طرح نگهداشت و افزایش تولید 27 مخزن

MECHANICAL CALCULATION BOOK FOR GLYCOL CONTACTOR (C-100)

نگهداشت و افزایش تولید میدان نفتی بینک

V00	DEC. 2024	IFI	MFS	M.Fakharian	S.Faramarzpour	
Rev.	**Date**	**Purpose of Issue/Status**	**Prepared by:**	**Checked by:**	**Approved by:**	**CLIENT Approval**

Status:

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

REVISION RECORD SHEET

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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\C-100\C

Date of Analysis       : Dec 25,2024   4:10pm

PV Elite 2020, January 2020
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ASME Code, Section VIII Division 1, 2019

```
Diameter Spec : 746.000 x 706.000 x 700.000 mm. ID
Vessel Design Length, Tangent to Tangent            10626.57  mm.

Distance of Bottom Tangent above Grade               1600.00  mm.
Distance of Base above Grade                          100.00  mm.
Specified Datum Line Distance                        1500.00  mm.

Internal Design Temperature                              148  °C
Internal Design Pressure                              62.000  bars

External Design Temperature                              100  °C
External Design Pressure                               1.034  bars

Maximum Allowable Working Pressure                    62.185  bars
External Max. Allowable Working Pressure              21.228  bars
Hydrostatic Test Pressure                             80.600  bars

Required Minimum Design Metal Temperature                5.0  °C
Warmest Computed Minimum Design Metal Temperature        2.0  °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
Skirt	SA-516 70	...	...	K02700	No	No
Nozzle	SA-106 B	...	...	K03006	No	No
Nozzle	SA-105	...	...	K03504	No	No
Nozzle Flg	SA-105	...	...	K03504	No	No
Nozzle Flg	SA-106 B	...	...	K03006	No	No
Basering	SA-283 C	...	...	K02401	No	No
Flg Bolting	SA-193 B7	...	<= 2 1/2	G41400	No	No
Base Bolting	SA-193 B7	...	<= 2 1/2	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
Bottom Head	62.189	1.03	77.500	0.0000	No	No
Cylinder	62.167	1.03	75.400	0.0000	N/A	No
Body Flg	62.103	1.03	62.700	0.0000	N/A	No
Body Flg	62.103	1.03	62.700	0.0000	N/A	No
Cylinder	62.103	1.03	75.500	0.0000	N/A	No
Body Flg	62.000	1.03	62.800	0.0000	N/A	No
Body Flg	62.000	1.03	62.800	3.0000	N/A	No
Cylinder	62.000	1.03	64.500	3.0000	N/A	No
Cylinder	62.000	1.03	64.500	3.0000	N/A	No
Cylinder	62.000	1.03	64.500	3.0000	N/A	No
Body Flg	62.000	1.03	62.800	3.0000	N/A	No
Body Flg	62.000	1.03	62.800	3.0000	N/A	No
Cylinder	62.000	1.03	64.500	3.0000	N/A	No
Top Head	62.000	1.03	66.800	3.0000	No	No

Liquid Level: 1925.00 mm. Dens.: 999.542 kg/m³ Sp. Gr.: 1.000

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
Skirt	0.0	1500.0	...	25.0	...	...	0.70	0.55
Ellipse	50.0	50.0	25.0	20.0	16.0	1.9	1.00	1.00
Cylinder	2050.0	2000.0	...	20.0	16.5	3.7	1.00	1.00
Body Flg	2220.0	170.0	...	110.0	103.7	64.6	1.00	1.00
Body Flg	2399.5	170.0	...	110.0	103.7	64.6	1.00	1.00
Cylinder	4399.5	2000.0	...	20.0	16.3	3.6	1.00	1.00
Body Flg	4569.5	170.0	...	110.0	103.6	64.6	1.00	1.00
Body Flg	4754.1	175.0	...	115.0	111.3	72.7	1.00	1.00
Cylinder	6254.0	1500.0	...	20.0	19.3	8.2	1.00	1.00
Cylinder	7754.1	1500.0	...	20.0	19.3	8.2	1.00	1.00
Cylinder	9354.0	1600.0	...	20.0	19.3	8.2	1.00	1.00
Body Flg	9529.0	175.0	...	115.0	111.3	72.7	1.00	1.00
Body Flg	9713.6	175.0	...	115.0	111.3	72.7	1.00	1.00
Cylinder	10576.6	863.0	...	20.0	19.3	5.7	1.00	1.00
Ellipse	10626.6	50.0	25.0	20.0	18.8	4.9	1.00	1.00

Wind/Earthquake Shear, Bending:

From	To	Distance to Support mm.	Cumulative Wind Shear kN	Earthquake Shear kN	Wind Bending N-m	Earthquake Bending N-m
10	20	750	4.38458	60.5027	31954.2	533734

20	30	1525	4.00598	59.7352	25658.8	443519
30	40	2550	3.99321	59.435	25458.7	440539
40	50	3635	3.48238	57.0514	17980.1	324005
50	60	3814.53	3.44101	56.2794	17358.6	313832
60	70	4899.53	3.39964	55.4693	16776.9	304329
70	80	5984.53	2.8888	50.4974	10485.9	198320
80	90	6166.55	2.84743	49.2263	9970.98	189371
90	100	7004.05	2.80517	47.8371	9476.18	180874
100	110	8504.05	2.42476	40.4122	5552.14	114660
110	120	10054	2.04434	35.7924	2198.96	57483.7
120	130	10941.5	0.36449	17.0336	271.113	15205.8
130	140	11126.1	0.32222	14.5687	207.932	12300.6
140	150	11645.1	0.27995	12.0622	155.221	9969.46
150	160	12101.6	0.06148	8.51807	7.83447	1085.47

Abs Max of the all of the Stress Ratio's : 0.7775

Basering Data : Continuous Top Ring W/Gussets

Thickness of Basering	80.0000	mm.
Inside Diameter of Basering	620.0000	mm.
Outside Diameter of Basering	1060.0000	mm.
Nominal Diameter of Bolts	48.0000	mm.
Diameter of Bolt Circle	960.0000	mm.
Number of Bolts	12	
Thickness of Gusset Plates	12.0000	mm.
Average Width of Gusset Plates	162.0000	mm.
Height of Gussets	265.0000	mm.
Distance between Gussets	100.0000	mm.
Thickness of Top Plate or Ring	35.0000	mm.
Circumferential Width of the Top Plate	170.5000	mm.
Radial Width of the Top Plate	200.0000	mm.

Basering Sketch for Cylindrical Skirts:

```
                    ----->| |<----- 25.0000 mm.
  736.00 mm.  ----------->|
                         _
  686.00 mm.  --------->| |
                        | |_____________    _
                        |  _____________|   _ 35.0000 mm.
                        | |        |
                        | |        |
                        | |        |
                        | |        |
                        | |        |
                        | |        |
                 _______| |__ _ ___|____    _
  620.00 mm. --->|___________|_|________|   _ 80.0000 mm.
  960.00 mm. ---------------->|         |
 1060.00 mm. -------------------------->|
```

Basering Cross Section View

Loads for Foundation/Support Design:

Factored Loads:

Total Wind Shear on Support	4.	kN
Total Earthquake Shear on Support	61.	kN
Wind Moment on Support	41470.	N-m
Earthquake Moment on Support	543250.	N-m
Maximum Initial Bolt Load	176.	kN

Un-Factored Loads:

Wind Shear on Support	7.	kN
Earthquake Shear on Support	86.	kN
Wind Moment on Support	69117.	N-m
Earthquake Moment on Support	776071.	N-m
Maximum Initial Bolt Load	293.	kN

Note:
Wind and Earthquake moments include the effects of user defined forces and moments if any exist in the job and were specified to act (compute loads and stresses) during these cases. Also included are moment effects due to eccentric weights if any are present in the input.

Local Stress Analysis Results:

Description	Analysis Type	Max Stress Ratio	High Stress Location	Pass Fail
N01 (6in)	WRC-107/537	0.817	n/a	Passed
N02 (6in)	WRC-107/537	0.837	n/a	Passed

Weights:

Fabricated	- Bare W/O Removable Internals	8361.9	kg.
Shop Test	- Fabricated + Water (Full)	12562.1	kg.
Shipping	- Fab. + Rem. Intls.+ Shipping App.	12038.0	kg.
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	14578.0	kg.
Empty	- Fab. + Intls. + Details + Wghts.	14578.0	kg.
Operating	- Empty + Operating Liquid (No CA)	15679.5	kg.
Field Test	- Empty Weight + Water (Full)	15348.5	kg.

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
N07 (1in)	72.7	OK	...	OK	3.22	OK	Passed
K07A (3in)	77.5	OK	...	OK	4.80	OK	Passed
K07A (3in)	77.5	OK	...	OK	4.80	OK	Passed
K09A (2in)	67.9	OK	...	OK	3.42	OK	Passed
K09A (2in)	68.9	OK	...	OK	3.42	OK	Passed
N01 (6in)	75.4	OK	...	OK	6.22	OK	Passed
N09 (1in)	75.4	OK	...	OK	3.42	OK	Passed
K07B (3in)	75.4	OK	...	OK	5.73	OK	Passed
K08A (2in)	75.4	OK	...	OK	4.80	OK	Passed
K08B (2in)	75.4	OK	...	OK	4.80	OK	Passed
K09B (2in)	75.4	OK	...	OK	4.80	OK	Passed
N10A (8in)	74.9	OK	...	...		OK	Passed
N05 (2in)	75.4	OK	...	OK	4.80	OK	Passed
N04 (1in)	75.5	OK	...	OK	3.42	OK	Passed
N10B (8in)	75.5	OK	...	...		OK	Passed
K2B (2in)	75.5	OK	...	OK	4.80	OK	Passed
K2A (2in)	75.5	OK	...	OK	4.80	OK	Passed
K3B (2in)	75.5	OK	...	OK	4.80	OK	Passed
K3A (2in)	75.5	OK	...	OK	4.80	OK	Passed
K4B (2in)	75.5	OK	...	OK	5.73	OK	Passed
K4A (2in)	75.5	OK	...	OK	5.73	OK	Passed
K10A (2in)	63.5	OK	...	OK	7.80	OK	Passed
K05 (2in)	63.5	OK	...	OK	7.80	OK	Passed
K10B (2in)	63.5	OK	...	OK	7.80	OK	Passed
K1 (2in)	63.5	OK	...	OK	7.80	OK	Passed
N06 (2in)	63.5	OK	...	OK	7.80	OK	Passed
K6A (2in)	63.5	OK	...	OK	7.80	OK	Passed
K6B (2in)	63.5	OK	...	OK	7.80	OK	Passed
N03 (2in)	64.5	OK	...	OK	6.42	OK	Passed
N10C (8in)	62.9	OK	...	...		OK	Passed
N02 (6in)	66.8	OK	...	OK	9.22	OK	Passed
N08 (2in)	62.2	OK	...	OK	7.80	OK	Passed
N08 (2in)	66.8	OK	...	OK	7.80	OK	Passed

Nozzle MAWP Summary:

```
Minimum MAWP Nozzles          :            62.2 Nozzle  : N08 (2in)
Minimum MAWP Shells/Flanges   :            62.7 Element :
Minimum MAPnc Shells/Flanges  :            62.8 Element :
-------------------------------------------------------
Computed Vessel M.A.W.P.      :            62.2 bars
```

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

Check the Spatial Relationship between the Nozzles:

From Node	Nozzle Description	Y Coordinate mm.	Layout Angle deg	Dia. Limit mm.
20	N07 (1in)	0.000	0.000	88.260
20	K07A (3in)	0.000	180.000	159.299
20	K09A (2in)	0.000	90.000	100.325
30	N01 (6in)	1400.000	90.000	311.658
30	N09 (1in)	200.000	90.000	93.848
30	K07B (3in)	776.000	180.000	157.000
30	K08A (2in)	520.000	45.000	124.328
30	K08B (2in)	776.000	45.000	124.328
30	K09B (2in)	694.000	90.000	124.328
30	N10A (8in)	1650.000	180.000	409.524
30	N05 (2in)	200.000	180.000	124.328
60	N04 (1in)	2499.525	90.000	94.000
60	N10B (8in)	3893.226	180.000	393.700
60	K2B (2in)	3770.525	45.000	124.000
60	K2A (2in)	3514.525	45.000	124.000
60	K3B (2in)	2692.526	0.000	124.000
60	K3A (2in)	2948.525	0.000	124.000
60	K4B (2in)	3770.525	315.000	157.000
60	K4A (2in)	2692.526	315.000	157.000
90	K10A (2in)	4874.050	90.000	118.000
90	K05 (2in)	5186.350	270.000	118.000
110	K10B (2in)	9247.050	90.000	118.000
140	K1 (2in)	9920.574	225.000	118.000
140	N06 (2in)	9920.574	270.000	118.000
140	K6A (2in)	9963.574	0.000	118.000
140	K6B (2in)	10263.575	0.000	118.000
140	N03 (2in)	9823.574	90.000	88.000
140	N10C (8in)	9963.574	180.000	405.700
150	N02 (6in)	0.000	0.000	310.145
150	N08 (2in)	0.000	0.000	118.000

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 !

Bill of Materials:

QTY	DESCRIPTION	MATERIAL
1	SKIRT: 25.0mm. THK X 686.0mm. ID X 1500.0mm.	SA-516 70
1	ELLIPTICAL HEAD: 2.0 X 1, 25.0mm. THK X 706.0mm. ID X 50.0mm.	SA-516 70
2	CYLINDER: 20.0mm. THK X 706.0mm. ID X 2000.0mm.	SA-516 70
3	BODY FLANGE: 110.0mm. THK X 706.0mm. OD	SA-105
3	BODY FLANGE: 115.0mm. THK X 700.0mm. OD	SA-105
2	CYLINDER: 20.0mm. THK X 700.0mm. ID X 1500.0mm.	SA-516 70
1	CYLINDER: 20.0mm. THK X 700.0mm. ID X 1600.0mm.	SA-516 70
1	CYLINDER: 20.0mm. THK X 700.0mm. ID X 863.0mm.	SA-516 70
1	ELLIPTICAL HEAD: 2.0 X 1, 25.0mm. THK X 700.0mm. ID X 50.0mm.	SA-516 70
3	INSULATION: 1500mm X 50mm THK	
2	INSULATION: 225mm X 50mm THK	
1	LINING: 212.500mm X 3.000mm THK	...
2	INSULATION: 2000mm X 50mm THK	
2	LINING: 2000.000mm X 3.000mm THK	...
4	INSULATION: 175mm X 50mm THK	
2	INSULATION: 169mm X 50mm THK	
1	PACKING: 1270.000mm	...
1	PACKING: 1500.000mm	...
1	PLATFORM: 1050mm X 1100mm WIDE	
1	LADDER: 10500mm	...
1	PACKING: 1380.000mm	...
1	INSULATION: 1600mm X 50mm THK	
1	INSULATION: 850mm X 50mm THK	
3	CLASS 600 GR 1.1, 8.0" BLIND FLANGE(S)	SA-105
1	CLASS 600 GR 1.1, 2.0" BLIND FLANGE(S)	SA-105

1	BASERING: 1060.0mm. OD X 620.0 ID X 80.0mm.	SA-283 C
12	BASERING BOLTS: 48.0mm. DIA	SA-193 B7
12	NUTS FOR BODY BASERING BOLTS: 48.0mm. DIA	...
1	BASERING TOP RING: 1020.0mm. OD X 620.0 ID X 35.0mm.	SA-283 C
24	BASERING GUSSET PLATES: 162mm. X 200mm. X 265mm. X 12mm.	...
3	GASKET: 787mm. OD X 736mm. ID	...
60	BODY FLANGE BOLTS: 41mm. DIA	SA-193 B7
120	NUTS FOR BODY FLANGE BOLTS: 41mm. 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
N09 (1in)	1.000 in	Actual	LW	2.120	14.224	...	...	545.0	600
N04 (1in)	1.000 in	Actual	LW	2.126	14.300	...	...	247.2	600
N03 (2in)	1.000 in	Actual	LW	2.126	14.300	...	...	221.0	600
N07 (1in)	1.500 in	XXS	WN	1.900	10.160	...	...	220.4	600
K09A (2in)	2.000 in	XXS	WN	2.375	11.074	...	...	231.5	600
K08A (2in)	2.000 in	Actual	LW	3.320	16.764	...	...	222.5	600
K08B (2in)	2.000 in	Actual	LW	3.320	16.764	...	...	222.5	600
K09B (2in)	2.000 in	Actual	LW	3.320	16.764	...	...	222.5	600
N05 (2in)	2.000 in	Actual	LW	3.320	16.764	...	...	222.5	600
K2B (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	222.5	600
K2A (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	222.5	600
K3B (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	222.5	600
K3A (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	222.5	600
K10A (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	222.5	600
K05 (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	222.5	600
K10B (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	222.5	600
K1 (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	222.5	600
N06 (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	222.5	600
K6A (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	222.5	600
K6B (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	222.5	600
N08 (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	246.5	600
K07A (3in)	3.000 in	STD	WN	3.500	5.486	...	...	243.5	600
K07B (3in)	3.000 in	Actual	LW	4.606	20.400	...	...	224.8	600
K4B (2in)	3.000 in	Actual	LW	4.606	20.400	...	...	224.8	600
K4A (2in)	3.000 in	Actual	LW	4.606	20.400	...	...	224.8	600
N01 (6in)	6.000 in	STD	WN	6.625	7.112	...	...	238.5	600
N02 (6in)	6.000 in	80	WN	6.625	10.973	...	...	229.3	600
N10A (8in)	8.000 in	STD	WN	8.625	8.179	...	...	252.2	600

N10B (8in)	8.000 in	80	WN	8.625	12.700	...	...	250.4	600
N10C (8in)	8.000 in	80	WN	8.625	12.700	...	...	250.7	600

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
N09 (1in)	SA-105	18.000	10.000	...	...	15.000
N04 (1in)	SA-105	18.000	10.000	...	...	...
N03 (2in)	SA-105	20.000	10.000	...	...	...
N07 (1in)	SA-106 B	18.000	10.000	...	...	...
K09A (2in)	SA-106 B	18.000	12.000	...	...	...
K08A (2in)	SA-105	18.000	10.000	...	...	...
K08B (2in)	SA-105	18.000	10.000	...	...	...
K09B (2in)	SA-105	18.000	10.000	...	...	...
N05 (2in)	SA-105	18.000	10.000	...	...	...
K2B (2in)	SA-105	18.000	10.000	...	...	...
K2A (2in)	SA-105	18.000	10.000	...	...	...
K3B (2in)	SA-105	18.000	10.000	...	...	...
K3A (2in)	SA-105	18.000	10.000	...	...	...
K10A (2in)	SA-105	18.000	10.000	...	...	...
K05 (2in)	SA-105	18.000	10.000	...	...	...
K10B (2in)	SA-105	18.000	10.000	...	...	...
K1 (2in)	SA-105	20.000	10.000	...	...	...
N06 (2in)	SA-105	20.000	10.000	...	...	...
K6A (2in)	SA-105	20.000	10.000	...	...	...
K6B (2in)	SA-105	20.000	10.000	...	...	...
N08 (2in)	SA-105	20.000	12.000	...	...	...
K07A (3in)	SA-105	18.000	10.000	...	...	...
K07B (3in)	SA-105	18.000	10.000	...	...	...
K4B (2in)	SA-105	18.000	10.000	...	...	...
K4A (2in)	SA-105	18.000	10.000	...	...	...
N01 (6in)	SA-105	15.000	10.000	...	...	...
N02 (6in)	SA-105	15.000	10.000	...	...	...
N10A (8in)	SA-105	18.000	10.000	...	...	...
N10B (8in)	SA-105	18.000	10.000	...	...	...
N10C (8in)	SA-105	20.000	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
N09 (1in)	200.000	90.0	200.00	325.00	Node: 30
N04 (1in)	2499.525	90.0	226.19	0.00	Node: 60
N03 (2in)	9823.574	90.0	200.00	0.00	Node: 140
N07 (1in)	...	0.0	200.00	0.00	Bottom Head
K09A (2in)	...	90.0	200.00	0.00	Bottom Head
K08A (2in)	520.000	45.0	200.00	0.00	Node: 30
K08B (2in)	776.000	45.0	200.00	0.00	Node: 30
K09B (2in)	694.000	90.0	200.00	0.00	Node: 30
N05 (2in)	200.000	180.0	200.00	0.00	Node: 30
K2B (2in)	3770.526	45.0	200.00	0.00	Node: 60
K2A (2in)	3514.525	45.0	200.00	0.00	Node: 60
K3B (2in)	2692.526	0.0	200.00	0.00	Node: 60
K3A (2in)	2948.525	0.0	200.00	0.00	Node: 60
K10A (2in)	4874.050	90.0	200.00	0.00	Node: 90
K05 (2in)	5186.350	270.0	200.00	0.00	Node: 90
K10B (2in)	9247.050	90.0	200.00	0.00	Node: 110
K1 (2in)	9920.574	225.0	200.00	0.00	Node: 140
N06 (2in)	9920.574	270.0	200.00	0.00	Node: 140
K6A (2in)	9963.574	0.0	200.00	0.00	Node: 140
K6B (2in)	10263.574	0.0	200.00	0.00	Node: 140
N08 (2in)	...	0.0	200.00	0.00	Top Head
K07A (3in)	...	180.0	200.00	0.00	Bottom Head
K07B (3in)	776.000	180.0	200.00	0.00	Node: 30
K4B (2in)	3770.526	315.0	200.00	0.00	Node: 60
K4A (2in)	2692.526	315.0	200.00	0.00	Node: 60
N01 (6in)	1400.000	90.0	200.00	0.00	Node: 30
N02 (6in)	...	0.0	200.00	0.00	Top Head
N10A (8in)	1650.000	180.0	200.00	0.00	Node: 30
N10B (8in)	3893.226	180.0	200.00	0.00	Node: 60
N10C (8in)	9963.574	180.0	200.00	0.00	Node: 140

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]	B	-11	-20	-29	0.824	18.000	1.00	Yes
	[11]	B	-11	-20	-29	0.824	18.000	1.00	Yes
	[11]	B	-11	-20	-29	0.823	18.000	1.00	Yes
	[11]	B	-7	-9	-29	0.963	20.000	1.00	Yes
	[11]	B	-7	-9	-29	0.963	20.000	1.00	Yes
	[11]	B	-7	-9	-29	0.963	20.000	1.00	Yes
Bottom Head	[10]	B	-7	-19	-29	0.800	20.000	1.00	Yes
Bottom Head	[7]	B	-1	-20	-29	0.655	25.000	1.00	Yes
	[8]	B	-7	-17	-29	0.828	20.000	1.00	Yes
	[8]	B	-7	-17	-29	0.819	20.000	1.00	Yes
	[8]	B	-7	-9	-29	0.962	20.000	1.00	Yes
	[8]	B	-7	-9	-29	0.962	20.000	1.00	Yes
	[8]	B	-7	-9	-29	0.962	20.000	1.00	Yes
	[8]	B	-7	-9	-29	0.962	20.000	1.00	Yes
Top Head	[10]	B	-7	-11	-29	0.930	20.000	1.00	Yes
Top Head	[7]	B	-1	-15	-29	0.744	25.000	1.00	Yes
N07 (1in)	[1]	B	-8	-104	-29	0.093	8.890	1.00	Yes
Nozzle Flg	[5]	A	-18	-39					
K07A (3in)	[1]	A	12	-3		0.720	20.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-39					
K09A (2in)	[1]	B	-8	-104	-29	0.115	9.690	1.00	Yes
Nozzle Flg	[5]	A	-18	-39					
N01 (6in)	[1]	B	-7	-29	-29	0.816	20.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
N09 (1in)	[1]	A	2	-104		0.041	14.224	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
K07B (3in)	[1]	A	12	2		0.816	20.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
K08A (2in)	[1]	A	7	-104		0.070	16.764	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
K08B (2in)	[1]	A	7	-104		0.070	16.764	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
K09B (2in)	[1]	A	7	-104		0.070	16.764	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
N10A (8in)	[1]	B	-8	-29	-29	0.661	7.156	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
N05 (2in)	[1]	A	7	-104		0.070	16.764	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
N04 (1in)	[1]	A	3	-104		0.041	14.300	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
N10B (8in)	[1]	B	-7	-29	-29	0.816	20.000	1.00	Yes
Nozzle Flg	[5]	!	-18	-40					
K2B (2in)	[1]	A	7	-104		0.070	16.600	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
K2A (2in)	[1]	A	7	-104		0.070	16.600	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
K3B (2in)	[1]	A	7	-104		0.070	16.600	1.00	Yes

Nozzle Flg	[5]	A	-18	-40					
K3A (2in)	[1]	A	7	-104		0.070	16.600	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
K4B (2in)	[1]	A	12	2		0.816	20.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
K4A (2in)	[1]	A	12	2		0.817	20.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
K10A (2in)	[1]	A	7	-104		0.096	16.600	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
K05 (2in)	[1]	A	7	-104		0.096	16.600	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
K10B (2in)	[1]	A	7	-104		0.096	16.600	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
K1 (2in)	[1]	A	7	-104		0.096	16.600	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
N06 (2in)	[1]	A	7	-104		0.096	16.600	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
K6A (2in)	[1]	A	7	-104		0.096	16.600	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
K6B (2in)	[1]	A	7	-104		0.096	16.600	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
N03 (2in)	[1]	A	3	-104		0.064	14.300	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
N10C (8in)	[1]	B	5	-19		0.578	11.113	1.00	Yes
Nozzle Flg	[5]	!	-18	-40					
N02 (6in)	[1]	B	-7	-29	-29	0.837	20.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
N08 (2in)	[1]	A	7	-104		0.096	16.600	1.00	Yes
Nozzle Flg	[5]	A	-18	-40					
Bolting	[21]		-48						
Bolting	[21]		-48						
Bolting	[21]		-48						
Warmest MDMT:			12	2					

Required Minimum Design Metal Temperature	5.0	°C
Warmest Computed Minimum Design Metal Temperature	2.0	°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.
==========================================================================
Note   10    30     There is a high jump in the Joint Eff.

Class From To: Check of Additional Element Data
==========================================================================
```

