.282|     0.704|        NA|
Area in Nozzle Wall        A2 |     3.942|     3.861|        NA|
Area in Inward Nozzle      A3 |     0.000|     0.000|        NA|
Area in Welds     A41+A42+A43 |     0.989|     0.989|        NA|
Area in Element            A5 |     0.000|     0.000|        NA|
TOTAL AREA AVAILABLE     Atot |     7.214|     5.555|        NA|
```

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(44.1*5.3937*1+2*11.45*5.3937*1(1-0.99))
  = 1.196 cm²
```

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 )
  = 44.1( 1.0 * 7.0 - 1.0 * 5.394 ) - 2 * 11.45
    ( 1.0 * 7.0 - 1.0 * 5.3937 ) * ( 1 - 0.989 )
  = 0.704 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 11.45 - 0.3 ) 0.9894
  = 3.861 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 3.3000 mm.
Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 4.7961 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 4.7961 mm.
Wall Thickness, shell/head, external pressure     trb2 = 3.4524 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                     tb3 = 7.5200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.52, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
```

```
  = max( 3.3, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 14.4500 mm. --> OK

<u>Weld Size Calculations, Description: N09A (1.5in)</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000   mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
 Nozzle Weld             4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.1959 - 0.7045 + 2 * 11.45 * 0.9894 *
     (1.0 * 7.0 - 5.3937 ) )138)
  = 11.79 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.861 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 66.88 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.861 + 0.0 + 0.9894 + ( 1.586 ) ) * 138
  = 88.75 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.861 + 0.0 + 0.9894 + 0.0 + ( 1.586 ) ) * 138
  = 88.75 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 67.0 * 10.0 * 0.49 * 136
  = 70. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 27.775) * ( 14.45 - 3.0 ) * 0.7 * 136
  = 95. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 67.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 75. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 70 + 95 ) = 166 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 70 + 0 + 75 + 0 ) = 146 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 70 + 75 + 0 ) = 146 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 165 kN , must exceed W = 11 kN  or W1 = 66 kN
Path 2-2 = 145 kN , must exceed W = 11 kN  or W2 = 88 kN
Path 3-3 = 145 kN , must exceed W = 11 kN  or W3 = 88 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 12.9850 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 173.5808 mm.

Input, Nozzle Desc: N09B (1.5in) **From: 40**

```
Pressure for Reinforcement Calculations          P        4.100  bars
Temperature for Internal Pressure             Temp          234  °C
Design External Pressure                      Pext         1.03  bars
Temperature for External Pressure           Tempex          100  °C

Shell Material                                        SA-516 70
Shell Allowable Stress at Temperature           Sv       137.90  N./mm²
Shell Allowable Stress At Ambient              Sva       137.90  N./mm²

Inside Diameter of Cylindrical Shell             D      1200.00  mm.
Design Length of Section                         L    2649.9998  mm.
Shell Finished (Minimum) Thickness               t      10.0000  mm.
Shell Internal Corrosion Allowance               c       3.0000  mm.
Shell External Corrosion Allowance              co       0.0000  mm.

Distance from Cylinder/Cone Centerline          L1     200.0000  mm.

Distance from Bottom/Left Tangent                       3750.00  mm.

User Entered Minimum Design Metal Temperature              5.00  °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                SA-105
Material UNS Number                                    K03504
Material Specification/Type                          Forgings
Allowable Stress at Temperature                 Sn       136.43  N./mm²
Allowable Stress At Ambient                    Sna       137.90  N./mm²

Diameter Basis (for tr calc only)                           ID
Layout Angle                                             250.86  deg
Diameter                                                 1.5000  in.

Size and Thickness Basis                                Actual
Actual Thickness                                tn      14.4500  mm.

Flange Material                                         SA-105
Flange Type                                     Long Weld Neck

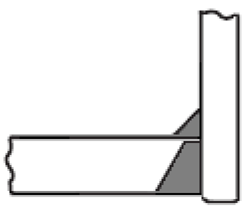
Corrosion Allowance                            can       3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     150.0000  mm.
Weld leg size between Nozzle and Pad/Shell      Wo      10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv        10.0000  mm.
Inside Projection                                h       0.0000  mm.
Weld leg size, Inside Element to Shell          Wi       0.0000  mm.

Flange Class                                          150
Flange Grade                                          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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: N09B (1.5in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              1.500   in.
Actual Thickness Used in Calculation                    0.569   in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 22.05(exp([4.1/(136.43*1.0]-1)
  = 0.0664 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3000 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl     93.4727  mm.
Parallel to Vessel Wall, opening length              d     46.7364  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |     Design|  External|      Mapnc|
---------------------------------------------------------------
```

```
Area Required              Ar |      0.422|      1.267|          NA|
Area in Shell              A1 |      2.837|      0.747|          NA|
Area in Nozzle Wall        A2 |      4.134|      4.050|          NA|
Area in Inward Nozzle      A3 |      0.000|      0.000|          NA|
Area in Welds     A41+A42+A43 |      0.989|      0.989|          NA|
Area in Element            A5 |      0.000|      0.000|          NA|
TOTAL AREA AVAILABLE     Atot |      7.961|      5.786|          NA|
```

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  70.66   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(46.7364*5.3937*1+2*11.45*5.3937*1(1-0.99))
  = 1.267 cm²
```

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 )
  = 46.736( 1.0 * 7.0 - 1.0 * 5.394 ) - 2 * 11.45
    ( 1.0 * 7.0 - 1.0 * 5.3937 ) * ( 1 - 0.989 )
  = 0.747 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 17.5 )( 11.45 - 0.3 ) 0.9894/sin( 72.4 )
  = 4.050 cm²
```

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)       -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)        -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

<u>Weld Size Calculations, Description: N09B (1.5in)</u>

```
Intermediate Calc. for nozzle/shell Welds    Tmin       7.0000   mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
Nozzle Weld             4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.267 - 0.7468 + 2 * 11.45 * 0.9894 *
     (1.0 * 7.0 - 5.3937 ) )138)
  = 12.19 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.0495 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 69.48 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.0495 + 0.0 + 0.9894 + ( 1.586 ) ) * 138
  = 91.35 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.0495 + 0.0 + 0.9894 + 0.0 + ( 1.586 ) ) * 138
  = 91.35 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 71.0054 * 10.0 * 0.49 * 136
  = 75. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 29.4354) * ( 14.45 - 3.0 ) * 0.7 * 136
  = 101. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 71.0054 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 80. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 75 + 101 ) = 176 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 75 + 0 + 80 + 0 ) = 154 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 75 + 80 + 0 ) = 154 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 175 kN , must exceed W = 12 kN  or W1 = 69 kN
 Path 2-2 = 154 kN , must exceed W = 12 kN  or W2 = 91 kN
 Path 3-3 = 154 kN , must exceed W = 12 kN  or W3 = 91 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

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

Reinforcement CALCULATION, Description: N09B (1.5in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation              1.500  in.
 Actual Thickness Used in Calculation                    0.569  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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 22.05(exp([4.1/(136.43*1.0]-1)
  = 0.0664 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3000 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)           Dl     88.2000  mm.
 Parallel to Vessel Wall, opening length             d     44.1000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.796	1.196	NA
Area in Shell	A1	2.282	0.704	NA
Area in Nozzle Wall	A2	3.942	3.861	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.989	0.989	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	7.214	5.555	NA

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(44.1*5.3937*1+2*11.45*5.3937*1(1-0.99))
  = 1.196 cm²
```

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 )
  = 44.1( 1.0 * 7.0 - 1.0 * 5.394 ) - 2 * 11.45
    ( 1.0 * 7.0 - 1.0 * 5.3937 ) * ( 1 - 0.989 )
  = 0.704 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 11.45 - 0.3 ) 0.9894
  = 3.861 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

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

```
 Wall Thickness for Internal/External pressures       ta = 3.3000 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 4.7961 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.4524 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 7.5200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.52, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
```

```
  = max( 3.3, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 14.4500 mm. --> OK

<u>Weld Size Calculations, Description: N09B (1.5in)</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000   mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
 Nozzle Weld            4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.1959 - 0.7045 + 2 * 11.45 * 0.9894 *
    (1.0 * 7.0 - 5.3937 ) )138)
  = 11.79 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.861 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 66.88 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.861 + 0.0 + 0.9894 + ( 1.586 ) ) * 138
  = 88.75 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.861 + 0.0 + 0.9894 + 0.0 + ( 1.586 ) ) * 138
  = 88.75 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 67.0 * 10.0 * 0.49 * 136
  = 70. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 27.775) * ( 14.45 - 3.0 ) * 0.7 * 136
  = 95. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 67.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 75. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 70 + 95 ) = 166 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 70 + 0 + 75 + 0 ) = 146 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 70 + 75 + 0 ) = 146 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 165 kN , must exceed W = 11 kN  or W1 = 66 kN
Path 2-2 = 145 kN , must exceed W = 11 kN  or W2 = 88 kN
Path 3-3 = 145 kN , must exceed W = 11 kN  or W3 = 88 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 12.9850 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 173.5808 mm.

Input, Nozzle Desc: K4A (2in) From: 40

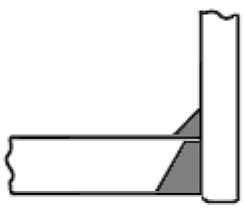
Pressure for Reinforcement Calculations	P	4.100	bars
Temperature for Internal Pressure	Temp	234	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1200.00	mm.
Design Length of Section	L	2649.9998	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Cylinder/Cone Centerline	L1	400.0000	mm.
Distance from Bottom/Left Tangent		4650.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	136.43	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		40.98	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K4A (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.000  in.
Actual Thickness Used in Calculation                    0.654  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
 = (4.1*603.0)/(138*1.0-0.6*4.1)
 = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
 = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
 = (4.1*28.4)/(136*1.0-0.6*4.1)
 = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3862 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    151.6108  mm.
Parallel to Vessel Wall, opening length              d     75.8054  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5     |     Design|  External|     Mapnc|
---------------------------------------------------------------
```

```
Area Required              Ar |      0.683|      2.052|          NA|
Area in Shell              A1 |      4.608|      1.213|          NA|
Area in Nozzle Wall        A2 |      5.959|      5.826|          NA|
Area in Inward Nozzle      A3 |      0.000|      0.000|          NA|
Area in Welds     A41+A42+A43 |      0.989|      0.989|          NA|
Area in Element            A5 |      0.000|      0.000|          NA|
TOTAL AREA AVAILABLE     Atot |     11.556|      8.028|          NA|
```

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  48.53   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(75.8054*5.3937*1+2*13.6*5.3937*1(1-0.99))
  = 2.052 cm²
```

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 )
  = 75.805( 1.0 * 7.0 - 1.0 * 5.394 ) - 2 * 13.6
     ( 1.0 * 7.0 - 1.0 * 5.3937 ) * ( 1 - 0.989 )
  = 1.213 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 17.5 )( 13.6 - 0.39 ) 0.9894/sin( 51.8 )
  = 5.826 cm²
```

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

<u>Weld Size Calculations, Description: K4A (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds    Tmin       7.0000   mm.
```

Results Per UW-16.1:

```
                           Required Thickness    Actual Thickness
Nozzle Weld              4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (2.0522 - 1.213 + 2 * 13.6 * 0.9894 *
    (1.0 * 7.0 - 5.3937 ) )138)
  = 17.53 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 5.8261 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 93.98 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 5.8261 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 119.95 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 5.8261 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 119.95 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 112.1066 * 10.0 * 0.49 * 136
  = 118. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 46.978) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 192. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 112.1066 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 126. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 118 + 192 ) = 309 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 118 + 0 + 126 + 0 ) = 243 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 118 + 126 + 0 ) = 243 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 309 kN , must exceed W = 17 kN  or W1 = 93 kN
 Path 2-2 = 243 kN , must exceed W = 17 kN  or W2 = 119 kN
 Path 3-3 = 243 kN , must exceed W = 17 kN  or W3 = 119 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    16   bars
```

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

```
 Nozzle is O.K. for the External Pressure           1   bars
```

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

Reinforcement CALCULATION, Description: K4A (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation             2.000   in.
 Actual Thickness Used in Calculation                   0.654   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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3862 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    113.6000  mm.
 Parallel to Vessel Wall, opening length              d     56.8000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |    Design|  External|     Mapnc|
---------------------------------------------------------------
Area Required              Ar |     1.025|     1.540|        NA|
Area in Shell              A1 |     2.941|     0.908|        NA|
Area in Nozzle Wall        A2 |     4.680|     4.576|        NA|
Area in Inward Nozzle      A3 |     0.000|     0.000|        NA|
Area in Welds     A41+A42+A43 |     0.989|     0.989|        NA|
Area in Element            A5 |     0.000|     0.000|        NA|
TOTAL AREA AVAILABLE     Atot |     8.610|     6.473|        NA|
```

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(56.8*5.3937*1+2*13.6*5.3937*1(1-0.99))
  = 1.540 cm²
```

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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 5.394 ) - 2 * 13.6
    ( 1.0 * 7.0 - 1.0 * 5.3937 ) * ( 1 - 0.989 )
  = 0.908 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 13.6 - 0.39 ) 0.9894
  = 4.576 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 3.3862 mm.
Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 4.7961 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 4.7961 mm.
Wall Thickness, shell/head, external pressure     trb2 = 3.4524 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                     tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
```

```
  = max( 3.3862, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Weld Size Calculations, Description: K4A (2in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000   mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
 Nozzle Weld             4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.5396 - 0.9077 + 2 * 13.6 * 0.9894 *
    (1.0 * 7.0 - 5.3937 ) )138)
  = 14.67 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.5757 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 76.74 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.5757 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 102.71 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.5757 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 102.71 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 136
  = 88. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 94. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 88 + 144 ) = 232 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 88 + 0 + 94 + 0 ) = 182 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 88 + 94 + 0 ) = 182 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 231 kN , must exceed W = 14 kN  or W1 = 76 kN
Path 2-2 = 182 kN , must exceed W = 14 kN  or W2 = 102 kN
Path 3-3 = 182 kN , must exceed W = 14 kN  or W3 = 102 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 41.4600 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 254.7896 mm.

Input, Nozzle Desc: K6 (2in) **From: 40**

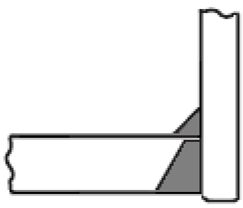
Pressure for Reinforcement Calculations	P	4.100	bars
Temperature for Internal Pressure	Temp	234	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1200.00	mm.
Design Length of Section	L	2649.9998	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		5000.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	136.43	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		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: K6 (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation             2.000  in.
 Actual Thickness Used in Calculation                   0.654  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*31.4)/(136*1.0-0.6*4.1)
  = 0.0945 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3430 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    125.6000  mm.
 Parallel to Vessel Wall, opening length              d     62.8000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
  = 0.989
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 136.4/137.9 )
```

= 0.989

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(0.989, 1.0)
= 0.989

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.132	1.700	NA
Area in Shell	A1	3.256	1.005	NA
Area in Nozzle Wall	A2	3.638	3.552	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.989	0.989	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	7.883	5.546	NA

The External 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 * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(62.8*5.3937*1+2*10.6*5.3937*1(1-0.99))
= 1.700 cm^2

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)
= 62.8(1.0 * 7.0 - 1.0 * 5.394) - 2 * 10.6
(1.0 * 7.0 - 1.0 * 5.3937) * (1 - 0.989)
= 1.005 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 17.5)(10.6 - 0.34) 0.9894
= 3.552 cm^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo^2 * fr2 + (Wi-can/0.707)^2 * fr2
= 10.0^2 * 0.9894 + (0.0)^2 * 0.9894
= 0.989 cm^2

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

Wall Thickness for Internal/External pressures ta = 6.3430 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 4.7961 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 7.5000 mm.
Wall Thickness, shell/head, external pressure trb2 = 3.4524 mm.

```
Wall Thickness                  tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                     tb3 = 10.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 10.8, max( 7.5, 7.5 ) ]
  = 7.5000 mm.
```

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

```
  = max( ta, tb )
  = max( 6.343, 7.5 )
  = 7.5000 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

```
----------------------------------------------------------------------
```

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

<u>Weld Size Calculations, Description: K6 (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.6997 - 1.0051 + 2 * 10.6 * 0.9894 *
    (1.0 * 7.0 - 5.3937 ) )138)
  = 14.22 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.5518 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 62.62 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.5518 + 0.0 + 0.9894 + ( 1.4682 ) ) * 138
  = 82.86 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.5518 + 0.0 + 0.9894 + 0.0 + ( 1.4682 ) ) * 138
  = 82.86 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 136
  = 88. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 36.7) * ( 16.6 - 6.0 ) * 0.7 * 136
  = 117. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 94. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 88 + 117 ) = 205 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 88 + 0 + 94 + 0 ) = 182 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 88 + 94 + 0 ) = 182 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 204 kN , must exceed W = 14 kN  or W1 = 62 kN
 Path 2-2 = 182 kN , must exceed W = 14 kN  or W2 = 82 kN
 Path 3-3 = 182 kN , must exceed W = 14 kN  or W3 = 82 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    16   bars
```

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

```
 Nozzle is O.K. for the External Pressure           1   bars
```

The Drop for this Nozzle is : 1.4718 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 161.4718 mm.