There were no geometry errors or warnings.

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PV Elite Vessel Analysis Program: Input Data

```
Design Internal Pressure (for Hydrotest)                         62  bars
Design Internal Temperature                                   148.0  °C
Type of Hydrotest                                 UG-99(b) Note [36]
Hydrotest Position                                         Vertical
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)                           N
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                                  2.000
Site Class                                                       C
Component Elevation Ratio                z/h                 0.000
Amplification Factor                      Ap                 0.000
Force Factor                                                 0.000
Consider Vertical Acceleration                                  No
Minimum Acceleration Multiplier                              0.000
User Value of Sds (used if > 0 )                             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                                            Skirt Sup.
Description                                              Skirt
Distance "FROM" to "TO"                                   1500   mm.
Skirt Outside Diameter                                     736   mm.
```

```
Diameter of Skirt at Base                                  736  mm.
Skirt Thickness                                             25  mm.
Internal Corrosion Allowance                                 0  mm.
Nominal Thickness                                            0  mm.
External Corrosion Allowance                                 0  mm.
Design Temperature Internal Pressure                       148  °C
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                             231.81  N./mm²
    UCS-66 Chart Curve Designation                           B
    External Pressure Chart Name                          CS-2
    UNS Number                                          K02700
    Product Form                                         Plate
Efficiency, Longitudinal Seam                              0.7
Efficiency, Head-to-Skirt or Circ. Seam                   0.55
Weld is pre-Heated                                          No

    Element From Node                                       10
    Detail Type                                     Insulation
    Detail ID                                        FIREPROOF
    Dist. from "FROM" Node / Offset dist                     0  mm.
    Height/Length of Insulation                           1500  mm.
    Thickness of Insulation                                 50  mm.
    Density                                               2500  kg/m³

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

Element From Node                                           20
Element To Node                                             30
Element Type                                        Elliptical
Description                                        Bottom Head
Distance "FROM" to "TO"                                     50  mm.
Inside Diameter                                            706  mm.
Element Thickness                                           20  mm.
Internal Corrosion Allowance                                 0  mm.
Nominal Thickness                                           25  mm.
External Corrosion Allowance                                 0  mm.
Design Internal Pressure                                    62  bars
Design Temperature Internal Pressure                       148  °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
Elliptical Head Factor                                     2.0
Weld is pre-Heated                                          No
```

Element From Node	20	
Detail Type	Liquid	
Detail ID	Liquid: 20	
Dist. from "FROM" Node / Offset dist	-175	mm.
Height/Length of Liquid	225	mm.
Liquid Density	999.54	kg/m³

Element From Node	20	
Detail Type	Insulation	
Detail ID	Ins: 30	
Dist. from "FROM" Node / Offset dist	-175	mm.
Height/Length of Insulation	225	mm.
Thickness of Insulation	50	mm.
Density	125	kg/m³

Element From Node	20	
Detail Type	Lining	
Detail ID	CLAD	
Dist. from "FROM" Node / Offset dist	-162.5	mm.
Height/Length of Lining	212.5	mm.
Thickness of Lining	3	mm.
Density	8027	kg/m³