Input, Nozzle Desc: K1 (2in) From: 40

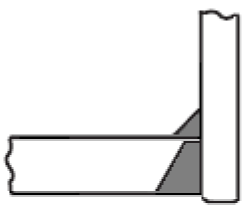
Pressure for Reinforcement Calculations	P	4.100	bars
Temperature for Internal Pressure	Temp	234	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1200.00	mm.
Design Length of Section	L	2649.9998	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Cylinder/Cone Centerline	L1	400.0000	mm.
Distance from Bottom/Left Tangent		5200.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	136.43	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		40.98	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K1 (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.000  in.
Actual Thickness Used in Calculation                    0.654  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
= (4.1*603.0)/(138*1.0-0.6*4.1)
= 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
= (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
= (4.1*28.4)/(136*1.0-0.6*4.1)
= 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3862 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)           Dl    151.6108   mm.
Parallel to Vessel Wall, opening length             d     75.8054   mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp     17.5000   mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

```
AREA AVAILABLE, A1 to A5      |     Design|  External|      Mapnc|
---------------------------------------------------------------
```

```
Area Required              Ar |      0.683|      2.052|         NA|
Area in Shell              A1 |      4.608|      1.213|         NA|
Area in Nozzle Wall        A2 |      5.959|      5.826|         NA|
Area in Inward Nozzle      A3 |      0.000|      0.000|         NA|
Area in Welds     A41+A42+A43 |      0.989|      0.989|         NA|
Area in Element            A5 |      0.000|      0.000|         NA|
TOTAL AREA AVAILABLE     Atot |     11.556|      8.028|         NA|
```

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  48.53   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(75.8054*5.3937*1+2*13.6*5.3937*1(1-0.99))
  = 2.052 cm²
```

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 )
  = 75.805( 1.0 * 7.0 - 1.0 * 5.394 ) - 2 * 13.6
     ( 1.0 * 7.0 - 1.0 * 5.3937 ) * ( 1 - 0.989 )
  = 1.213 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 17.5 )( 13.6 - 0.39 ) 0.9894/sin( 51.8 )
  = 5.826 cm²
```

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A               -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
Min Metal Temp. w/o impact per UG-20(f)                     -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/51.10 = 0.080
```

Weld Size Calculations, Description: K1 (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin       7.0000   mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
Nozzle Weld             4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (2.0522 - 1.213 + 2 * 13.6 * 0.9894 *
    (1.0 * 7.0 - 5.3937 ) )138)
  = 17.53 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 5.8261 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 93.98 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 5.8261 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 119.95 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 5.8261 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 119.95 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 112.1066 * 10.0 * 0.49 * 136
  = 118. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 46.978) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 192. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 112.1066 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 126. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 118 + 192 ) = 309 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 118 + 0 + 126 + 0 ) = 243 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 118 + 126 + 0 ) = 243 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 309 kN , must exceed W = 17 kN  or W1 = 93 kN
 Path 2-2 = 243 kN , must exceed W = 17 kN  or W2 = 119 kN
 Path 3-3 = 243 kN , must exceed W = 17 kN  or W3 = 119 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   16   bars
```

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

```
 Nozzle is O.K. for the External Pressure           1   bars
```

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

Reinforcement CALCULATION, Description: K1 (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation            2.000   in.
 Actual Thickness Used in Calculation                  0.654   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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*28.4)/(136*1.0-0.6*4.1)
  = 0.0855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3862 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    113.6000  mm.
 Parallel to Vessel Wall, opening length              d     56.8000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

```
AREA AVAILABLE, A1 to A5      |    Design|  External|      Mapnc|
----------------------------------------------------------------
Area Required              Ar |     1.025|     1.540|         NA|
Area in Shell              A1 |     2.941|     0.908|         NA|
Area in Nozzle Wall        A2 |     4.680|     4.576|         NA|
Area in Inward Nozzle      A3 |     0.000|     0.000|         NA|
Area in Welds     A41+A42+A43 |     0.989|     0.989|         NA|
Area in Element            A5 |     0.000|     0.000|         NA|
TOTAL AREA AVAILABLE     Atot |     8.610|     6.473|         NA|
```

The External 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 * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(56.8*5.3937*1+2*13.6*5.3937*1(1-0.99))
  = 1.540 cm²
```

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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 5.394 ) - 2 * 13.6
    ( 1.0 * 7.0 - 1.0 * 5.3937 ) * ( 1 - 0.989 )
  = 0.908 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 13.6 - 0.39 ) 0.9894
  = 4.576 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.9894 + ( 0.0 )² * 0.9894
  = 0.989 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures       ta = 3.3862 mm.
Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure      trb1 = 4.7961 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 4.7961 mm.
Wall Thickness, shell/head, external pressure      trb2 = 3.4524 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( 3.3862, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Weld Size Calculations, Description: K1 (2in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000   mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
 Nozzle Weld             4.9000 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

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, (1.5396 - 0.9077 + 2 * 13.6 * 0.9894 *
     (1.0 * 7.0 - 5.3937 ) )138)
  = 14.67 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.5757 + 0.0 + 0.9894 - 0.0 * 0.99 ) * 138
  = 76.74 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.5757 + 0.0 + 0.9894 + ( 1.8838 ) ) * 138
  = 102.71 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.5757 + 0.0 + 0.9894 + 0.0 + ( 1.8838 ) ) * 138
  = 102.71 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 136
  = 88. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 136
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 94. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 88 + 144 ) = 232 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 88 + 0 + 94 + 0 ) = 182 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 88 + 94 + 0 ) = 182 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 231 kN , must exceed W = 14 kN  or W1 = 76 kN
Path 2-2 = 182 kN , must exceed W = 14 kN  or W2 = 102 kN
Path 3-3 = 182 kN , must exceed W = 14 kN  or W3 = 102 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   16  bars
```

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

```
Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 41.4600 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 254.7896 mm.

Input, Nozzle Desc: N01 (10in) **From: 50**

```
Pressure for Reinforcement Calculations        P        4.100   bars
Temperature for Internal Pressure           Temp          234   °C
Design External Pressure                    Pext         1.03   bars
Temperature for External Pressure         Tempex          100   °C

Shell Material                                     SA-516 70
Shell Allowable Stress at Temperature         Sv       137.90   N./mm²
Shell Allowable Stress At Ambient            Sva       137.90   N./mm²

Inside Diameter of Cylindrical Shell           D      1200.00   mm.
Design Length of Section                       L    2649.9998   mm.
Shell Finished (Minimum) Thickness             t      10.0000   mm.
Shell Internal Corrosion Allowance             c       3.0000   mm.
Shell External Corrosion Allowance            co       0.0000   mm.

Distance from Bottom/Left Tangent                     5900.00   mm.

User Entered Minimum Design Metal Temperature            5.00   °C
```

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       117.90   N./mm²
Allowable Stress At Ambient                  Sna       117.90   N./mm²

Diameter Basis (for tr calc only)                          ID
Layout Angle                                            90.00   deg
Diameter                                              10.0000   in.

Size and Thickness Basis                                 Minimum
Nominal Thickness                             tn           40

Flange Material                                        SA-105
Flange Type                                  Weld Neck Flange

Corrosion Allowance                          can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle      E1         1.00
Joint Efficiency of Nozzle Neck               En         1.00

Outside Projection                            ho     150.0000   mm.
Weld leg size between Nozzle and Pad/Shell    Wo      10.0000   mm.
Groove weld depth between Nozzle and Vessel Wgnv      10.0000   mm.
Inside Projection                              h       0.0000   mm.
Weld leg size, Inside Element to Shell        Wi       0.0000   mm.

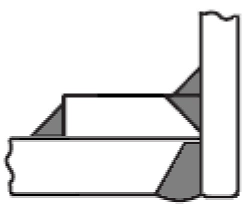
Pad Material                                       SA-516 70
Pad Allowable Stress at Temperature           Sp       137.90   N./mm²
Pad Allowable Stress At Ambient              Spa       137.90   N./mm²
Diameter of Pad along vessel surface          Dp     450.0000   mm.
Thickness of Pad                              te      10.0000   mm.
```

```
Weld leg size between Pad and Shell          Wp      10.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn     10.0000  mm.
Reinforcing Pad Width                                88.4750  mm.

Flange Class                                       150
Flange Grade                                       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: N01 (10in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation            10.111  in.
Actual Thickness Used in Calculation                   0.319  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*603.0)/(138*1.0-0.6*4.1)
  = 1.7961 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (4.1*131.41)/(118*1.0-0.6*4.1)
  = 0.4580 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.6850 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    525.6515   mm.
Parallel to Vessel Wall, opening length              d    262.8257   mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000   mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr4]:
```
  = min( 1, Sp/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

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

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	4.747	7.128	NA
Area in Shell	A1	13.600	4.198	NA
Area in Nozzle Wall	A2	1.393	1.325	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.802	1.802	NA
Area in Element	A5	17.695	17.695	NA
TOTAL AREA AVAILABLE	Atot	34.489	25.019	NA

The External 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:	273.0500	10.0000	mm.
Based on given Pad Diameter:	450.0000	0.0000	mm.
Based on Shell or Nozzle Thickness:	273.0500	8.1121	mm.

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(262.8257*5.3937*1+2*5.1121*5.3937*1(1-0.86))
  = 7.128 cm²
```

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 )
```

```
  = 262.826( 1.0 * 7.0 - 1.0 * 5.394 ) - 2 * 5.112
    ( 1.0 * 7.0 - 1.0 * 5.3937 ) * ( 1 - 0.855 )
  = 4.198 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 5.11 - 0.69 ) * 0.855
  = 1.325 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.9375 ) * 0.86 + (0.0 ) * 0.86 + 254.0² * 1.0
  = 1.802 cm²
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 450.0 - 273.05 ) * 10.0 * 1.0
  = 17.695 cm²
```

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

```
 Wall Thickness for Internal/External pressures       ta = 3.6850 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 4.7961 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 4.7961 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.4524 mm.
 Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 11.1026 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 11.103, max( 4.7961, 4.5 ) ]
  = 4.7961 mm.
```

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

```
  = max( ta, tb )
  = max( 3.685, 4.7961 )
  = 4.7961 mm.
```

Available Nozzle Neck Thickness = 8.1121 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
 Sustained   :      53.0,  Allowable :    117.9 N./mm²  Passed
 Expansion   :       0.0,  Allowable :    241.8 N./mm²  Passed
 Occasional  :       5.2,  Allowable :    156.8 N./mm²  Passed
 Shear       :       8.3,  Allowable :     82.5 N./mm²  Passed
```

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 8.112, tr = 0.458, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.09, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

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

Govrn. thk, tg = 8.112, tr = 0.458, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.09, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

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

Govrn. thk, tg = 8.112, tr = 0.458, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.09, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

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

Govrn. thk, tg = 10.0, tr = 1.796, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.257, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

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

Govrn. thk, tg = 8.112, tr = 0.458, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.09, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C

Gov. MDMT of the Nozzle                                :  -104 °C
Gov. MDMT of the Reinforcement Pad                     :  -104 °C
Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

Weld Size Calculations, Description: N01 (10in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin        5.1121  mm.
Intermediate Calc. for pad/shell Welds    TminPad       7.0000  mm.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
Nozzle Weld           3.5785 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
Pad Weld              3.5000 = 0.5*TminPad  7.0700 = 0.7 * Wp mm.
```

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, (7.128 - 4.1979 + 2 * 5.1121 * 0.855 *
    (1.0 * 7.0 - 5.3937 ) )138)
  = 42.34 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.3248 + 17.695 + 1.8016 - 0.0 * 0.86 ) * 138
  = 287.10 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.3248 + 0.0 + 0.855 + ( 0.6119 ) ) * 138
  = 38.49 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.3248 + 0.0 + 1.8016 + 17.695 + ( 0.6119 ) ) * 138
  = 295.54 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 273.05 * 10.0 * 0.49 * 118
  = 248. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 450.0 * 10.0 * 0.49 * 138
  = 478. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 133.9689) * ( 8.1121 - 3.0 ) * 0.7 * 118
  = 178. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
```

```
  =  (3.1416/2 ) * 273.05 * 10.0 * 0.74 * 138
  = 438. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 273.05 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 306. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 478 + 178 ) = 655 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 248 + 438 + 306 + 0 ) = 992 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 478 + 306 + 0 ) = 784 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 655 kN , must exceed W = 42 kN  or W1 = 287 kN
 Path 2-2 = 991 kN , must exceed W = 42 kN  or W2 = 38 kN
 Path 3-3 = 783 kN , must exceed W = 42 kN  or W3 = 295 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   12   bars
```

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

```
 Nozzle is O.K. for the External Pressure           1   bars
```

The Drop for this Nozzle is : 15.7390 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.7390 mm.

Input Echo, WRC107/537 Item 1, Description: N01 (10in) :

```
 Diameter Basis for Vessel                   Vbasis       ID
 Cylindrical or Spherical Vessel             Cylsph       Cylindrical
 Internal Corrosion Allowance                   Cas       3.0000   mm.
 Vessel Diameter                                 Dv     1200.000   mm.
 Vessel Thickness                                Tv       10.000   mm.

 Design Temperature                              T1        234.0   °C
 Vessel Material                                        SA-516 70
 Vessel UNS Number                                         K02700
 Vessel Cold S.I. Allowable                     Smc       137.90   N./mm²
 Vessel Hot  S.I. Allowable                     Smh       137.90   N./mm²
```

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

```
 Attachment Type                               Type       Round

 Diameter Basis for Nozzle                   Nbasis       ID
```

```
Corrosion Allowance for Nozzle                Can       3.0000  mm.
Nozzle Diameter                               Dn       256.826  mm.
Nozzle Thickness                              Tn         8.112  mm.
Nozzle Material                                     SA-106 B
Nozzle UNS Number                                       K03006
Nozzle Cold S.I. Allowable                   SNmc       117.90  N./mm²
Nozzle Hot  S.I. Allowable                   SNmh       117.90  N./mm²

Thickness of Reinforcing Pad                 Tpad       10.000  mm.
Diameter  of Reinforcing Pad                 Dpad      450.000  mm.

Design Internal Pressure                       Dp        4.100  bars
Include Pressure Thrust                                     No
```

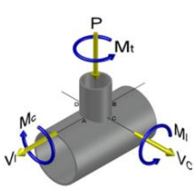
External Forces and Moments in WRC 107/537 Convention:

```
Radial Load              (SUS)                  P         14.0  kN
Longitudinal Shear       (SUS)                 Vl         14.0  kN
Circumferential Shear    (SUS)                 Vc        -10.5  kN
Circumferential Moment   (SUS)                 Mc      -7000.0  N-m
Longitudinal Moment      (SUS)                 Ml     -10500.0  N-m
Torsional Moment         (SUS)                 Mt      -9100.0  N-m


Use Interactive Control                          No
WRC107 Version                         Version   March   1979

Include Pressure Stress Indices per Div. 2                  No
Compute Pressure Stress per WRC-368                         No
Local Loads applied at end of Nozzle/Attachment             No
```

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 273.05 + 2 * 1.65 * sqrt( 606.5 ( 10.0 - 3.0 ) )
  = 488.070 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
Radial Load                                     P         14.0  kN
Circumferential Shear                          VC        -10.5  kN
Longitudinal Shear                             VL         14.0  kN
Circumferential Moment                         MC      -7000.0  N-m
Longitudinal Moment                            ML     -10500.0  N-m
```

```
Torsional Moment                            MT       -9100.0   N-m

Dimensionless Parameters used :    Gamma =    35.97
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.195	4C	5.137	(A,B)
N(PHI) / (P/Rm)	0.195	3C	3.416	(C,D)
M(PHI) / (P)	0.195	2C1	0.039	(A,B)
M(PHI) / (P)	0.195	1C !	0.070	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.195	3A	1.457	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.195	1A	0.080	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.195	3B	3.709	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.195	1B	0.027	(A,B,C,D)
N(x) / (P/Rm)	0.195	3C	3.416	(A,B)
N(x) / (P/Rm)	0.195	4C	5.137	(C,D)
M(x) / (P)	0.195	1C1	0.072	(A,B)
M(x) / (P)	0.195	2C !	0.039	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.195	4A	2.685	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.195	2A	0.039	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.195	4B	1.461	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.195	2B	0.042	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Memb.	P	-6.9	-6.9	-6.9	-6.9	-4.6	-4.6	-4.6	-4.6
Circ. Bend.	P	-11.3	11.3	-11.3	11.3	-20.2	20.2	-20.2	20.2
Circ. Memb.	MC	0.0	0.0	0.0	0.0	8.2	8.2	-8.2	-8.2
Circ. Memb.	MC	0.0	0.0	0.0	0.0	97.0	-97.0	-97.0	97.0
Circ. Memb.	ML	31.4	31.4	-31.4	-31.4	0.0	0.0	0.0	0.0
Circ. Bend.	ML	50.1	-50.1	-50.1	50.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.		63.3	-14.4	-99.7	23.1	80.4	-73.2	-130.1	104.4
Long. Memb.	P	-4.6	-4.6	-4.6	-4.6	-6.9	-6.9	-6.9	-6.9
Long. Bend.	P	-20.9	20.9	-20.9	20.9	-11.2	11.2	-11.2	11.2
Long. Memb.	MC	0.0	0.0	0.0	0.0	15.1	15.1	-15.1	-15.1
Long. Bend.	MC	0.0	0.0	0.0	0.0	46.9	-46.9	-46.9	46.9
Long. Memb.	ML	12.3	12.3	-12.3	-12.3	0.0	0.0	0.0	0.0
Long. Bend.	ML	77.0	-77.0	-77.0	77.0	0.0	0.0	0.0	0.0

Tot. Long. Str.	63.9	-48.4	-114.9	81.0	43.9	-27.4	-80.2	36.1
Shear VC	-1.4	-1.4	1.4	1.4	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.9	-1.9	1.9	1.9
Shear MT	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6
Tot. Shear	-6.0	-6.0	-3.1	-3.1	-6.5	-6.5	-2.6	-2.6
Str. Int.	69.6	49.4	115.5	81.1	81.6	74.1	130.2	104.5

Dimensionless Parameters used : Gamma = 86.64

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.325	4C	6.644	(A,B)
N(PHI) / (P/Rm)	0.325	3C	2.278	(C,D)
M(PHI) / (P)	0.325	2C1	0.007	(A,B)
M(PHI) / (P)	0.325	1C !	0.067	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.325	3A	1.925	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.325	1A	0.055	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.325	3B	3.838	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.325	1B	0.005	(A,B,C,D)
N(x) / (P/Rm)	0.325	3C	2.278	(A,B)
N(x) / (P/Rm)	0.325	4C	6.644	(C,D)
M(x) / (P)	0.325	1C1	0.020	(A,B)
M(x) / (P)	0.325	2C !	0.036	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.325	4A	7.630	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.325	2A	0.021	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.325	4B	2.131	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.325	2B	0.007	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-21.9	-21.9	-21.9	-21.9	-7.5	-7.5	-7.5	-7.5
Circ. Bend. P	-11.7	11.7	-11.7	11.7	-115.4	115.4	-115.4	115.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	16.1	16.1	-16.1	-16.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	238.1	-238.1	-238.1	238.1
Circ. Memb. ML	48.2	48.2	-48.2	-48.2	0.0	0.0	0.0	0.0
Circ. Bend. ML	34.2	-34.2	-34.2	34.2	0.0	0.0	0.0	0.0
Tot. Circ. Str.	48.7	3.8	-116.0	-24.2	131.3	-114.1	-377.1	329.8

```
Long. Memb. P  |     -7.5|     -7.5|     -7.5|     -7.5|    -21.9|    -21.9|    -21.9|    -21.9|
Long. Bend. P  |    -33.5|     33.5|    -33.5|     33.5|    -61.7|     61.7|    -61.7|     61.7|
Long. Memb. MC |      0.0|      0.0|      0.0|      0.0|     63.9|     63.9|    -63.9|    -63.9|
Long. Bend. MC |      0.0|      0.0|      0.0|      0.0|     91.6|    -91.6|    -91.6|     91.6|
Long. Memb. ML |     26.8|     26.8|    -26.8|    -26.8|      0.0|      0.0|      0.0|      0.0|
Long. Bend. ML |     48.3|    -48.3|    -48.3|     48.3|      0.0|      0.0|      0.0|      0.0|
               |                                                                              |
Tot. Long. Str.|     34.1|      4.4|   -116.0|     47.5|     71.9|     12.1|   -239.1|     67.5|
----------------------------------------------------------------------------------------------
      Shear VC |     -2.1|     -2.1|      2.1|      2.1|      0.0|      0.0|      0.0|      0.0|
      Shear VL |      0.0|      0.0|      0.0|      0.0|     -2.8|     -2.8|      2.8|      2.8|
      Shear MT |     -4.1|     -4.1|     -4.1|     -4.1|     -4.1|     -4.1|     -4.1|     -4.1|
               |                                                                              |
     Tot. Shear|     -6.2|     -6.2|     -2.0|     -2.0|     -6.9|     -6.9|     -1.3|     -1.3|
----------------------------------------------------------------------------------------------
     Str. Int. |     51.0|     12.4|    118.0|     71.8|    132.1|    126.9|    377.1|    329.8|

----------------------------------------------------------------------------------------------
```

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

```
               |                   Stress Intensity Values at                                 |
Type of        |                                                                              |
Stress    Load |       Au       Al       Bu       Bl       Cu       Cl       Du       Dl|
----------------------------------------------------------------------------------------------
Circ. Pm (SUS) |     14.3|     14.8|     14.3|     14.8|     14.3|     14.8|     14.3|     14.8|
Circ. Pl (SUS) |     24.4|     24.4|    -38.3|    -38.3|      3.6|      3.6|    -12.8|    -12.8|
Circ. Q  (SUS) |     38.8|    -38.8|    -61.4|     61.4|     76.8|    -76.8|   -117.3|    117.3|
----------------------------------------------------------------------------------------------
Long. Pm (SUS) |      7.2|      7.2|      7.2|      7.2|      7.2|      7.2|      7.2|      7.2|
Long. Pl (SUS) |      7.7|      7.7|    -16.9|    -16.9|      8.2|      8.2|    -22.0|    -22.0|
Long. Q  (SUS) |     56.2|    -56.2|    -97.9|     97.9|     35.7|    -35.7|    -58.1|     58.1|
----------------------------------------------------------------------------------------------
Shear Pm (SUS) |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
Shear Pl (SUS) |     -1.4|     -1.4|      1.4|      1.4|     -1.9|     -1.9|      1.9|      1.9|
Shear Q  (SUS) |     -4.6|     -4.6|     -4.6|     -4.6|     -4.6|     -4.6|     -4.6|     -4.6|
Pm (SUS)       |     14.3|     14.8|     14.3|     14.8|     14.3|     14.8|     14.3|     14.8|
----------------------------------------------------------------------------------------------
Pm+Pl (SUS)    |     38.9|     39.3|     24.1|     23.7|     19.0|     19.3|     16.8|     17.2|
----------------------------------------------------------------------------------------------
Pm+Pl+Q (Total)|     81.2|     43.3|    108.1|     88.3|     95.7|     59.5|    115.9|    119.3|
```

Vessel Stress Summation Comparison (N./mm²):

```
Type of        |     Max. S.I.     S.I. Allowable     |       Result     |
Stress Int.    |                                      |                  |
--------------------------------------------------------------------------
Pm (SUS)       |        14.75           137.90        |       Passed     |
Pm+Pl (SUS)    |        39.27           206.85        |       Passed     |
Pm+Pl+Q (TOTAL)|       119.29           413.70        |       Passed     |
```

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm²)

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	35.1	35.5	35.1	35.5	35.1	35.5	35.1	35.5
Circ. Pl	(SUS)	26.3	26.3	-70.1	-70.1	8.6	8.6	-23.6	-23.6
Circ. Q	(SUS)	22.4	-22.4	-45.9	45.9	122.7	-122.7	-353.4	353.4
Long. Pm	(SUS)	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6
Long. Pl	(SUS)	19.2	19.2	-34.3	-34.3	42.0	42.0	-85.8	-85.8
Long. Q	(SUS)	14.8	-14.8	-81.8	81.8	29.9	-29.9	-153.3	153.3
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	-2.1	-2.1	2.1	2.1	-2.8	-2.8	2.8	2.8
Shear Q	(SUS)	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1
Pm (SUS)		35.1	35.5	35.1	35.5	35.1	35.5	35.1	35.5
Pm+Pl (SUS)		61.6	62.0	35.2	34.8	60.0	60.0	79.9	80.3
Pm+Pl+Q (Total)		85.0	41.4	98.7	65.1	167.0	109.1	342.0	365.3

Stress Intensity Values at Au–Dl.

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	35.53	137.90	Passed
Pm+Pl (SUS)	80.33	206.85	Passed
Pm+Pl+Q (TOTAL)	365.34	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: N03 (10in) **From: 70**

```
Pressure for Reinforcement Calculations          P        4.100   bars
Temperature for Internal Pressure             Temp          234   °C
Design External Pressure                      Pext         1.03   bars
Temperature for External Pressure           Tempex          100   °C

Shell Material                                           SA-105
Shell Allowable Stress at Temperature           Sv       136.40   N./mm²
Shell Allowable Stress At Ambient              Sva       137.90   N./mm²

Outside Diameter of Bolted Blind Flange          D      1420.00   mm.
Head Finished (Minimum) Thickness                t      60.0000   mm.
Head Internal Corrosion Allowance                c       3.0000   mm.
Head External Corrosion Allowance               co       0.0000   mm.
```

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

```
Physical Maximum for Diameter Limit          Dmax    450.0000   mm.

Distance from Head Centerline                   L1     320.0000   mm.

User Entered Minimum Design Metal Temperature             5.00   °C
```

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       117.90   N./mm²
Allowable Stress At Ambient                    Sna       117.90   N./mm²

Diameter Basis (for tr calc only)                            ID
Layout Angle                                             320.00   deg
Diameter                                                10.0000   in.

Size and Thickness Basis                                  Minimum
Nominal Thickness                               tn        80

Flange Material                                           SA-105
Flange Type                                     Weld Neck Flange

Corrosion Allowance                            can       3.0000   mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     200.0000   mm.
Weld leg size between Nozzle and Pad/Shell      Wo      20.0000   mm.
Groove weld depth between Nozzle and Vessel   Wgnv      26.0000   mm.
Inside Projection                                h    4000.0000   mm.
Weld leg size, Inside Element to Shell          Wi      20.0000   mm.

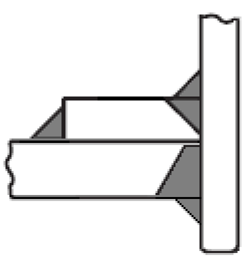
Pad Material                                          SA-516 70
Pad Allowable Stress at Temperature             Sp       137.90   N./mm²
```

```
Pad Allowable Stress At Ambient              Spa       137.90  N./mm²
Diameter of Pad along vessel surface          Dp     450.0000  mm.
Thickness of Pad                              te      15.0000  mm.
Weld leg size between Pad and Shell           Wp      12.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn      15.0000  mm.
Reinforcing Pad Width                                 88.4750  mm.

Flange Class                                        150
Flange Grade                                        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

Reinforcement CALCULATION, Description: N03 (10in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation            9.710  in.
Actual Thickness Used in Calculation                  0.520  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*126.32)/(118*1.0-0.6*4.1)
  = 0.4402 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.7666 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)             Dl    450.0000   mm.
Parallel to Vessel Wall, opening length               d    225.0000   mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp      40.5041   mm.
Normal to Vessel Wall, Inward                               18.0041   mm.
```

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 117.9/136.4)
= 0.864

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/136.4)
= 0.864

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 137.9/136.4)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(0.864, 1.0)
= 0.864

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	59.858	59.876	NA
Area in Shell	A1	19.709	19.681	NA
Area in Nozzle Wall	A2	6.835	6.607	NA
Area in Inward Nozzle	A3	2.242	2.242	NA
Area in Welds	A41+A42+A43	5.604	5.604	NA
Area in Element	A5	26.542	26.542	NA
TOTAL AREA AVAILABLE	Atot	60.932	60.676	NA

The External 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:	444.6669	15.0000	mm.
Based on given Pad Diameter:	450.0000	14.5479	mm.
Based on the Estimated Diameter Limit:	448.4125	14.6796	mm.

Area Required [A]:
= 0.5 * d * t + t * tn(1-fr1) per UG-39(a)(1)
= 0.5*252.6467*46.8856+46.8856*10.2016(1-0.86)
= 59.876 cm^2

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)
= 197.353(1.0 * 57.0 - 1.0 * 46.886) - 2 * 10.202

```
    ( 1.0 * 57.0 - 1.0 * 46.8856 ) * ( 1 - 0.864 )
  = 19.681 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 40.5 ) * ( 10.2 - 0.77 ) * 0.8644
  = 6.607 cm²
```

Area Available in Inward Nozzle [A3]:

```
  = 2 * ti * min( h, Tl, 2.5 * ti) * fr2
  = 2 * 7.2016 * ( 18.0041 ) * 0.8644
  = 2.242 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
  = 20.0² * 0.86 + (15.7573)² * 0.86 + 0.0² * 1.0
  = 5.604 cm²
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 450.0 - 273.05 ) * 15.0 * 1.0
  = 26.542 cm²
```

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

```
 Wall Thickness for Internal/External pressures       ta = 3.7666 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure       trb1 = 49.8715 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 49.8715 mm.
 Wall Thickness, shell/head, external pressure       trb2 = 3.4524 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                        tb3 = 11.1026 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 11.103, max( 49.8715, 4.5 ) ]
  = 11.1026 mm.
```

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

```
  = max( ta, tb )
  = max( 3.7666, 11.1026 )
  = 11.1026 mm.
```

Available Nozzle Neck Thickness = 13.2016 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 13.202, tr = 0.44, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.043, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -20 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

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

Govrn. thk, tg = 13.202, tr = 0.44, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.043, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -20 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
Min Metal Temp. w/o impact per UG-20(f)                   -29 °C
```

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

Govrn. thk, tg = 13.202, tr = 0.44, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.043, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -20 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
Min Metal Temp. w/o impact per UG-20(f)                   -29 °C
```

Shell to Pad Weld Junction at Pad OD, min(Curve:B, Curve:A)

Govrn. thk, tg = 15.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.037, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve A              4 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

Govrn. thk, tg = 13.202, tr = 0.44, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.043, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              0 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C

Gov. MDMT of the Nozzle                                :  -104 °C
Gov. MDMT of the Reinforcement Pad                     :  -104 °C
Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

<u>Weld Size Calculations, Description: N03 (10in)</u>

```
Intermediate Calc. for nozzle/shell Welds    Tmin      10.2016  mm.
Intermediate Calc. for pad/shell Welds     TminPad     15.0000  mm.
Intermediate Calc. for Inward Weld         TminIns     10.2016  mm.
```

Results Per UW-16.1:

```
                           Required Thickness    Actual Thickness
 Nozzle Weld              6.0000 = Min per Code14.1400 = 0.7 * Wo mm.
 Pad Weld                 7.5000 = 0.5*TminPad  8.4840 = 0.7 * Wp mm.
 Inward Weld              6.0000 = Min per Code11.1400 = 0.7 * Wi-Can mm.
```

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, (59.876 - 19.6813 + 2 * 10.2016 * 0.8644 *
     (1.0 * 57.0 - 46.8856 ) )136)
  = 572.54 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 6.6068 + 26.5425 + 5.6039 - 9.7753 * 0.86 ) * 136
  = 499.28 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 6.6068 + 2.2416 + 5.6039 + ( 10.0529 ) ) * 136
  = 334.22 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 6.6068 + 2.2416 + 5.6039 + 26.5425 + ( 10.0529 ) ) * 136
  = 696.23 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 273.05 * 20.0 * 0.49 * 118
  = 496. kN
```

Shear, Inward Nozzle Weld [Sinw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 273.05 * 15.7573 * 0.49 * 118
  = 390. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 450.0 * 12.0 * 0.49 * 136
  = 567. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 131.4242) * ( 13.2016 - 3.0 ) * 0.7 * 118
  = 348. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 273.05 * 15.0 * 0.74 * 138
  = 656. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 273.05 * ( 26.0 - 3.0 ) * 0.74 * 136
  = 996. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 567 + 348 ) = 914 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 496 + 656 + 996 + 390 ) = 2538 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 567 + 996 + 390 ) = 1953 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 914 kN , must exceed W = 572 kN  or W1 = 499 kN
 Path 2-2 = 2538 kN , must exceed W = 572 kN  or W2 = 334 kN
 Path 3-3 = 1952 kN , must exceed W = 572 kN  or W3 = 696 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    5  bars

 Nozzle is O.K. for the External Pressure            1  bars
```

The Cut Length for this Nozzle is, Drop + Ho + H + T : 4260.0000 mm.