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N07 (1in)	
Dist. from "FROM" Node / Offset dist	0	mm.
Nozzle Diameter	1.5	in.
Nozzle Schedule	XXS	
Nozzle Class	600	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.09588	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	K07A (3in)	
Dist. from "FROM" Node / Offset dist	200	mm.
Nozzle Diameter	3	in.
Nozzle Schedule	STD	
Nozzle Class	600	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.219	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	K09A (2in)	
Dist. from "FROM" Node / Offset dist	200	mm.
Nozzle Diameter	2	in.

```
    Nozzle Schedule                                        XXS
    Nozzle Class                                           600
    Layout Angle                                          90.0
    Blind Flange (Y/N)                                       N
    Weight of Nozzle ( Used if > 0 )                    0.1431  kN
    Grade of Attached Flange                            GR 1.1
    Nozzle Matl                                       SA-106 B

    Element From Node                                       20
    Detail Type                                         Weight
    Detail ID                                   VORTEX BREAKER
    Dist. from "FROM" Node / Offset dist                -162.5  mm.
    Miscellaneous Weight                                0.4903  kN
    Offset from Element Centerline                           0  mm.

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

Element From Node                                           30
Element To Node                                             40
Element Type                                          Cylinder
Description
Distance "FROM" to "TO"                                   2000  mm.
Element Outside Diameter                                   746  mm.
Element Thickness                                           20  mm.
Internal Corrosion Allowance                                 0  mm.
Nominal Thickness                                            0  mm.
External Corrosion Allowance                                 0  mm.
Design Internal Pressure                                    62  bars
Design Temperature Internal Pressure                       148  °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                                         Liquid
    Detail ID                                       Liquid: 30
    Dist. from "FROM" Node / Offset dist                     0  mm.
    Height/Length of Liquid                                650  mm.
    Liquid Density                                      999.54  kg/m³

    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                                 50  mm.
    Density                                                125  kg/m³

    Element From Node                                       30
    Detail Type                                         Lining
```

```
Detail ID                                                   CLAD
Dist. from "FROM" Node / Offset dist                           0  mm.
Height/Length of Lining                                     2000  mm.
Thickness of Lining                                            3  mm.
Density                                                     8027  kg/m³

Element From Node                                             30
Detail Type                                               Nozzle
Detail ID                                              N01 (6in)
Dist. from "FROM" Node / Offset dist                        1350  mm.
Nozzle Diameter                                                6  in.
Nozzle Schedule                                              STD
Nozzle Class                                                 600
Layout Angle                                                90.0
Blind Flange (Y/N)                                             N
Weight of Nozzle ( Used if > 0 )                          0.7592  kN
Grade of Attached Flange                                  GR 1.1
Nozzle Matl                                               SA-105 [Impact Tested]

Element From Node                                             30
Detail Type                                               Nozzle
Detail ID                                              N09 (1in)
Dist. from "FROM" Node / Offset dist                         150  mm.
Nozzle Diameter                                                1  in.
Nozzle Schedule                                             None
Nozzle Class                                                 600
Layout Angle                                                90.0
Blind Flange (Y/N)                                             N
Weight of Nozzle ( Used if > 0 )                         0.09225  kN
Grade of Attached Flange                                  GR 1.1
Nozzle Matl                                               SA-105

Element From Node                                             30
Detail Type                                               Nozzle
Detail ID                                             K07B (3in)
Dist. from "FROM" Node / Offset dist                         726  mm.
Nozzle Diameter                                                3  in.
Nozzle Schedule                                             None
Nozzle Class                                                 600
Layout Angle                                               180.0
Blind Flange (Y/N)                                             N
Weight of Nozzle ( Used if > 0 )                          0.1851  kN
Grade of Attached Flange                                  GR 1.1
Nozzle Matl                                               SA-105

Element From Node                                             30
Detail Type                                               Nozzle
Detail ID                                             K08A (2in)
Dist. from "FROM" Node / Offset dist                         470  mm.
Nozzle Diameter                                                2  in.
Nozzle Schedule                                             None
Nozzle Class                                                 600
Layout Angle                                                45.0
Blind Flange (Y/N)                                             N
```

```
Weight of Nozzle ( Used if > 0 )                  0.1032  kN
Grade of Attached Flange                          GR 1.1
Nozzle Matl                                       SA-105

Element From Node                                     30
Detail Type                                       Nozzle
Detail ID                                     K08B (2in)
Dist. from "FROM" Node / Offset dist                 726  mm.
Nozzle Diameter                                        2  in.
Nozzle Schedule                                     None
Nozzle Class                                         600
Layout Angle                                        45.0
Blind Flange (Y/N)                                     N
Weight of Nozzle ( Used if > 0 )                  0.1032  kN
Grade of Attached Flange                          GR 1.1
Nozzle Matl                                       SA-105

Element From Node                                     30
Detail Type                                       Nozzle
Detail ID                                     K09B (2in)
Dist. from "FROM" Node / Offset dist                 644  mm.
Nozzle Diameter                                        2  in.
Nozzle Schedule                                     None
Nozzle Class                                         600
Layout Angle                                        90.0
Blind Flange (Y/N)                                     N
Weight of Nozzle ( Used if > 0 )                  0.1032  kN
Grade of Attached Flange                          GR 1.1
Nozzle Matl                                       SA-105

Element From Node                                     30
Detail Type                                       Nozzle
Detail ID                                     N10A (8in)
Dist. from "FROM" Node / Offset dist                1600  mm.
Nozzle Diameter                                        8  in.
Nozzle Schedule                                      STD
Nozzle Class                                         600
Layout Angle                                       180.0
Blind Flange (Y/N)                                     Y
Weight of Nozzle ( Used if > 0 )                   1.405  kN
Grade of Attached Flange                          GR 1.1
Nozzle Matl                                       SA-105 [Impact Tested]

Element From Node                                     30
Detail Type                                       Nozzle
Detail ID                                      N05 (2in)
Dist. from "FROM" Node / Offset dist                 150  mm.
Nozzle Diameter                                        2  in.
Nozzle Schedule                                     None
Nozzle Class                                         600
Layout Angle                                       180.0
Blind Flange (Y/N)                                     N
Weight of Nozzle ( Used if > 0 )                  0.1032  kN
Grade of Attached Flange                          GR 1.1
```

```
    Nozzle Matl                                        SA-105

    Element From Node                                      30
    Detail Type                                        Weight
    Detail ID                                  DEMISTER PAD 1
    Dist. from "FROM" Node / Offset dist                 1800  mm.
    Miscellaneous Weight                               0.9806  kN
    Offset from Element Centerline                          0  mm.

    Element From Node                                      30
    Detail Type                                        Weight
    Detail ID                                       N01 INLET
    Dist. from "FROM" Node / Offset dist                 1350  mm.
    Miscellaneous Weight                               0.9806  kN
    Offset from Element Centerline                          0  mm.

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

Element From Node                                          40
Element To Node                                            50
Element Type                                          Flange
Description
Distance "FROM" to "TO"                                   170  mm.
Flange Inside Diameter                                    706  mm.
Element Thickness                                         110  mm.
Internal Corrosion Allowance                                0  mm.
Nominal Thickness                                           0  mm.
External Corrosion Allowance                                0  mm.
Design Internal Pressure                                   62  bars
Design Temperature Internal Pressure                      148  °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                         137.9  N./mm²
    Allowable Stress, Hydrotest                         223.4  N./mm²
    Material Density                                   7750.4  kg/m³
    P Number Thickness                                 30.988  mm.
    Yield Stress, Operating                             219.4  N./mm²
    UCS-66 Chart Curve Designation                          B
    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                                      40
    Detail Type                                    Insulation
    Detail ID                                         Ins: 40
    Dist. from "FROM" Node / Offset dist                    0  mm.
```

```
    Height/Length of Insulation                        175   mm.
    Thickness of Insulation                             50   mm.
    Density                                            125   kg/m³

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

Element From Node                                       50
Element To Node                                         60
Element Type                                       Flange
Description
Distance "FROM" to "TO"                                170   mm.
Flange Inside Diameter                                 706   mm.
Element Thickness                                      110   mm.
Internal Corrosion Allowance                             0   mm.
Nominal Thickness                                        0   mm.
External Corrosion Allowance                             0   mm.
Design Internal Pressure                                62   bars
Design Temperature Internal Pressure                   148   °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                                   50
    Detail Type                                 Insulation
    Detail ID                                      Ins: 50
    Dist. from "FROM" Node / Offset dist                 0   mm.
    Height/Length of Insulation                        170   mm.
    Thickness of Insulation                             50   mm.
    Density                                            125   kg/m³

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

Element From Node                                       60
Element To Node                                         70
Element Type                                      Cylinder
Description
Distance "FROM" to "TO"                               2000   mm.
Inside Diameter                                        706   mm.
Element Thickness                                       20   mm.
Internal Corrosion Allowance                             0   mm.
Nominal Thickness                                        0   mm.
External Corrosion Allowance                             0   mm.
Design Internal Pressure                                62   bars
Design Temperature Internal Pressure                   148   °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	231.81	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	
Weld is pre-Heated	No	

Element From Node	60	
Detail Type	Liquid	
Detail ID	Liquid: 40	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1050	mm.
Liquid Density	999.54	kg/m³

Element From Node	60	
Detail Type	Insulation	
Detail ID	Ins: 30	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	2000	mm.
Thickness of Insulation	50	mm.
Density	125	kg/m³

Element From Node	60	
Detail Type	Lining	
Detail ID	CLAD	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Lining	2000	mm.
Thickness of Lining	3	mm.
Density	8027	kg/m³

Element From Node	60	
Detail Type	Nozzle	
Detail ID	N04 (1in)	
Dist. from "FROM" Node / Offset dist	100	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	600	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.05226	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

Element From Node	60	
Detail Type	Nozzle	
Detail ID	N10B (8in)	
Dist. from "FROM" Node / Offset dist	1493.7	mm.

```
Nozzle Diameter                                      8   in.
Nozzle Schedule                                     80
Nozzle Class                                       600
Layout Angle                                     180.0
Blind Flange (Y/N)                                   Y
Weight of Nozzle ( Used if > 0 )                1.4249   kN
Grade of Attached Flange                        GR 1.1
Nozzle Matl                                     SA-105 [Impact Tested]

Element From Node                                   60
Detail Type                                     Nozzle
Detail ID                                    K2B (2in)
Dist. from "FROM" Node / Offset dist              1371   mm.
Nozzle Diameter                                      2   in.
Nozzle Schedule                                   None
Nozzle Class                                       600
Layout Angle                                      45.0
Blind Flange (Y/N)                                   N
Weight of Nozzle ( Used if > 0 )                0.1025   kN
Grade of Attached Flange                        GR 1.1
Nozzle Matl                                     SA-105

Element From Node                                   60
Detail Type                                     Nozzle
Detail ID                                    K2A (2in)
Dist. from "FROM" Node / Offset dist              1115   mm.
Nozzle Diameter                                      2   in.
Nozzle Schedule                                   None
Nozzle Class                                       600
Layout Angle                                      45.0
Blind Flange (Y/N)                                   N
Weight of Nozzle ( Used if > 0 )                0.1025   kN
Grade of Attached Flange                        GR 1.1
Nozzle Matl                                     SA-105