Input, Nozzle Desc: Chimney Nozzle From: 70

Pressure for Reinforcement Calculations	P	4.100	bars
Temperature for Internal Pressure	Temp	234	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-105	
Shell Allowable Stress at Temperature	Sv	136.40	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Outside Diameter of Bolted Blind Flange	D	1420.00	mm.
Head Finished (Minimum) Thickness	t	60.0000	mm.
Head Internal Corrosion Allowance	c	3.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.

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

Physical Maximum for Diameter Limit	Dmax	450.0000	mm.
Distance from Head Centerline	L1	320.0000	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

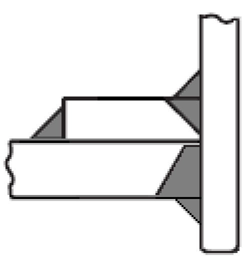
Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		220.00	deg
Diameter		10.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-105	
Flange Type		None	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	20.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	26.0000	mm.
Inside Projection	h	4000.0000	mm.
Weld leg size, Inside Element to Shell	Wi	20.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm²

```
Pad Allowable Stress At Ambient              Spa      137.90  N./mm²
Diameter of Pad along vessel surface          Dp    450.0000  mm.
Thickness of Pad                              te     15.0000  mm.
Weld leg size between Pad and Shell           Wp     12.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn     15.0000  mm.
Reinforcing Pad Width                                88.4750  mm.

Flange Class                                        150
Flange Grade                                        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

Reinforcement CALCULATION, Description: Chimney Nozzle

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              9.710   in.
Actual Thickness Used in Calculation                    0.520   in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (4.1*126.32)/(118*1.0-0.6*4.1)
  = 0.4402 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.7666 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    450.0000   mm.
Parallel to Vessel Wall, opening length              d    225.0000   mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     40.5041   mm.
Normal to Vessel Wall, Inward                              18.0041   mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/136.4 )
  = 0.864
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/136.4 )
  = 0.864
```

Weld Strength Reduction Factor [fr4]:
```
  = min( 1, Sp/Sv )
  = min( 1, 137.9/136.4 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.864, 1.0 )
  = 0.864
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	59.858	59.876	NA
Area in Shell	A1	19.709	19.681	NA
Area in Nozzle Wall	A2	6.835	6.607	NA
Area in Inward Nozzle	A3	2.242	2.242	NA
Area in Welds	A41+A42+A43	5.604	5.604	NA
Area in Element	A5	26.542	26.542	NA
TOTAL AREA AVAILABLE	Atot	60.932	60.676	NA

The External 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:	444.6669	15.0000	mm.
Based on given Pad Diameter:	450.0000	14.5479	mm.
Based on the Estimated Diameter Limit:	448.4125	14.6796	mm.

Area Required [A]:
```
  = 0.5 * d * t + t * tn(1-fr1) per UG-39(a)(1)
  = 0.5*252.6467*46.8856+46.8856*10.2016(1-0.86)
  = 59.876 cm²
```

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 )
  = 197.353( 1.0 * 57.0 - 1.0 * 46.886 ) - 2 * 10.202
```

```
    ( 1.0 * 57.0 - 1.0 * 46.8856 ) * ( 1 - 0.864 )
  = 19.681 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 40.5 ) * ( 10.2 - 0.77 ) * 0.8644
  = 6.607 cm²
```

Area Available in Inward Nozzle [A3]:

```
  = 2 * ti * min( h, Tl, 2.5 * ti) * fr2
  = 2 * 7.2016 * ( 18.0041 ) * 0.8644
  = 2.242 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
  = 20.0² * 0.86 + (15.7573)² * 0.86 + 0.0² * 1.0
  = 5.604 cm²
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 450.0 - 273.05 ) * 15.0 * 1.0
  = 26.542 cm²
```

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

```
 Wall Thickness for Internal/External pressures      ta = 3.7666 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 49.8715 mm.
 Wall Thickness                tb1 = max(trb1, tr16b) = 49.8715 mm.
 Wall Thickness, shell/head, external pressure     trb2 = 3.4524 mm.
 Wall Thickness                tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 11.1026 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 11.103, max( 49.8715, 4.5 ) ]
  = 11.1026 mm.
```

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

```
  = max( ta, tb )
  = max( 3.7666, 11.1026 )
  = 11.1026 mm.
```

Available Nozzle Neck Thickness = 13.2016 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 13.202, tr = 0.44, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.043, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -20 °C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                   -29 °C
```

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

Govrn. thk, tg = 13.202, tr = 0.44, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.043, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -20 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
Min Metal Temp. w/o impact per UG-20(f)                     -29 °C
```

Shell to Pad Weld Junction at Pad OD, min(Curve:B, Curve:A)

Govrn. thk, tg = 15.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.037, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve A                4 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

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

Govrn. thk, tg = 13.202, tr = 0.44, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.043, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A                0 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C

Gov. MDMT of the Nozzle                                 :  -104 °C
Gov. MDMT of the Reinforcement Pad                      :  -104 °C
Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
```

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

```
Design Pressure/Ambient Rating = 4.10/19.60 = 0.209
```

<u>Weld Size Calculations, Description: Chimney Nozzle</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      10.2016  mm.
Intermediate Calc. for pad/shell Welds    TminPad     15.0000  mm.
Intermediate Calc. for Inward Weld        TminIns     10.2016  mm.
```

Results Per UW-16.1:

```
                           Required Thickness     Actual Thickness
Nozzle Weld            6.0000 = Min per Code14.1400 = 0.7 * Wo mm.
Pad Weld               7.5000 = 0.5*TminPad  8.4840 = 0.7 * Wp mm.
Inward Weld            6.0000 = Min per Code11.1400 = 0.7 * Wi-Can mm.
```

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, (59.876 - 19.6813 + 2 * 10.2016 * 0.8644 *
   (1.0 * 57.0 - 46.8856 ) )136)
 = 572.54 kN
```

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

Weld Load [W1]:
```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 6.6068 + 26.5425 + 5.6039 - 9.7753 * 0.86 ) * 136
 = 499.28 kN
```

Weld Load [W2]:
```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 6.6068 + 2.2416 + 5.6039 + ( 10.0529 ) ) * 136
 = 334.22 kN
```

Weld Load [W3]:
```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = ( 6.6068 + 2.2416 + 5.6039 + 26.5425 + ( 10.0529 ) ) * 136
 = 696.23 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
 = (pi/2) * Dlo * Wo * 0.49 * Snw
 = ( 3.1416/2.0 ) * 273.05 * 20.0 * 0.49 * 118
 = 496. kN
```

Shear, Inward Nozzle Weld [Sinw]:
```
 = (pi/2) * Dlo * Wo * 0.49 * Snw
 = ( 3.1416/2.0 ) * 273.05 * 15.7573 * 0.49 * 118
 = 390. kN
```

Shear, Pad Element Weld [Spew]:
```
 = (pi/2) * DP * WP * 0.49 * SEW
 = ( 3.1416/2.0 ) * 450.0 * 12.0 * 0.49 * 136
 = 567. kN
```

Shear, Nozzle Wall [Snw]:
```
 = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
 = (3.1416 * 131.4242) * ( 13.2016 - 3.0 ) * 0.7 * 118
 = 348. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
 = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
 =  (3.1416/2 ) * 273.05 * 15.0 * 0.74 * 138
 = 656. kN
```

Tension, Shell Groove Weld [Tngw]:
```
 = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
 = ( 3.1416/2.0 ) * 273.05 * ( 26.0 - 3.0 ) * 0.74 * 136
 = 996. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 567 + 348 ) = 914 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 496 + 656 + 996 + 390 ) = 2538 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 567 + 996 + 390 ) = 1953 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 914 kN , must exceed W = 572 kN  or W1 = 499 kN
 Path 2-2 = 2538 kN , must exceed W = 572 kN  or W2 = 334 kN
 Path 3-3 = 1952 kN , must exceed W = 572 kN  or W3 = 696 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    5  bars

 Nozzle is O.K. for the External Pressure            1  bars
```

The Cut Length for this Nozzle is, Drop + Ho + H + T : 4260.0000 mm.

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FEA N03 10INCH

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Tue Dec 24 18:16:42 2024.

- Model Notes
- Load Case Report
- Solution Data
- ASME Code Stress Output Plots
- Stress Results - Notes
- ASME Overstressed Areas
- Highest Primary Stress Ratios
- Highest Secondary Stress Ratios
- Highest Fatigue Stress Ratios
- Highest Stress Ratios Per Region
- Stress Intensification Factors
- Allowable Loads
- Compressive Stress Summary
- Flexibilities
- Graphical Results

```
Model Notes
Model Notes

  Input Echo:

  Model Type                    : Flat Head

  Parent Geometry
         Parent Outside Diam.   :    1420.000 mm.
         Thickness              :      57.000 mm.
         Attached Shell Length  :     426.000 mm.
         Attached Shell Thick   :       0.000 mm.

  Parent Properties:
         Cold Allowable         :       137.9 MPa
         Hot  Allowable         :       136.5 MPa
         Material DB # 1015022.
         Ultimate Tensile (Amb) :       482.6 MPa
         Yield Strength (Amb)   :       248.2 MPa
         Yield Strength (Hot)   :       206.8 MPa
         Elastic Modulus (Amb)  :    201341.0 MPa
         Poissons Ratio         :       0.300
         Expansion Coefficient  :  0.1297E-04 mm./mm./deg.
         Weight Density         :  0.0000E+00  N /cu.mm.(NOT USED)

  Nozzle Geometry
```

```
       Nozzle Outside Diam.   :     273.000 mm.
       Thickness              :      10.200 mm.
       Length                 :     300.000 mm.
       RePad Width            :      88.400 mm.
       RePad Thickness        :      15.000 mm.
       Location perpendicular
       to the head centerline :     300.000 mm.

       Nozzle Tilt Angle      :       0.000 deg.

Nozzle Properties
       Cold Allowable         :       117.9 MPa
       Hot  Allowable         :       117.9 MPa
       Material DB # 1009922.
       Ultimate Tensile (Amb) :       413.7 MPa
       Yield Strength (Amb)   :       241.3 MPa
       Yield Strength (Hot)   :       201.3 MPa
       Elastic Modulus (Amb)  :    202720.0 MPa
       Poissons Ratio         :       0.300
       Expansion Coefficient  :  0.1297E-04 mm./mm./deg.
       Weight Density         :  0.0000E+00  N /cu.mm. (NOT USED)

Design Operating Cycles       :       7000.
Ambient Temperature (Deg.)    :       21.10

Uniform thermal expansion produces no stress in this geometry.
Any thermal loads will come through operating forces and
moments applied through the nozzle.

Nozzle Inside  Temperature    :      234.00 deg.
Nozzle Outside Temperature    :      234.00 deg.
Vessel Inside  Temperature    :      234.00 deg.
Vessel Outside Temperature    :      234.00 deg.

Nozzle Pressure               :       0.410 MPa
Vessel Pressure               :       0.410 MPa

User Defined Load Input Echo for the ATTACHMENT:
Loads are given at the End of Nozzle
Loads are defined in Global Coordinates

Forces(  N )  Moments  (N-m)

Load Case        FX          FY          FZ          MX          MY          MZ
---------------------------------------------------------------------------
 WEIGHT:    14000.0     14000.0     10500.0         0.0         0.0         0.0


FEA Model Loads:
These are the actual Attachment loads applied to
the FEA model.
These are the User Defined Loads translated to the
end of the nozzle and reported in global coordinates.

Forces(  N )  Moments  (N-m)

Load Case        FX          FY          FZ          MX          MY          MZ
---------------------------------------------------------------------------
 WEIGHT:    14000.0     14000.0     10500.0         0.0         0.0         0.0

Stresses ARE nodally AVERAGED.

No weld dimensions have been given for the nozzle
connection to the shell. This will produce conservative
results for external loads and may tend to produce more
realistic inside surface pressure stresses.
```

```
No pad weld dimensions have been given for the pad
connection to the shell. Few correlations have been
performed to investigate the sensitivity of peak stresses
to this value. Reasonable lengths have been assumed.

Vessel Centerline       Vector:  0.000   1.000   0.000
Nozzle Centerline       Vector:  0.000   1.000   0.000
Zero Degree Orientation Vector:  1.000   0.000   0.000

Nozzle Orientation Angle      :320.000
```

Table of Contents

```
Load Case Report
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             6:16pm   DEC 24,2024



Load Case Report                                      $X

Inner and outer element temperatures are the same
throughout the model.  No thermal ratcheting
calculations will be performed.

THE    9  LOAD CASES ANALYZED ARE:

  1    WEIGHT ONLY     (Wgt Only)

       Weight ONLY case run to get the stress range
       between the installed and the operating states.

       /-------- Loads in Case    1
         Loads due to Weight

  2    SUSTAINED       (Wgt+Pr)

       Sustained case run to satisfy local primary
       membrane and bending stress limits.

       /-------- Loads in Case    2
         Loads due to Weight
         Pressure Case     1

  3    OPERATING

       Case run to compute the operating stresses used in
       secondary, peak and range calculations as needed.

       /-------- Loads in Case    3
         Pressure Case     1
         Loads from (Operating)

  4    RANGE           (Fatigue Calc Performed)

       Case run to get the RANGE of stresses.
       as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

       /-------- Combinations in Range Case    4
         Plus  Stress Results from CASE    3
         Minus Stress Results from CASE    1
```

```
5    Program Generated -- Force Only

     Case run to compute sif's and flexibilities.
     /-------- Loads in Case   5
       Loads from (Axial)

6    Program Generated -- Force Only

     Case run to compute sif's and flexibilities.
     /-------- Loads in Case   6
       Loads from (Inplane)

7    Program Generated -- Force Only

     Case run to compute sif's and flexibilities.
     /-------- Loads in Case   7
       Loads from (Outplane)

8    Program Generated -- Force Only

     Case run to compute sif's and flexibilities.
     /-------- Loads in Case   8
       Loads from (Torsion)

9    Program Generated -- Force Only

     Case run to compute sif's and flexibilities.
     /-------- Loads in Case   9
       Pressure Case    1
```

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```
Solution Data
FEPipe Version 15.0           Jobname: NOZZLE              $P
Released Jan. 2021             6:16pm   DEC 24,2024
```

Solution Data

```
Maximum Solution Row Size =     948
Number of Nodes           =    2560
Number of Elements        =     855
Number of Solution Cases  =       8
```

Summation of Loads per Case

Case #	FX	FY	FZ
1	14000.	14000.	10500.
2	14000.	612222.	10500.
3	0.	598222.	0.
4	0.	1161253.	0.
5	0.	0.	0.
6	0.	0.	0.
7	0.	0.	0.
8	0.	598222.	0.