Element From Node                                   60
Detail Type                                     Nozzle
Detail ID                                    K3B (2in)
Dist. from "FROM" Node / Offset dist               293   mm.
Nozzle Diameter                                      2   in.
Nozzle Schedule                                   None
Nozzle Class                                       600
Layout Angle                                       0.0
Blind Flange (Y/N)                                   N
Weight of Nozzle ( Used if > 0 )                0.1025   kN
Grade of Attached Flange                        GR 1.1
Nozzle Matl                                     SA-105

Element From Node                                   60
Detail Type                                     Nozzle
Detail ID                                    K3A (2in)
Dist. from "FROM" Node / Offset dist               549   mm.
Nozzle Diameter                                      2   in.
Nozzle Schedule                                   None
```

```
    Nozzle Class                                      600
    Layout Angle                                      0.0
    Blind Flange (Y/N)                                  N
    Weight of Nozzle ( Used if > 0 )               0.1025   kN
    Grade of Attached Flange                       GR 1.1
    Nozzle Matl                                    SA-105

    Element From Node                                  60
    Detail Type                                    Nozzle
    Detail ID                                   K4B (2in)
    Dist. from "FROM" Node / Offset dist             1371   mm.
    Nozzle Diameter                                     3   in.
    Nozzle Schedule                                  None
    Nozzle Class                                      600
    Layout Angle                                    315.0
    Blind Flange (Y/N)                                  N
    Weight of Nozzle ( Used if > 0 )               0.1851   kN
    Grade of Attached Flange                       GR 1.1
    Nozzle Matl                                    SA-105

    Element From Node                                  60
    Detail Type                                    Nozzle
    Detail ID                                   K4A (2in)
    Dist. from "FROM" Node / Offset dist              293   mm.
    Nozzle Diameter                                     3   in.
    Nozzle Schedule                                  None
    Nozzle Class                                      600
    Layout Angle                                    315.0
    Blind Flange (Y/N)                                  N
    Weight of Nozzle ( Used if > 0 )                0.186   kN
    Grade of Attached Flange                       GR 1.1
    Nozzle Matl                                    SA-105

    Element From Node                                  60
    Detail Type                                    Weight
    Detail ID                                     CHIMNEY
    Dist. from "FROM" Node / Offset dist              193   mm.
    Miscellaneous Weight                           2.4515   kN
    Offset from Element Centerline                      0   mm.

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

Element From Node                                      70
Element To Node                                        80
Element Type                                       Flange
Description
Distance "FROM" to "TO"                               170   mm.
Flange Inside Diameter                                706   mm.
Element Thickness                                     110   mm.
Internal Corrosion Allowance                            0   mm.
Nominal Thickness                                       0   mm.
External Corrosion Allowance                            0   mm.
Design Internal Pressure                               62   bars
Design Temperature Internal Pressure                  148   °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                       137.9  N./mm²
    Allowable Stress, Hydrotest                       223.4  N./mm²
    Material Density                                 7750.4  kg/m³
    P Number Thickness                               29.997  mm.
    Yield Stress, Operating                           219.4  N./mm²
    UCS-66 Chart Curve Designation                        B
    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                                    70
    Detail Type                                  Insulation
    Detail ID                                       Ins: 70
    Dist. from "FROM" Node / Offset dist                  0  mm.
    Height/Length of Insulation                         170  mm.
    Thickness of Insulation                              50  mm.
    Density                                             125  kg/m³

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

Element From Node                                        80
Element To Node                                          90
Element Type                                       Flange
Description
Distance "FROM" to "TO"                                 175  mm.
Flange Inside Diameter                                  700  mm.
Element Thickness                                       115  mm.
Internal Corrosion Allowance                              3  mm.
Nominal Thickness                                         0  mm.
External Corrosion Allowance                              0  mm.
Design Internal Pressure                                 62  bars
Design Temperature Internal Pressure                    148  °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                                    80
    Detail Type                                  Insulation
```

```
    Detail ID                                       Ins: 80
    Dist. from "FROM" Node / Offset dist                  0  mm.
    Height/Length of Insulation                         175  mm.
    Thickness of Insulation                              50  mm.
    Density                                             125  kg/m³

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

Element From Node                                        90
Element To Node                                         100
Element Type                                       Cylinder
Description
Distance "FROM" to "TO"                                1500  mm.
Inside Diameter                                         700  mm.
Element Thickness                                        20  mm.
Internal Corrosion Allowance                              3  mm.
Nominal Thickness                                         0  mm.
External Corrosion Allowance                              0  mm.
Design Internal Pressure                                 62  bars
Design Temperature Internal Pressure                    148  °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                          231.81  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
Weld is pre-Heated                                       No

    Element From Node                                    90
    Detail Type                                     Packing
    Detail ID                                  Pack: [1 of 1]
    Dist. from "FROM" Node / Offset dist                230  mm.
    Height of Packed Section                           1270  mm.
    Density                                             350  kg/m³
    Percent Volume Holdup                              30.0
    Specific Gravity of Packing Liquid                  1.0

    Element From Node                                    90
    Detail Type                                  Insulation
    Detail ID                                       Ins: 30
    Dist. from "FROM" Node / Offset dist                  0  mm.
    Height/Length of Insulation                        1500  mm.
    Thickness of Insulation                              50  mm.
    Density                                             125  kg/m³
```

```
    Element From Node                                        90
    Detail Type                                          Nozzle
    Detail ID                                        K10A (2in)
    Dist. from "FROM" Node / Offset dist                    120  mm.
    Nozzle Diameter                                           2  in.
    Nozzle Schedule                                        None
    Nozzle Class                                            600
    Layout Angle                                           90.0
    Blind Flange (Y/N)                                        N
    Weight of Nozzle ( Used if > 0 )                     0.1025  kN
    Grade of Attached Flange                             GR 1.1
    Nozzle Matl                                          SA-105

    Element From Node                                        90
    Detail Type                                          Nozzle
    Detail ID                                         K05 (2in)
    Dist. from "FROM" Node / Offset dist                  432.3  mm.
    Nozzle Diameter                                           2  in.
    Nozzle Schedule                                        None
    Nozzle Class                                            600
    Layout Angle                                          270.0
    Blind Flange (Y/N)                                        N
    Weight of Nozzle ( Used if > 0 )                     0.1025  kN
    Grade of Attached Flange                             GR 1.1
    Nozzle Matl                                          SA-105

    Element From Node                                        90
    Detail Type                                          Weight
    Detail ID                                      SUPPORT GRID
    Dist. from "FROM" Node / Offset dist                    230  mm.
    Miscellaneous Weight                                 0.9806  kN
    Offset from Element Centerline                            0  mm.

    Element From Node                                        90
    Detail Type                                          Weight
    Detail ID                                       ATTACHMENTS
    Dist. from "FROM" Node / Offset dist                      0  mm.
    Miscellaneous Weight                                  8.237  kN
    Offset from Element Centerline                            0  mm.

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

Element From Node                                           100
Element To Node                                             110
Element Type                                           Cylinder
Description
Distance "FROM" to "TO"                                    1500  mm.
Inside Diameter                                             700  mm.
Element Thickness                                            20  mm.
Internal Corrosion Allowance                                  3  mm.
Nominal Thickness                                             0  mm.
External Corrosion Allowance                                  0  mm.
Design Internal Pressure                                     62  bars
```

```
Design Temperature Internal Pressure                       148   °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                                      100
    Detail Type                                        Packing
    Detail ID                                    Pack: [1 of 1]
    Dist. from "FROM" Node / Offset dist                     0   mm.
    Height of Packed Section                              1500   mm.
    Density                                                350   kg/m³
    Percent Volume Holdup                                 30.0
    Specific Gravity of Packing Liquid                     1.0

    Element From Node                                      100
    Detail Type                                     Insulation
    Detail ID                                          Ins: 30
    Dist. from "FROM" Node / Offset dist                     0   mm.
    Height/Length of Insulation                           1500   mm.
    Thickness of Insulation                                 50   mm.
    Density                                                125   kg/m³

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

Element From Node                                          110
Element To Node                                            120
Element Type                                          Cylinder
Description
Distance "FROM" to "TO"                                   1600   mm.
Inside Diameter                                            700   mm.
Element Thickness                                           20   mm.
Internal Corrosion Allowance                                 3   mm.
Nominal Thickness                                            0   mm.
External Corrosion Allowance                                 0   mm.
Design Internal Pressure                                    62   bars
Design Temperature Internal Pressure                       148   °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                                      110
    Detail Type                                       Platform
    Detail ID                                     PLAT:[1 OF 1]
    Dist. from "FROM" Node / Offset dist                   800   mm.
    Platform Start Angle (degrees)                         0.0
    Platform End Angle   (degrees)                       360.0
```

```
Platform Wind Area                                   27720  cm²
Platform Weight                                     20.966  kN
Platform Railing Weight                                  0  kN/mm.
Platform Grating Weight                              0.025  Kgs/cm²
Platform Width                                        1100  mm.
Platform Height                                       1050  mm.
Platform Clearance or End Offset                       100  mm.
Platform Force Coefficient                             1.2
Ladder Layout Angle                                    0.0
Ladder Start Elevation                                   0  mm.
Ladder End Elevation                                 10500  mm.
Unit Weight of Ladder                              0.00035  kN/mm.
Platform Length (top head platform)                      0  mm.