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```
ASME Code Stress Output Plots
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             6:16pm   DEC 24,2024
```

```
ASME Code Stress Output Plots                          $X
```

1) Pl < SPL (SUS,Membrane) Case 2

2) Qb < SPS (SUS,Bending) Case 2

3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

8) Membrane < User (OPE,Membrane) Case 3

9) Bending < User (OPE,Bending) Case 3

10) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 5

11) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 6

12) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 7

13) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 8

14) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 9

15) Pl+Pb+Q < SPS (EXP,Inside) Case 4

16) Pl+Pb+Q < SPS (EXP,Outside) Case 4

17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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```
Stress Results - Notes
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             6:16pm   DEC 24,2024
```

```
Stress Results - Notes
```

```
- Results  in  this  analysis  were  generated using the finite
  element solution method.

- Using 2019 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Ratio between Operating and Design Pressure =   1.000000
  Range cases use operating pressure. Primary cases
  use design pressure.

- Assume free end displacements of attached pipe
  (e.g. thermal loads) are secondary loads.

- Primary bending stresses at discontinuities
  are treated like secondary stresses. (Pb=0)

- Use Equivalent Stress (Von Mises).

- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.

- Use local tensor values for averaged and not averaged stresses.
```

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```
ASME Overstressed Areas
FEPipe Version 15.0          Jobname: NOZZLE               $P
Released Jan. 2021            6:16pm   DEC 24,2024



ASME Overstressed Areas                                 $X


             *** NO OVERSTRESSED NODES IN THIS MODEL ***
```

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```
Highest Primary Stress Ratios
FEPipe Version 15.0          Jobname: NOZZLE               $P
Released Jan. 2021            6:16pm   DEC 24,2024



Highest Primary Stress Ratios                           $X


Pad Next to Nozzle 1

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
      49             455     Min Prin. Stress = -11. (89% Neg, 0% NegHi)
```

```
      MPa            MPa      Plot Reference:
                              4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            10%


Nozzle 1 Next to Shell

       Pl            SPL      Primary Membrane Load Case 2
       51            201      Min Prin. Stress = -34. (79% Neg, 63% NegHi)
      MPa            MPa      Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
            25%


Shell Next to Nozzle 1 Pad

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 2
       43            455      Min Prin. Stress = -14. (99% Neg, 81% NegHi)
      MPa            MPa      Plot Reference:
                              4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             9%


Nozzle 1

       Pl            SPL      Primary Membrane Load Case 2
       18            201      Min Prin. Stress = -10. (67% Neg, 61% NegHi)
      MPa            MPa      Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
             8%
```

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```
Highest Secondary Stress Ratios
FEPipe Version 15.0           Jobname: NOZZLE                 $P
Released Jan. 2021             6:16pm   DEC 24,2024



Highest Secondary Stress Ratios                        $X

In combination case  4 the max range stress divided
by the max component stress is 1.91. The case tensor components
are in some directions additive and so the combination
case will have HIGHER stresses than the largest of any
of the individual cases by more than 50%.

Load      Combined/Max        Combined/Max
Case       (Inside)             (Outside)
------    -------------      -------------
   4         1.619               1.914


Pad Next to Nozzle 1

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 2
       49            455      Min Prin. Stress = -11. (89% Neg, 0% NegHi)
      MPa            MPa      Plot Reference:
                              4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            10%
```

```
Nozzle 1 Next to Shell

  Pl+Pb+Q             SPS     Primary+Secondary (Inner) Load Case 2
      113             443     Min Prin. Stress = -34. (79% Neg, 63% NegHi)
      MPa             MPa     Plot Reference:
                              3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
            25%


Shell Next to Nozzle 1 Pad

  Pl+Pb+Q             SPS     Primary+Secondary (Outer) Load Case 2
       43             455     Min Prin. Stress = -14. (99% Neg, 81% NegHi)
      MPa             MPa     Plot Reference:
                              4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             9%


Nozzle 1

  Pl+Pb+Q             SPS     Primary+Secondary (Inner) Load Case 2
       22             443     Min Prin. Stress = -10. (67% Neg, 61% NegHi)
      MPa             MPa     Plot Reference:
                              3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             4%
```

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```
Highest Fatigue Stress Ratios
FEPipe Version 15.0            Jobname: NOZZLE              $P
Released Jan. 2021              6:16pm   DEC 24,2024



Highest Fatigue Stress Ratios                          $X


Pad Next to Nozzle 1

Pl+Pb+Q+F     Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
       37      0.000 Life     Stress Concentration Factor = 1.350
      MPa      0.064 Stress   Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 686.0
    574.2                     Markl Fatigue Stress Allowable = 575.0
      MPa                     WRC 474 Mean Cycles to Failure = 98,740,944.
                              WRC 474 99% Probability Cycles = 22,938,418.
       6%                     WRC 474 95% Probability Cycles = 31,847,108.
                              BS5500 Allowed Cycles(Curve F) = 18,274,966.
                              Membrane-to-Bending Ratio = 0.189
                              Bending-to-PL+PB+Q Ratio = 0.841
                              Plot Reference:
                              18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Nozzle 1 Next to Shell

Pl+Pb+Q+F     Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       73      0.000 Life     Stress Concentration Factor = 1.350
      MPa      0.126 Stress   Strain Concentration Factor = 1.000
```

```
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 589.5
    579.9                    Markl Fatigue Stress Allowable = 575.0
      MPa                    WRC 474 Mean Cycles to Failure = 43,591,768.
                             WRC 474 99% Probability Cycles = 10,126,763.
      12%                    WRC 474 95% Probability Cycles = 14,059,737.
                             BS5500 Allowed Cycles(Curve F) = 4,364,570.
                             Membrane-to-Bending Ratio = 0.721
                             Bending-to-PL+PB+Q Ratio = 0.581
                             Plot Reference:
                             17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4


Shell Next to Nozzle 1 Pad

Pl+Pb+Q+F     Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 4
       40      0.000 Life    Stress Concentration Factor = 1.350
      MPa      0.070 Stress  Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 686.0
    574.2                    Markl Fatigue Stress Allowable = 575.0
      MPa                    WRC 474 Mean Cycles to Failure = 92,355,320.
                             WRC 474 99% Probability Cycles = 21,454,980.
       7%                    WRC 474 95% Probability Cycles = 29,787,538.
                             BS5500 Allowed Cycles(Curve F) = 16,084,873.
                             Membrane-to-Bending Ratio = 0.125
                             Bending-to-PL+PB+Q Ratio = 0.889
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Nozzle 1

Pl+Pb+Q+F     Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 4
       20      0.000 Life    Stress Concentration Factor = 1.000
      MPa      0.034 Stress  Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 589.5
    579.9                    Markl Fatigue Stress Allowable = 575.0
      MPa                    WRC 474 Mean Cycles to Failure = 9.4231E8
                             WRC 474 99% Probability Cycles = 2.1891E8
       3%                    WRC 474 95% Probability Cycles = 3.0392E8
                             BS5500 Allowed Cycles(Curve F) = 4.0373E8
                             Membrane-to-Bending Ratio = 4.676
                             Bending-to-PL+PB+Q Ratio = 0.176
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
```

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```
Highest Stress Ratios Per Region
FEPipe Version 15.0          Jobname: NOZZLE              $P
Released Jan. 2021             6:16pm   DEC 24,2024



Highest Stress Ratios Per Region                      $X


Pad Next to Nozzle 1
```

```
         Pl            SPL      Primary Membrane Load Case 2
         16            207      Min Prin. Stress = -11. (89% Neg, 0% NegHi)
        MPa            MPa      Plot Reference:
                                1) Pl < SPL (SUS,Membrane) Case 2
                7%

         Qb            SPS      Primary Bending Load Case 2
         46            455      Min Prin. Stress = -11. (89% Neg, 0% NegHi)
        MPa            MPa      Plot Reference:
                                2) Qb < SPS (SUS,Bending) Case 2
               10%

    Pl+Pb+Q            SPS      Primary+Secondary (Inner) Load Case 2
         43            455      Min Prin. Stress = -11. (89% Neg, 0% NegHi)
        MPa            MPa      Plot Reference:
                                3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
                9%

    Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 2
         49            455      Min Prin. Stress = -11. (89% Neg, 0% NegHi)
        MPa            MPa      Plot Reference:
                                4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
               10%

   S1+S2+S3             4S      Part 5 (5.3.2) Load Case 2
          9            546      Min Prin. Stress = -11. (89% Neg, 0% NegHi)
        MPa            MPa      Plot Reference:
                                5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
                1%

    Pl+Pb+Q            SPS      Primary+Secondary (Inner) Load Case 3
         32            455      Min Prin. Stress = -9. (93% Neg, 0% NegHi)
        MPa            MPa      Plot Reference:
                                6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
                6%

    Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 3
         38            455      Min Prin. Stress = -9. (93% Neg, 0% NegHi)
        MPa            MPa      Plot Reference:
                                7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
                8%

   Membrane           User      Component Evaluation Load Case 3
         11            455      Min Prin. Stress = -9. (93% Neg, 0% NegHi)
        MPa            MPa      Plot Reference:
                                8) Membrane < User (OPE,Membrane) Case 3
                2%

    Bending           User      Component Evaluation Load Case 3
         35            455      Min Prin. Stress = -9. (93% Neg, 0% NegHi)
        MPa            MPa      Plot Reference:
                                9) Bending < User (OPE,Bending) Case 3
                7%

    Pl+Pb+Q            SPS      Primary+Secondary (Inner) Load Case 4
         21            455      Min Prin. Stress = -6. (78% Neg, 0% NegHi)
        MPa            MPa      Plot Reference:
                                15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
                4%

    Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 4
         27            455      Min Prin. Stress = -6. (78% Neg, 0% NegHi)
        MPa            MPa      Plot Reference:
                                16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
                6%
```

```
Pl+Pb+Q+F     Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 4
       28      0.000 Life      Stress Concentration Factor = 1.350
      MPa      0.049 Stress    Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.0000E11
Allowable                      "B31" Fatigue Stress Allowable = 686.0
    574.2                      Markl Fatigue Stress Allowable = 575.0
      MPa                      WRC 474 Mean Cycles to Failure = 3.0274E8
                               WRC 474 99% Probability Cycles = 70,329,584.
       4%                      WRC 474 95% Probability Cycles = 97,643,768.
                               BS5500 Allowed Cycles(Curve F) = 75,109,856.
                               Membrane-to-Bending Ratio = 0.189
                               Bending-to-PL+PB+Q Ratio = 0.841
                               Plot Reference:
                               17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F     Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 4
       37      0.000 Life      Stress Concentration Factor = 1.350
      MPa      0.064 Stress    Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.0000E11
Allowable                      "B31" Fatigue Stress Allowable = 686.0
    574.2                      Markl Fatigue Stress Allowable = 575.0
      MPa                      WRC 474 Mean Cycles to Failure = 98,740,944.
                               WRC 474 99% Probability Cycles = 22,938,418.
       6%                      WRC 474 95% Probability Cycles = 31,847,108.
                               BS5500 Allowed Cycles(Curve F) = 18,274,966.
                               Membrane-to-Bending Ratio = 0.189
                               Bending-to-PL+PB+Q Ratio = 0.841
                               Plot Reference:
                               18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Nozzle 1 Next to Shell

       Pl             SPL      Primary Membrane Load Case 2
       51             201      Min Prin. Stress = -34. (79% Neg, 63% NegHi)
      MPa             MPa      Plot Reference:
                               1) Pl < SPL (SUS,Membrane) Case 2
            25%

       Qb             SPS      Primary Bending Load Case 2
       94             443      Min Prin. Stress = -34. (79% Neg, 63% NegHi)
      MPa             MPa      Plot Reference:
                               2) Qb < SPS (SUS,Bending) Case 2
            21%

  Pl+Pb+Q             SPS      Primary+Secondary (Inner) Load Case 2
      113             443      Min Prin. Stress = -34. (79% Neg, 63% NegHi)
      MPa             MPa      Plot Reference:
                               3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
            25%

  Pl+Pb+Q             SPS      Primary+Secondary (Outer) Load Case 2
      102             443      Min Prin. Stress = -34. (79% Neg, 63% NegHi)
      MPa             MPa      Plot Reference:
                               4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            22%

 S1+S2+S3              4S      Part 5 (5.3.2) Load Case 2
       56             472      Min Prin. Stress = -34. (79% Neg, 63% NegHi)
      MPa             MPa      Plot Reference:
                               5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            11%

  Pl+Pb+Q             SPS      Primary+Secondary (Inner) Load Case 3
       83             443      Min Prin. Stress = -30. (82% Neg, 65% NegHi)
      MPa             MPa      Plot Reference:
```

```
                                 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
             18%

  Pl+Pb+Q           SPS          Primary+Secondary (Outer) Load Case 3
       65           443          Min Prin. Stress = -30. (82% Neg, 65% NegHi)
      MPa           MPa          Plot Reference:
                                 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
             14%

 Membrane          User          Component Evaluation Load Case 3
       39           443          Min Prin. Stress = -30. (82% Neg, 65% NegHi)
      MPa           MPa          Plot Reference:
                                 8) Membrane < User (OPE,Membrane) Case 3
              8%

  Bending          User          Component Evaluation Load Case 3
       62           443          Min Prin. Stress = -30. (82% Neg, 65% NegHi)
      MPa           MPa          Plot Reference:
                                 9) Bending < User (OPE,Bending) Case 3
             14%

  Pl+Pb+Q           SPS          Primary+Secondary (Inner) Load Case 4
       54           443          Min Prin. Stress = -25. (83% Neg, 65% NegHi)
      MPa           MPa          Plot Reference:
                                 15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
             12%

  Pl+Pb+Q           SPS          Primary+Secondary (Outer) Load Case 4
       49           443          Min Prin. Stress = -25. (83% Neg, 65% NegHi)
      MPa           MPa          Plot Reference:
                                 16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
             11%

Pl+Pb+Q+F    Damage Ratio        Primary+Secondary+Peak (Inner) Load Case 4
       73     0.000 Life         Stress Concentration Factor = 1.350
      MPa     0.126 Stress       Strain Concentration Factor = 1.000
                                 Cycles Allowed for this Stress = 1.0000E11
Allowable                        "B31" Fatigue Stress Allowable = 589.5
    579.9                        Markl Fatigue Stress Allowable = 575.0
      MPa                        WRC 474 Mean Cycles to Failure = 43,591,768.
                                 WRC 474 99% Probability Cycles = 10,126,763.
      12%                        WRC 474 95% Probability Cycles = 14,059,737.
                                 BS5500 Allowed Cycles(Curve F) = 4,364,570.
                                 Membrane-to-Bending Ratio = 0.721
                                 Bending-to-PL+PB+Q Ratio = 0.581
                                 Plot Reference:
                                 17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio        Primary+Secondary+Peak (Outer) Load Case 4
       67     0.000 Life         Stress Concentration Factor = 1.350
      MPa     0.115 Stress       Strain Concentration Factor = 1.000
                                 Cycles Allowed for this Stress = 1.0000E11
Allowable                        "B31" Fatigue Stress Allowable = 589.5
    579.9                        Markl Fatigue Stress Allowable = 575.0
      MPa                        WRC 474 Mean Cycles to Failure = 63,116,128.
                                 WRC 474 99% Probability Cycles = 14,662,449.
      11%                        WRC 474 95% Probability Cycles = 20,356,966.
                                 BS5500 Allowed Cycles(Curve F) = 5,776,221.
                                 Membrane-to-Bending Ratio = 0.578
                                 Bending-to-PL+PB+Q Ratio = 0.634
                                 Plot Reference:
                                 18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Shell Next to Nozzle 1 Pad
```

```
      Pl           SPL      Primary Membrane Load Case 2
      10           207      Min Prin. Stress = -14. (99% Neg, 81% NegHi)
     MPa           MPa      Plot Reference:
                            1) Pl < SPL (SUS,Membrane) Case 2
             4%

      Qb           SPS      Primary Bending Load Case 2
      40           455      Min Prin. Stress = -14. (99% Neg, 81% NegHi)
     MPa           MPa      Plot Reference:
                            2) Qb < SPS (SUS,Bending) Case 2
             8%

 Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 2
      37           455      Min Prin. Stress = -14. (99% Neg, 81% NegHi)
     MPa           MPa      Plot Reference:
                            3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             8%

 Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 2
      43           455      Min Prin. Stress = -14. (99% Neg, 81% NegHi)
     MPa           MPa      Plot Reference:
                            4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             9%