Element From Node                                      110
Detail Type                                        Packing
Detail ID                                   Pack: [1 of 1]
Dist. from "FROM" Node / Offset dist                     0  mm.
Height of Packed Section                              1380  mm.
Density                                                350  kg/m³
Percent Volume Holdup                                 30.0
Specific Gravity of Packing Liquid                     1.0

Element From Node                                      110
Detail Type                                     Insulation
Detail ID                                          Ins: 30
Dist. from "FROM" Node / Offset dist                     0  mm.
Height/Length of Insulation                           1600  mm.
Thickness of Insulation                                 50  mm.
Density                                                125  kg/m³

Element From Node                                      110
Detail Type                                         Nozzle
Detail ID                                       K10B (2in)
Dist. from "FROM" Node / Offset dist                  1493  mm.
Nozzle Diameter                                          2  in.
Nozzle Schedule                                       None
Nozzle Class                                           600
Layout Angle                                          90.0
Blind Flange (Y/N)                                       N
Weight of Nozzle ( Used if > 0 )                    0.1025  kN
Grade of Attached Flange                            GR 1.1
Nozzle Matl                                         SA-105

Element From Node                                      110
Detail Type                                         Weight
Detail ID                                      BED LIMMITER
Dist. from "FROM" Node / Offset dist                  1380  mm.
Miscellaneous Weight                                0.4903  kN
Offset from Element Centerline                           0  mm.

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

Element From Node                                          120
```

```
Element To Node                                         130
Element Type                                         Flange
Description
Distance "FROM" to "TO"                                 175  mm.
Flange Inside Diameter                                  700  mm.
Element Thickness                                       115  mm.
Internal Corrosion Allowance                              3  mm.
Nominal Thickness                                         0  mm.
External Corrosion Allowance                              0  mm.
Design Internal Pressure                                 62  bars
Design Temperature Internal Pressure                    148  °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                       137.9  N./mm²
    Allowable Stress, Hydrotest                       223.4  N./mm²
    Material Density                                 7750.4  kg/m³
    P Number Thickness                               30.988  mm.
    Yield Stress, Operating                           219.4  N./mm²
    UCS-66 Chart Curve Designation                        B
    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                                   120
    Detail Type                                  Insulation
    Detail ID                                      Ins: 120
    Dist. from "FROM" Node / Offset dist                  0  mm.
    Height/Length of Insulation                         175  mm.
    Thickness of Insulation                              50  mm.
    Density                                             125  kg/m³

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

Element From Node                                       130
Element To Node                                         140
Element Type                                         Flange
Description
Distance "FROM" to "TO"                                 175  mm.
Flange Inside Diameter                                  700  mm.
Element Thickness                                       115  mm.
Internal Corrosion Allowance                              3  mm.
Nominal Thickness                                         0  mm.
External Corrosion Allowance                              0  mm.
Design Internal Pressure                                 62  bars
Design Temperature Internal Pressure                    148  °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                                      130
    Detail Type                                     Insulation
    Detail ID                                         Ins: 130
    Dist. from "FROM" Node / Offset dist                     0  mm.
    Height/Length of Insulation                            175  mm.
    Thickness of Insulation                                 50  mm.
    Density                                                125  kg/m³

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

Element From Node                                          140
Element To Node                                            150
Element Type                                          Cylinder
Description
Distance "FROM" to "TO"                                    863  mm.
Inside Diameter                                            700  mm.
Element Thickness                                           20  mm.
Internal Corrosion Allowance                                 3  mm.
Nominal Thickness                                            0  mm.
External Corrosion Allowance                                 0  mm.
Design Internal Pressure                                    62  bars
Design Temperature Internal Pressure                       148  °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                             231.81  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
Weld is pre-Heated                                          No

    Element From Node                                      140
    Detail Type                                     Insulation
    Detail ID                                         Ins: 140
    Dist. from "FROM" Node / Offset dist                     0  mm.
    Height/Length of Insulation                            850  mm.
```

```
Thickness of Insulation                                    50   mm.
Density                                                   125   kg/m³

Element From Node                                         140
Detail Type                                            Nozzle
Detail ID                                           K1  (2in)
Dist. from "FROM" Node / Offset dist                      207   mm.
Nozzle Diameter                                             2   in.
Nozzle Schedule                                          None
Nozzle Class                                              600
Layout Angle                                            225.0
Blind Flange (Y/N)                                          N
Weight of Nozzle ( Used if > 0 )                       0.1025   kN
Grade of Attached Flange                               GR 1.1
Nozzle Matl                                            SA-105

Element From Node                                         140
Detail Type                                            Nozzle
Detail ID                                          N06  (2in)
Dist. from "FROM" Node / Offset dist                      207   mm.
Nozzle Diameter                                             2   in.
Nozzle Schedule                                          None
Nozzle Class                                              600
Layout Angle                                            270.0
Blind Flange (Y/N)                                          N
Weight of Nozzle ( Used if > 0 )                       0.1025   kN
Grade of Attached Flange                               GR 1.1
Nozzle Matl                                            SA-105

Element From Node                                         140
Detail Type                                            Nozzle
Detail ID                                          K6A  (2in)
Dist. from "FROM" Node / Offset dist                      250   mm.
Nozzle Diameter                                             2   in.
Nozzle Schedule                                          None
Nozzle Class                                              600
Layout Angle                                              0.0
Blind Flange (Y/N)                                          N
Weight of Nozzle ( Used if > 0 )                       0.1025   kN
Grade of Attached Flange                               GR 1.1
Nozzle Matl                                            SA-105

Element From Node                                         140
Detail Type                                            Nozzle
Detail ID                                          K6B  (2in)
Dist. from "FROM" Node / Offset dist                      550   mm.
Nozzle Diameter                                             2   in.
Nozzle Schedule                                          None
Nozzle Class                                              600
Layout Angle                                              0.0
Blind Flange (Y/N)                                          N
Weight of Nozzle ( Used if > 0 )                       0.1025   kN
Grade of Attached Flange                               GR 1.1
Nozzle Matl                                            SA-105
```

```
    Element From Node                                     140
    Detail Type                                        Nozzle
    Detail ID                                       N03 (2in)
    Dist. from "FROM" Node / Offset dist                  110  mm.
    Nozzle Diameter                                         1  in.
    Nozzle Schedule                                      None
    Nozzle Class                                          600
    Layout Angle                                         90.0
    Blind Flange (Y/N)                                      N
    Weight of Nozzle ( Used if > 0 )                  0.04871  kN
    Grade of Attached Flange                           GR 1.1
    Nozzle Matl                                        SA-105

    Element From Node                                     140
    Detail Type                                        Nozzle
    Detail ID                                      N10C (8in)
    Dist. from "FROM" Node / Offset dist                  250  mm.
    Nozzle Diameter                                         8  in.
    Nozzle Schedule                                        80
    Nozzle Class                                          600
    Layout Angle                                        180.0
    Blind Flange (Y/N)                                      Y
    Weight of Nozzle ( Used if > 0 )                   1.4249  kN
    Grade of Attached Flange                           GR 1.1
    Nozzle Matl                                        SA-105 [Impact Tested]

    Element From Node                                     140
    Detail Type                                        Weight
    Detail ID                                 DEMISTER PAD 2
    Dist. from "FROM" Node / Offset dist                  400  mm.
    Miscellaneous Weight                               0.9806  kN
    Offset from Element Centerline                          0  mm.