S1+S2+S3            4S      Part 5 (5.3.2) Load Case 2
       6           546      Min Prin. Stress = -14. (99% Neg, 81% NegHi)
     MPa           MPa      Plot Reference:
                            5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
             1%

 Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 3
      31           455      Min Prin. Stress = -11. (99% Neg, 78% NegHi)
     MPa           MPa      Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
             6%

 Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 3
      36           455      Min Prin. Stress = -11. (99% Neg, 78% NegHi)
     MPa           MPa      Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
             7%

Membrane          User      Component Evaluation Load Case 3
       8           455      Min Prin. Stress = -11. (99% Neg, 78% NegHi)
     MPa           MPa      Plot Reference:
                            8) Membrane < User (OPE,Membrane) Case 3
             1%

 Bending          User      Component Evaluation Load Case 3
      34           455      Min Prin. Stress = -11. (99% Neg, 78% NegHi)
     MPa           MPa      Plot Reference:
                            9) Bending < User (OPE,Bending) Case 3
             7%

 Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 4
      26           455      Min Prin. Stress = -8. (99% Neg, 74% NegHi)
     MPa           MPa      Plot Reference:
                            15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
             5%

 Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 4
      30           455      Min Prin. Stress = -8. (99% Neg, 74% NegHi)
     MPa           MPa      Plot Reference:
                            16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
             6%
```

```
Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       35     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.060 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 686.0
    574.2                    Markl Fatigue Stress Allowable = 575.0
      MPa                    WRC 474 Mean Cycles to Failure = 1.6676E8
                             WRC 474 99% Probability Cycles = 38,740,632.
       6%                    WRC 474 95% Probability Cycles = 53,786,488.
                             BS5500 Allowed Cycles(Curve F) = 34,175,576.
                             Membrane-to-Bending Ratio = 0.125
                             Bending-to-PL+PB+Q Ratio = 0.889
                             Plot Reference:
                             17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
       40     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.070 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 686.0
    574.2                    Markl Fatigue Stress Allowable = 575.0
      MPa                    WRC 474 Mean Cycles to Failure = 92,355,320.
                             WRC 474 99% Probability Cycles = 21,454,980.
       7%                    WRC 474 95% Probability Cycles = 29,787,538.
                             BS5500 Allowed Cycles(Curve F) = 16,084,873.
                             Membrane-to-Bending Ratio = 0.125
                             Bending-to-PL+PB+Q Ratio = 0.889
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Nozzle 1

       Pl            SPL     Primary Membrane Load Case 2
       18            201     Min Prin. Stress = -10. (67% Neg, 61% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             8%

       Qb            SPS     Primary Bending Load Case 2
       14            443     Min Prin. Stress = -10. (67% Neg, 61% NegHi)
      MPa            MPa     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
             3%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
       22            443     Min Prin. Stress = -10. (67% Neg, 61% NegHi)
      MPa            MPa     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             4%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
       17            443     Min Prin. Stress = -10. (67% Neg, 61% NegHi)
      MPa            MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             3%

 S1+S2+S3             4S     Part 5 (5.3.2) Load Case 2
       28            472     Min Prin. Stress = -10. (67% Neg, 61% NegHi)
      MPa            MPa     Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
             6%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 3
       17            443     Min Prin. Stress = -5. (60% Neg, 57% NegHi)
      MPa            MPa     Plot Reference:
```

```
                              6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
            3%

   Pl+Pb+Q          SPS       Primary+Secondary (Outer) Load Case 3
        17          443       Min Prin. Stress = -5. (60% Neg, 57% NegHi)
       MPa          MPa       Plot Reference:
                              7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
            3%

  Membrane         User       Component Evaluation Load Case 3
        16          443       Min Prin. Stress = -5. (60% Neg, 57% NegHi)
       MPa          MPa       Plot Reference:
                              8) Membrane < User (OPE,Membrane) Case 3
            3%

   Bending         User       Component Evaluation Load Case 3
        10          443       Min Prin. Stress = -5. (60% Neg, 57% NegHi)
       MPa          MPa       Plot Reference:
                              9) Bending < User (OPE,Bending) Case 3
            2%

   Pl+Pb+Q          SPS       Primary+Secondary (Inner) Load Case 4
        17          443       Min Prin. Stress = -12. (80% Neg, 76% NegHi)
       MPa          MPa       Plot Reference:
                              15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
            3%

   Pl+Pb+Q          SPS       Primary+Secondary (Outer) Load Case 4
        20          443       Min Prin. Stress = -12. (80% Neg, 76% NegHi)
       MPa          MPa       Plot Reference:
                              16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
            4%

 Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
        17     0.000 Life     Stress Concentration Factor = 1.000
       MPa     0.029 Stress   Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
 Allowable                    "B31" Fatigue Stress Allowable = 589.5
     579.9                    Markl Fatigue Stress Allowable = 575.0
       MPa                    WRC 474 Mean Cycles to Failure = 1.5884E9
                              WRC 474 99% Probability Cycles = 3.6901E8
        2%                    WRC 474 95% Probability Cycles = 5.1232E8
                              BS5500 Allowed Cycles(Curve F) = 9.2658E8
                              Membrane-to-Bending Ratio = 4.676
                              Bending-to-PL+PB+Q Ratio = 0.176
                              Plot Reference:
                              17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
        20     0.000 Life     Stress Concentration Factor = 1.000
       MPa     0.034 Stress   Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
 Allowable                    "B31" Fatigue Stress Allowable = 589.5
     579.9                    Markl Fatigue Stress Allowable = 575.0
       MPa                    WRC 474 Mean Cycles to Failure = 9.4231E8
                              WRC 474 99% Probability Cycles = 2.1891E8
        3%                    WRC 474 95% Probability Cycles = 3.0392E8
                              BS5500 Allowed Cycles(Curve F) = 4.0373E8
                              Membrane-to-Bending Ratio = 4.676
                              Bending-to-PL+PB+Q Ratio = 0.176
                              Plot Reference:
                              18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
```

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```
Stress Intensification Factors
FEPipe Version 15.0          Jobname: NOZZLE               $P
Released Jan. 2021            6:16pm   DEC 24,2024




Stress Intensification Factors                         $X


Branch/Nozzle Sif Summary

                 Peak      Primary    Secondary      SSI
Axial   :        3.593       2.661       5.322       1.342
Inplane :        1.891       1.401       2.802       1.236
Outplane:        1.852       1.372       2.743       1.152
Torsion :        0.595       0.837       0.882       0.771
Pressure:       10.970       8.126      16.252       1.735

The above stress intensification factors are to be used
in a beam-type analysis of the piping system.  Inplane,
Outplane and Torsional sif's should be used with the
matching branch pipe whose diameter and thickness is given
below.  The axial sif should be used to intensify the
axial stress in the branch pipe calculated by F/A.  The
pressure sif should be used to intensify the nominal
pressure stress in the PARENT or HEADER, calculated
from PDo/2T. B31 calculations use mean diameters and
Section VIII calculations use outside diameters. SSIs are
based on peak stress factors and correlated test results.

Pipe OD :      273.000  mm.
Pipe Thk:       10.200  mm.
Z approx:   553274.125  cu.mm.
Z exact :   533404.750  cu.mm.

  (SSI = SIF^x)        Axial   Inpl    Outpl   Tors    Pres
SIF/SSI Exponents:     0.765   0.529   0.513   0.343   0.875

SIF/SSI exponent based on relationship between primary and
peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor =       21.214
      Header Pressure i-factor =       22.858

The B31.3 pressure i-factors should be used with with
F/A, where F is the axial force due to pressure, and
A is the area of the pipe wall. This is equivalent to
finding the pressure stress from (ip)(PD/4T).

B31.3   (Branch)
Peak Stress Sif ....    0.000         Axial
                        1.000         Inplane
                        1.000         Outplane
                        1.000         Torsional
B31.1  (Branch)
Peak Stress Sif ....    0.000         Axial
                        1.000         Inplane
                        1.000         Outplane
                        1.000         Torsional
WRC 330  (Branch)
Peak Stress Sif ....    0.000         Axial
                        3.830         Inplane
```

```
1.000        Outplane
3.830        Torsional
```

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```
Allowable Loads
FEPipe Version 15.0          Jobname: NOZZLE                  $P
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Allowable Loads                                        $X


SECONDARY                      Maximum     Conservative         Realistic
Load Type (Range):          Individual     Simultaneous        Simultaneous
                              Occuring       Occuring            Occuring
Axial Force      ( N      )     679738.       192080.              288120.
Inplane   Moment (mm.  N )   81778656.     16340499.            34663432.
Outplane  Moment (mm.  N )   83528856.     16690214.            35405288.
Torsional Moment (mm.  N )  259920672.     73448200.           110172304.
Pressure         (MPa     )        2.12          0.41                 0.41

PRIMARY                        Maximum     Conservative         Realistic
Load Type:                  Individual     Simultaneous        Simultaneous
                              Occuring       Occuring            Occuring
Axial Force      ( N      )     637020.       168564.              252847.
Inplane   Moment (mm.  N )   76639336.     14340007.            30419748.
Outplane  Moment (mm.  N )   78279536.     14646906.            31070778.
Torsional Moment (mm.  N )  128279912.     33944644.            50916968.
Pressure         (MPa     )        1.99          0.41                 0.41

        NOTES:

        1) Maximum Individual Occuring Loads are the maximum
           allowed values of the respective loads if all other
           load components are zero, i.e. the listed axial force
           may be applied if the inplane, outplane and torsional
           moments, and the pressure are zero.

        2) The Conservative Allowable Simultaneous loads are
           the maximum loads that can be applied simultaneously.
           A conservative stress combination equation is used
           that typically produces stresses within 50-70% of the
           allowable stress.

        3) The Realistic Allowable Simultaneous loads are the
           maximum loads that can be applied simultaneously.  A
           more realistic stress combination equation is used
           based on experience at Paulin Research.  Stresses are
           typically produced within 80-105% of the allowable.

        4) Secondary allowable loads are limits for expansion
           and operating piping loads.

        5) Primary allowable loads are limits for weight,
           primary and sustained type piping loads.

        6) High D/T low pressure systems may be subject to
           instability and should be checked when compressive
```

stresses are present.

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```
Compressive Stress Summary
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             6:16pm   DEC 24,2024



Compressive Stress Summary (MPa)                        $X

Nomenclature:
-------------
Min Stress        - Compressive Membrane and Bending Stress
Pts in Region     - No. of nodes in the model region
>5% Compression   - 5% or more of Compressive Stress Limit
>50% Compression  - 50% or more of Compressive Stress Limit

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section
slenderness ratio (elastic buckling) not considered.
                                              >5%    >50%
                          Min         Pts     Compression
 #  Load Type  Case     Stress   in Region   and Bending    Region
--  ---------  ----     ------   ----------  ------------   ----------------
 1  SUSTAINED    2        -34.       352       79%    63%   Nozzle 1 Next to Shell
 2  OPERATING    3        -30.       352       82%    65%   Nozzle 1 Next to Shell
 3  EXPANSION    4        -25.       352       83%    65%   Nozzle 1 Next to Shell
 4  SUSTAINED    2        -10.       928       67%    61%   Nozzle 1
 5  OPERATING    3         -5.       928       60%    57%   Nozzle 1

 6  EXPANSION    4        -12.       928       80%    76%   Nozzle 1
 7  SUSTAINED    2        -11.      1024       89%     0%   Pad Next to Nozzle 1
 8  OPERATING    3         -9.      1024       93%     0%   Pad Next to Nozzle 1
 9  EXPANSION    4         -6.      1024       78%     0%   Pad Next to Nozzle 1
10  SUSTAINED    2        -14.        96       99%    81%   Shell Next to Nozzle 1 Pad

11  OPERATING    3        -11.        96       99%    78%   Shell Next to Nozzle 1 Pad
12  EXPANSION    4         -8.        96       99%    74%   Shell Next to Nozzle 1 Pad
```

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Flexibilities
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             6:16pm   DEC 24,2024



Flexibilities                                           $X


  The following stiffnesses should be used in a piping,
  "beam-type" analysis of the intersection.  The stiff-
  nesses should be inserted at the surface of the
  branch/header or nozzle/vessel junction.  The general
  characteristics used for the branch pipe should be:

  Outside Diameter =  273.000  mm.
```

```
Wall Thickness    =   10.200  mm.

Axial Translational Stiffness    =        607636.   N /mm.
Inplane Rotational Stiffness     =     616889344.  mm. N /deg
Outplane Rotational Stiffness    =     711035840.  mm. N /deg

The following stiffness(es) were not generated because
of errors in input or because the finite element model
is stiffer than the piping model.

Torsional Rotational Stiffness


Estimated Radial Shell Displacement due to Allowable Loads
SECONDARY:
Axial (mm.) =  1.119  In-Plane (mm.) =  0.304  Out-Plane (mm.) =  0.269

PRIMARY
Axial (mm.) =  1.048  In-Plane (mm.) =  0.285  Out-Plane (mm.) =  0.252

Secondary Conservative Displacement =  0.431 mm.
Secondary Realistic    Displacement =  0.717 mm.

Primary Conservative Displacement =  0.378 mm.
Primary Realistic Displacement    =  0.629 mm.



Intersection Flexibility Factors for Branch/Nozzle
:

Find axial stiffness: K = 3EI/(kd)^3   N /mm.
Find bending and torsional stiffnesses: K = EI/(kd)  mm. N per radian.
The EI product is   0.14635E+14    N mm.^2
The value of (d) to use is: 262.800  mm..
The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor      (k) =     1.585
Inplane Flexibility Factor    (k) =     1.576
Outplane Flexibility Factor   (k) =     1.367
```

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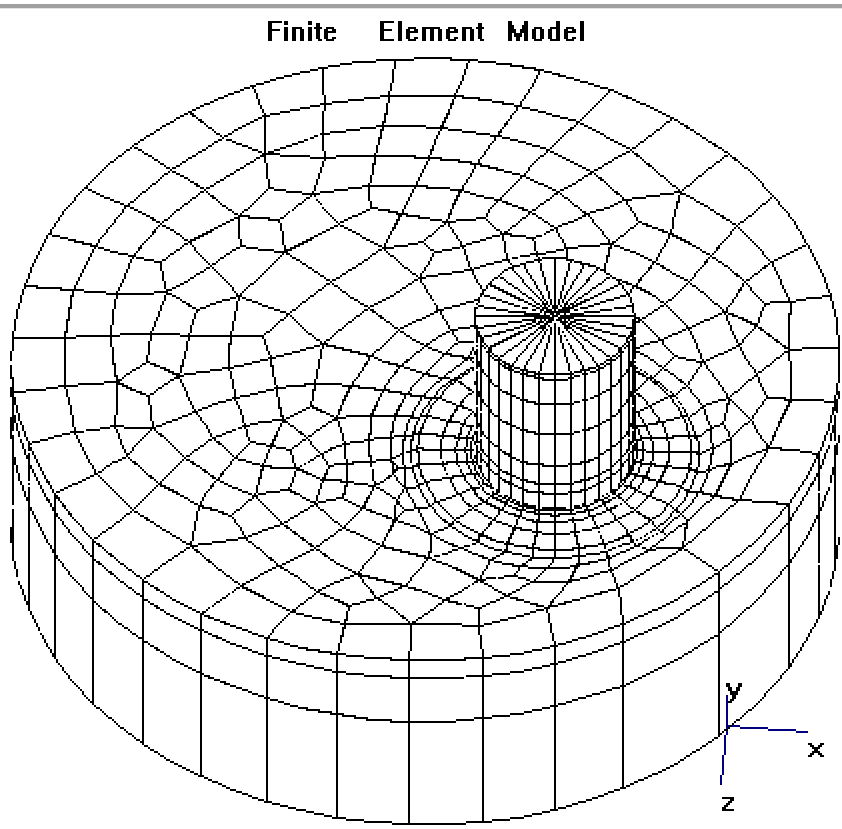
Finite Element Model

- Finite Element Model

Area of Discontinuity at Nozzle

- 1) Pl < SPL (SUS Membrane) Case 2
- 2) Qb < SPS (SUS Bending) Case 2
- 3) Pl+Pb+Q < SPS (SUS Inside) Case 2
- 4) Pl+Pb+Q < SPS (SUS Outside) Case 2
- 5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2
- 6) Pl+Pb+Q < SPS (OPE Inside) Case 3
- 7) Pl+Pb+Q < SPS (OPE Outside) Case 3
- 8) Membrane < User (OPE Membrane) Case 3
- 9) Bending < User (OPE Bending) Case 3
- 15) Pl+Pb+Q < SPS (EXP Inside) Case 4

- 16) Pl+Pb+Q < SPS (EXP Outside) Case 4
- 17) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 4
- 18) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 4
- 10) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 5
- 11) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 6
- 12) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 7
- 13) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 8
- 14) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 9



3d

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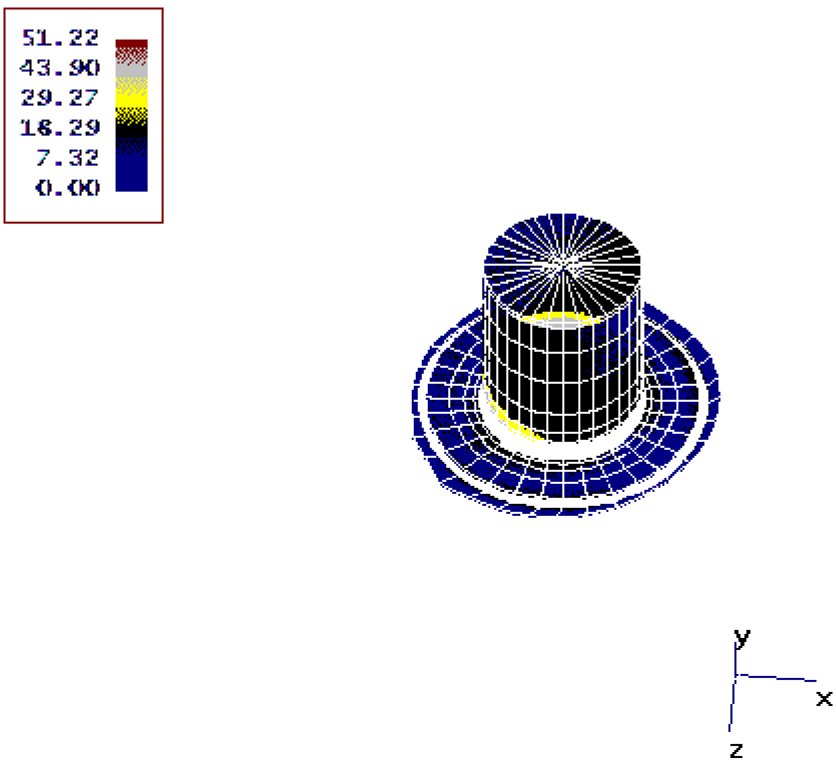
1) Pl < SPL (SUS Membrane) Case 2



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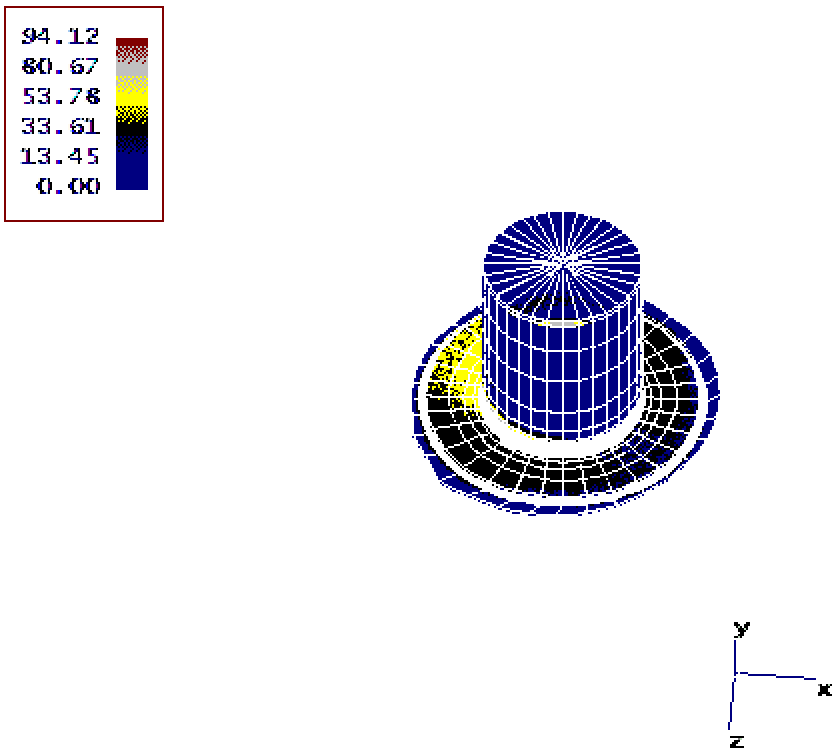
2) Qb < SPS (SUS Bending) Case 2



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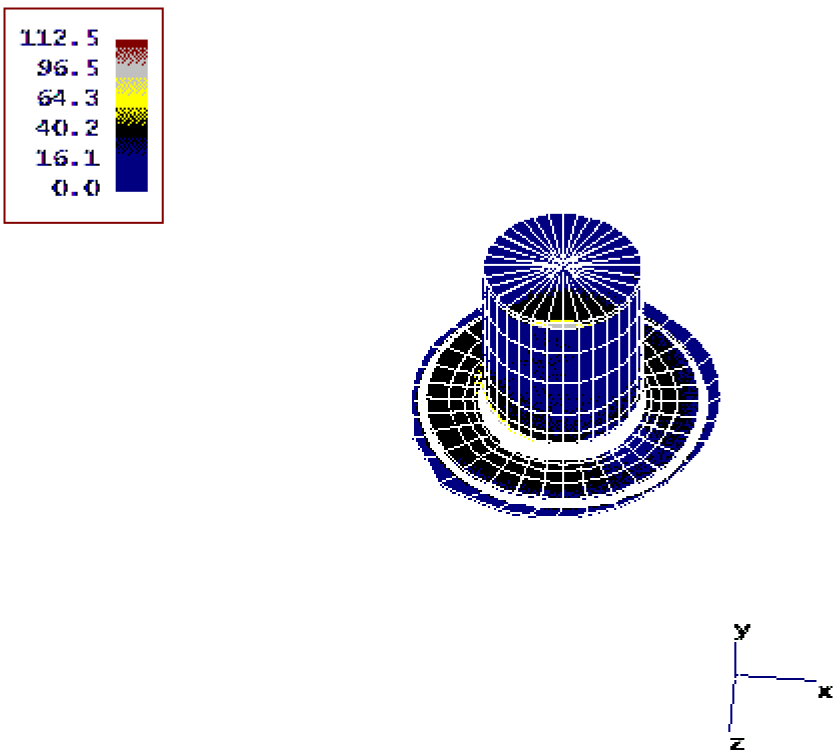
3) Pl+Pb+Q < SPS (SUS Inside) Case 2



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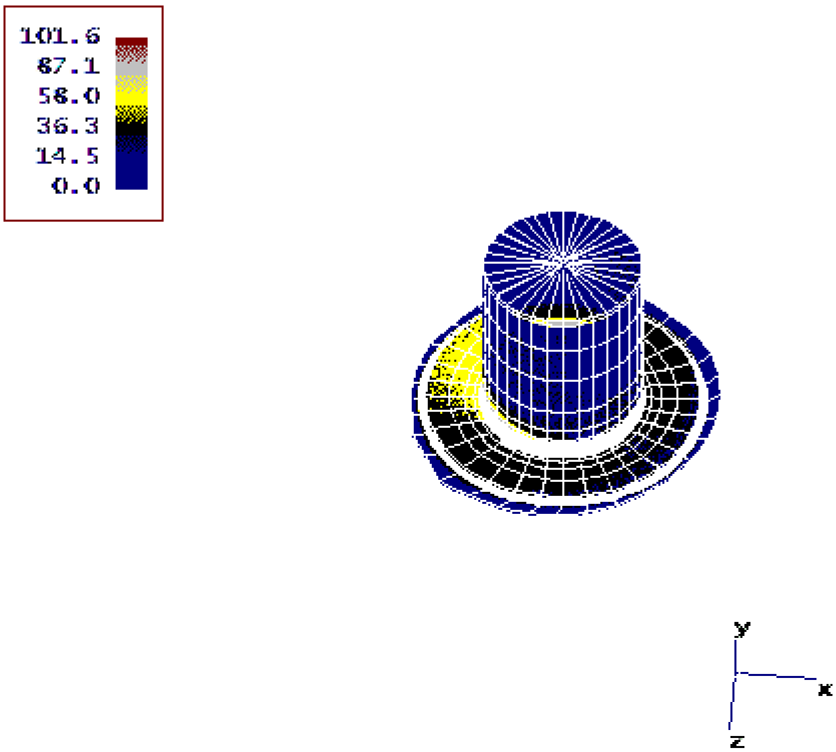
4) Pl+Pb+Q < SPS (SUS Outside) Case 2



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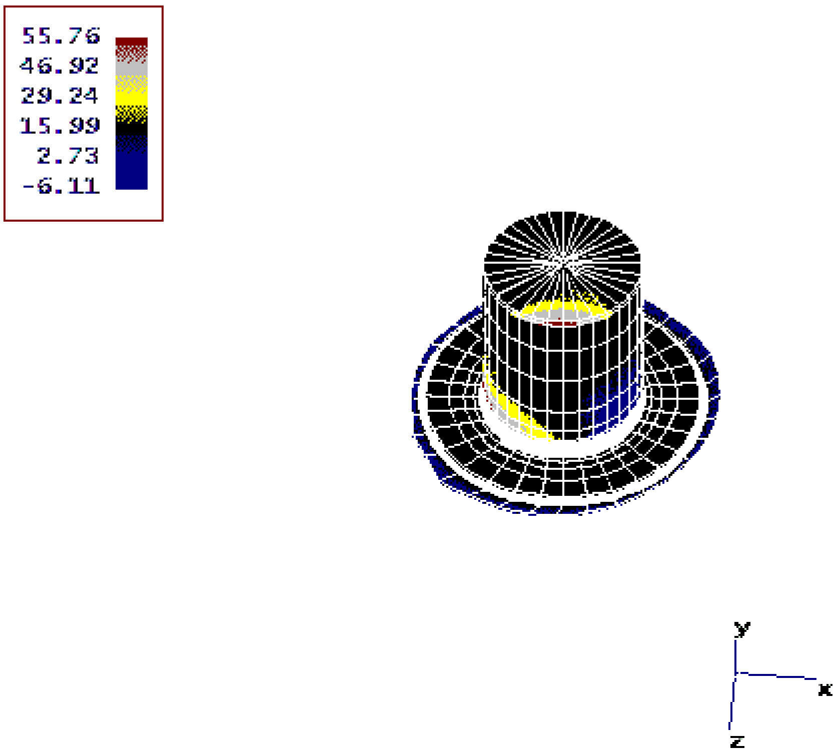
5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2



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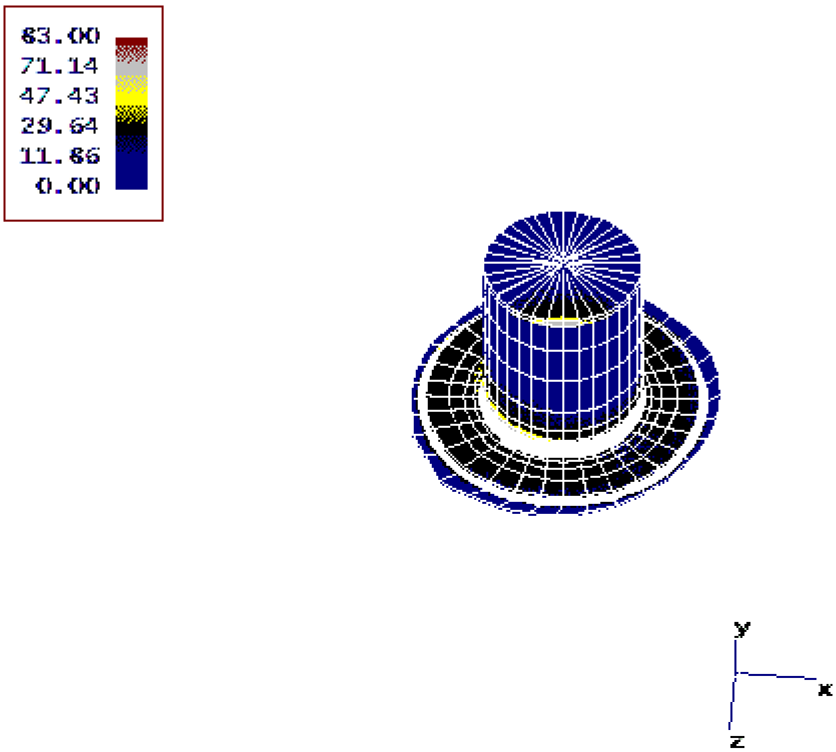
6) Pl+Pb+Q < SPS (OPE Inside) Case 3



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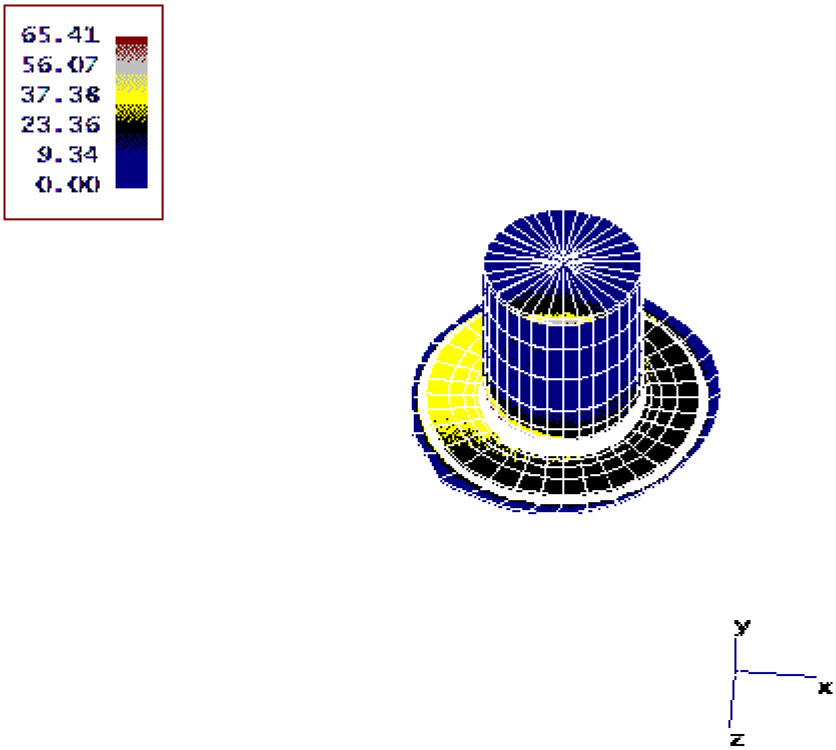
7) Pl+Pb+Q < SPS (OPE Outside) Case 3



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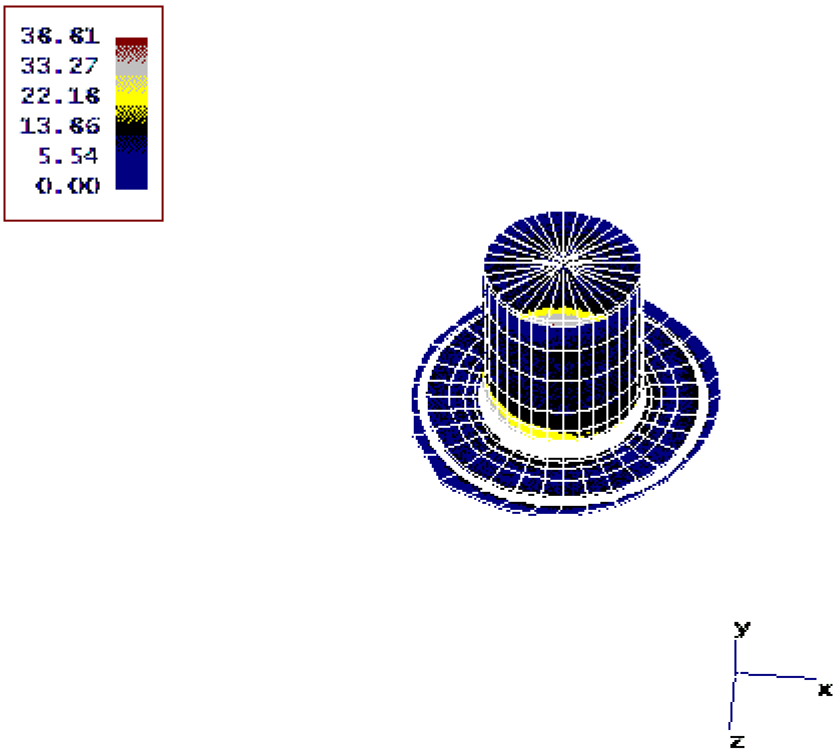
8) Membrane < User (OPE Membrane) Case 3



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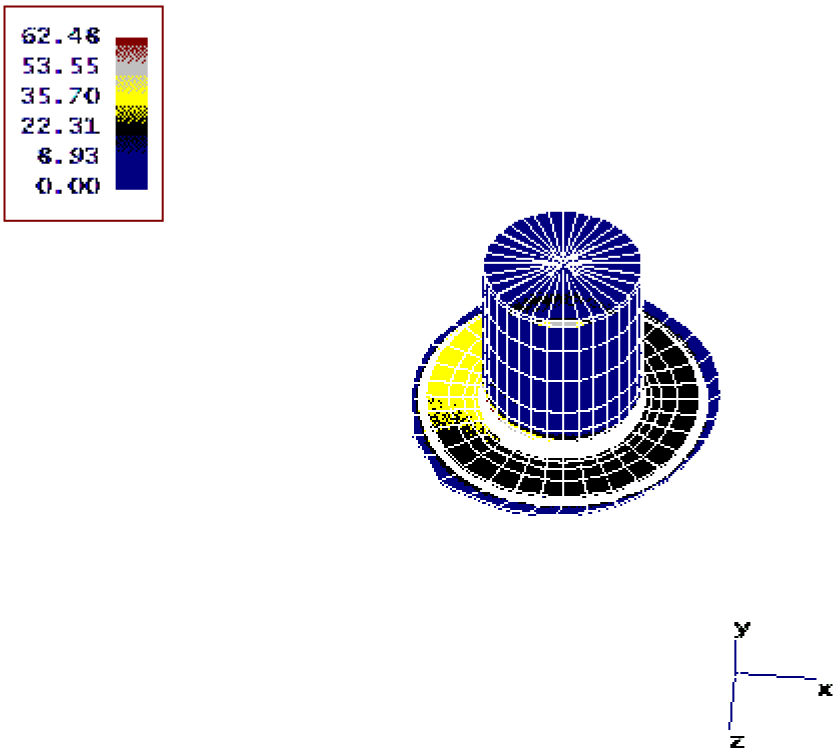
9) Bending < User (OPE Bending) Case 3



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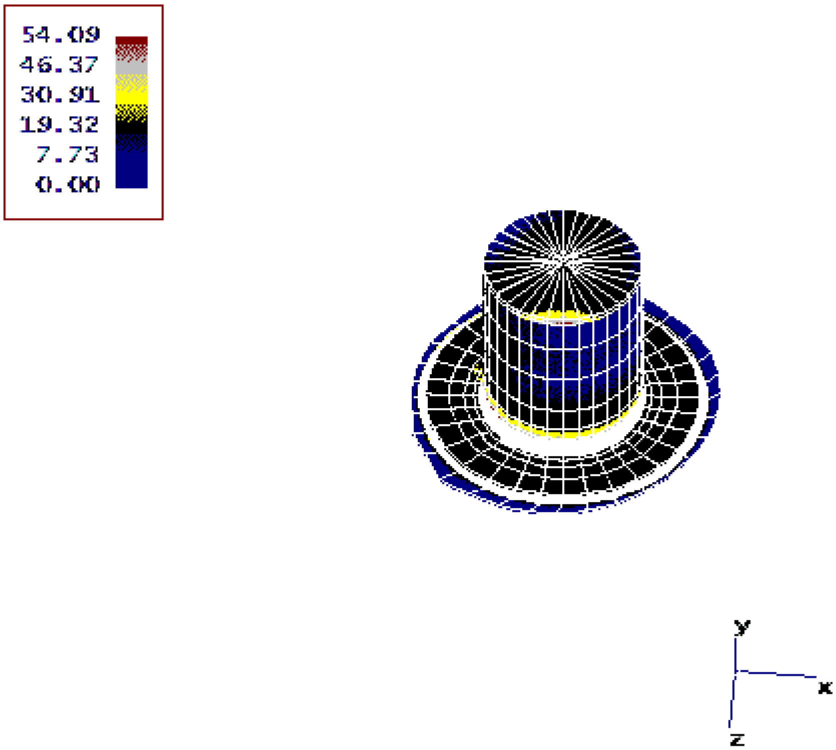
15) Pl+Pb+Q < SPS (EXP Inside) Case 4



3d

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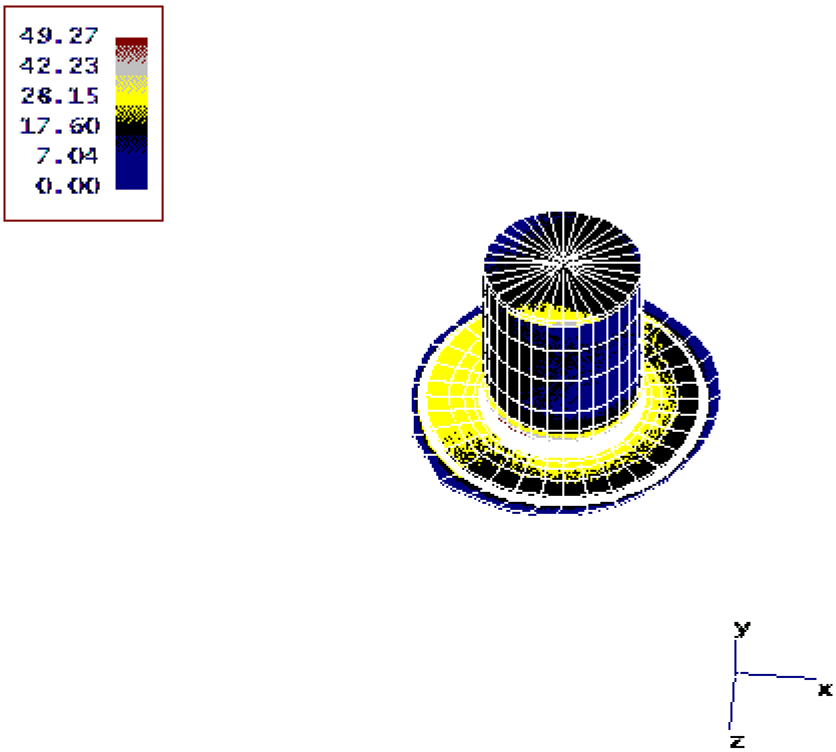
16) Pl+Pb+Q < SPS (EXP Outside) Case 4



3d

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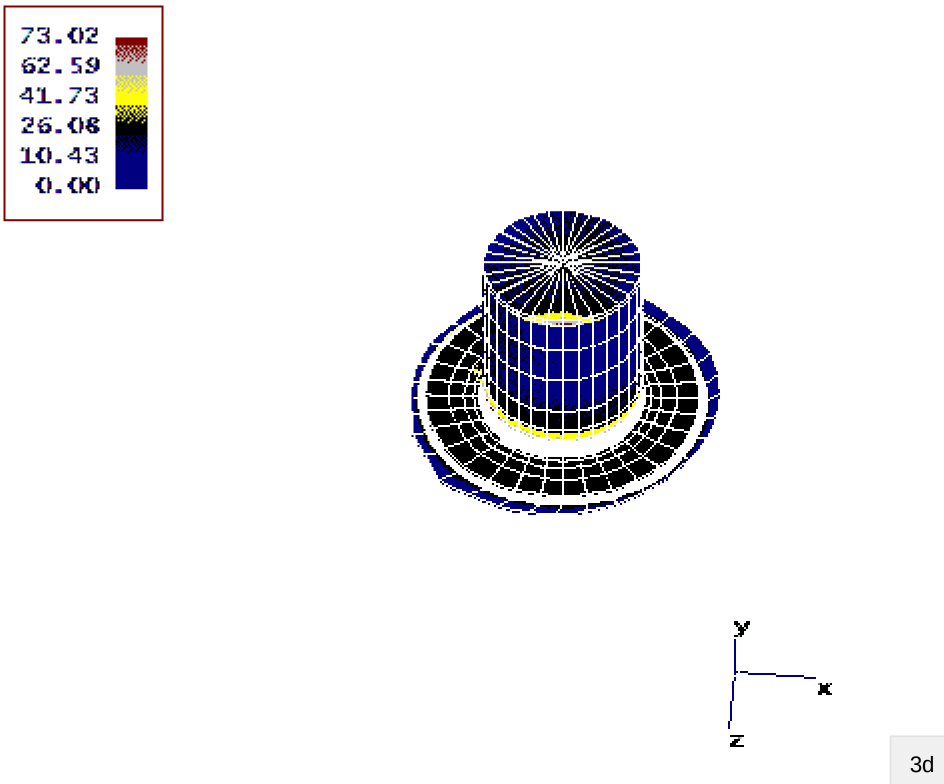
17) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 4



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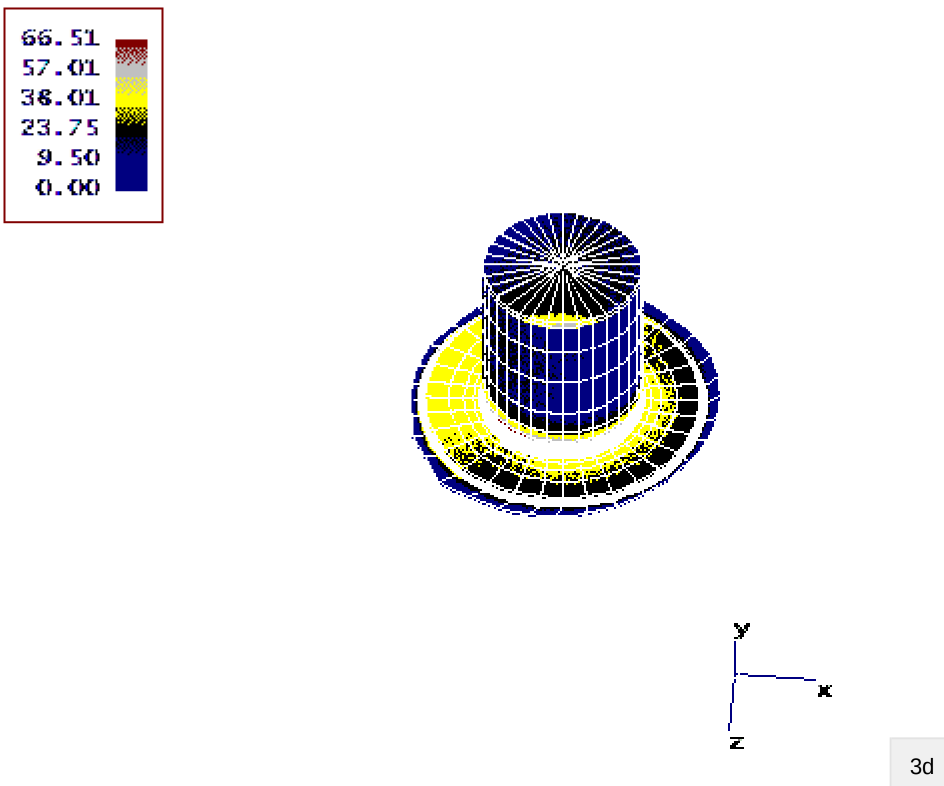
18) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 4



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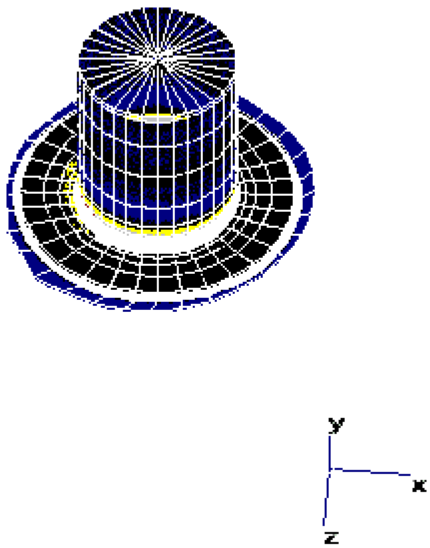
10) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 5



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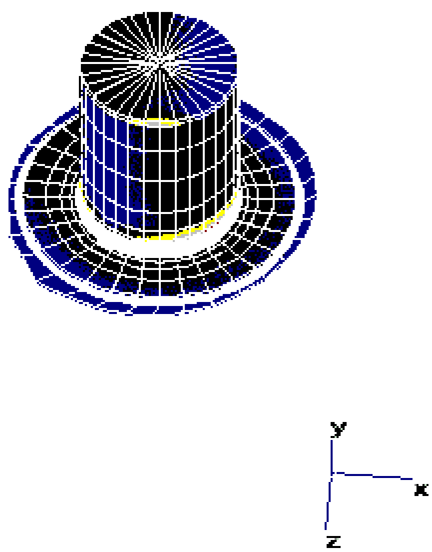
11) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 6



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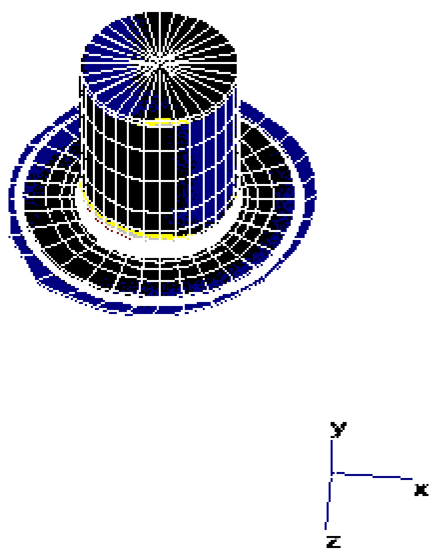
12) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 7



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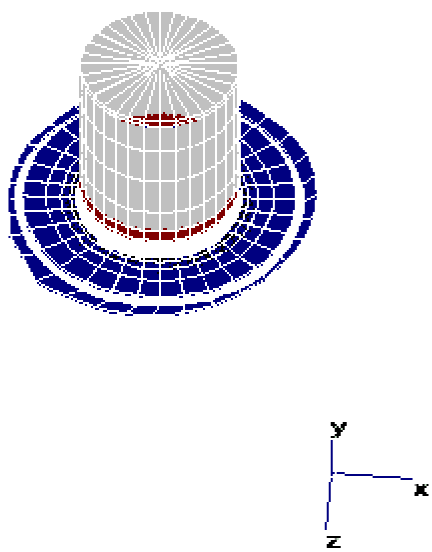
13) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 8



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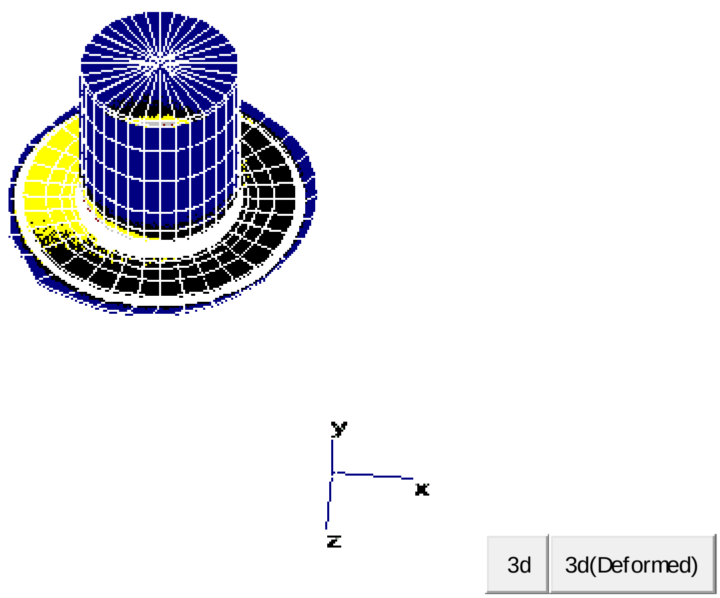
14) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 9



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