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

Element From Node                                         150
Element To Node                                           160
Element Type                                       Elliptical
Description                                          Top Head
Distance "FROM" to "TO"                                    50  mm.
Inside Diameter                                           700  mm.
Element Thickness                                          20  mm.
Internal Corrosion Allowance                                3  mm.
Nominal Thickness                                          25  mm.
External Corrosion Allowance                                0  mm.
Design Internal Pressure                                   62  bars
Design Temperature Internal Pressure                      148  °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
```

```
Elliptical Head Factor                                       2.0
Weld is pre-Heated                                            No

    Element From Node                                        150
    Detail Type                                       Insulation
    Detail ID                                            Ins: 30
    Dist. from "FROM" Node / Offset dist                       0  mm.
    Height/Length of Insulation                              225  mm.
    Thickness of Insulation                                   50  mm.
    Density                                                  125  kg/m³

    Element From Node                                        150
    Detail Type                                           Nozzle
    Detail ID                                         N02 (6in)
    Dist. from "FROM" Node / Offset dist                       0  mm.
    Nozzle Diameter                                            6  in.
    Nozzle Schedule                                           80
    Nozzle Class                                             600
    Layout Angle                                             0.0
    Blind Flange (Y/N)                                         N
    Weight of Nozzle ( Used if > 0 )                      0.5493  kN
    Grade of Attached Flange                              GR 1.1
    Nozzle Matl                                           SA-105 [Impact Tested]

    Element From Node                                        150
    Detail Type                                           Nozzle
    Detail ID                                         N08 (2in)
    Dist. from "FROM" Node / Offset dist                     300  mm.
    Nozzle Diameter                                            2  in.
    Nozzle Schedule                                         None
    Nozzle Class                                             600
    Layout Angle                                             0.0
    Blind Flange (Y/N)                                         Y
    Weight of Nozzle ( Used if > 0 )                      0.1438  kN
    Grade of Attached Flange                              GR 1.1
    Nozzle Matl                                           SA-105

    Element From Node                                        150
    Detail Type                                           Weight
    Detail ID                                             PIPING
    Dist. from "FROM" Node / Offset dist                       0  mm.
    Miscellaneous Weight                                   9.806  kN
    Offset from Element Centerline                           970  mm.
```

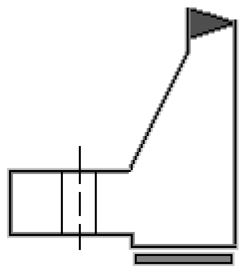
XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
Skirt		...	1500	...	1500
Bottom Head		...	1550	...	50
30	40	...	3550	...	2000
40	50	...	3720	...	170
50	60	...	3899.53	...	170
60	70	...	5899.52	...	2000
70	80	...	6069.53	...	170
80	90	...	6254.05	...	175
90	100	...	7754.05	...	1500
100	110	...	9254.05	...	1500
110	120	...	10854	...	1600
120	130	...	11029	...	175
130	140	...	11213.6	...	175
140	150	...	12076.6	...	863
Top Head		...	12126.6	...	50

Flange Input Data Values **Description: New Flange :**

Item: Node 40 to 50

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	62.10	bars
Design Temperature		148	°C
Internal Corrosion Allowance	ci	0.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	706.000	mm.
Flange Outside Diameter	A	990.000	mm.
Flange Thickness	t	110.0000	mm.
Thickness of Hub at Small End	go	18.0000	mm.
Thickness of Hub at Large End	g1	35.0000	mm.
Length of Hub	h	60.0000	mm.
Flange Material		SA-105	
Flange Material UNS number		K03504	
Flange Allowable Stress At Temperature	Sfo	137.90	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	900.000	mm.
Nominal Bolt Diameter	a	41.2750	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		20	
Flange Face Outside Diameter	Fod	800.000	mm.
Flange Face Inside Diameter	Fid	706.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	787.400	mm.
Gasket Inside Diameter	Gi	736.600	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)
  = (62.1*(706/2+0))/(138*1-0.6*62.1)+Ca
  = 16.3397 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138 * 1 * 18 )/(353 + 0.6 * 18 )
  = 68.226 bars
```

```
 Corroded Flange ID,       Bcor = B+2*Fcor                706.000  mm.
 Corroded Large Hub,       g1Cor = g1-ci                   35.000  mm.
 Corroded Small Hub,       g0Cor = go-ci                   18.000  mm.
 Code R Dimension,             R = (C-B)/2 - g1            62.000  mm.

 Gasket Contact Width,         N = (Go - Gi) / 2           25.400  mm.
 Basic Gasket Width,          bo = N / 2                   12.700  mm.
 Effective Gasket Width,       b = Cb sqrt(bo)              8.980  mm.
 Gasket Reaction Diameter,     G = Go - 2 * b             769.440  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.79 * 769² * 62.1
  = 2887.614 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P
  = 2 * 8.98 * 3.14 * 769 * 3 * 62.1
  = 808.844 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.14 * 706² *62.1/4
  = 2431.082 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 2888 - 2431
  = 456.532 kN
```

Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 2888 + 809 + 0, 0 )
  = 3696.458 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.9*8.98*3.141*769+0*0*0
  = 1496.617 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 3696/172, 1497/172
  = 214.461 cm²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 41.3 + 6 * 110/(3 + 0.5)
  = 271.121 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 900 * sin( 3.14/20 )
  = 140.791 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 141/( 2 * 41.3 + 110 )), 1 )
  = 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area, cm²	214.461	216.774	
Radial Distance between Hub and Bolts:	53.975	62.000	
Radial Distance between Bolts and Edge:	41.275	45.000	
Circ. Spacing between the Bolts:	88.900	140.791	271.121

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 217  * 172/(68.9 * 3.14 * (787 + 737 ) )
  = 11.319 mm.
```

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :
```
  = 25.000 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa * ( Am + Ab ) / 2
  = 172 * ( 214 + 217 )/2
  = 3716.39 kN
```
Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 3696 - 2888
```

= 808.84 kN

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (900 - 769)/2
= 65.2802 mm.

Distance to Face Pressure Reaction [ht]:
= (R + g1 + hg) / 2
= (62 + 35 + 65.3)/2
= 81.1401 mm.

Distance to End Pressure Reaction [hd]:
= R + (g1 / 2)
= 62 + (35/2.0)
= 79.5000 mm.

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	2431.	79.5000	1.0000	193349.
Face Pressure, Mt	457.	81.1401	1.0000	37058.
Gasket Load, Mg	809.	65.2802	1.0000	52823.
Gasket Seating, Matm	3716.	65.2802	1.0000	242705.

Total Moment for Operation, Mop 283230. N-m
Total Moment for Gasket seating, Matm 242705. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor) 112.730 mm.
Hub Ratio, h/h0 = HL / H0 0.532
Thickness Ratio, g1/g0 = (g1Cor/goCor) 1.944

Flange Factors for Integral Flange:

Factor F				0.820
Factor V				0.225
Factor f				1.051
Factors from Figure 2-7.1			K =	1.402
	T =	1.753	U =	6.492
	Y =	5.908	Z =	3.070
	d =	0.10517E+07 $mm.^3$	e =	0.0073 mm.^-1
Stress Factors			ALPHA =	1.801
	BETA =	2.067	GAMMA =	1.027
	DELTA =	1.266	Lamda =	2.293

Longitudinal Hub Stress, Operating [SHo]:
= (f * Mop / Bcor) / (L * $g1^2$)
= (1.05*283230/706)/(2.29*35^2)
= 150.10 $N./mm^2$

Longitudinal Hub Stress, Seating [SHa]:
= (f * Matm / Bcor) / (L * $g1^2$)
= (1.05*242705/706)/(2.29*35^2)
= 128.63 $N./mm^2$

Radial Flange Stress, Operating [SRo]:
```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2.07*283230/706)/(2.29*110²)
  = 29.89 N./mm²
```
Radial Flange Stress, Seating [SRa]:
```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2.07*242705/706)/(2.29*110²)
  = 25.61 N./mm²
```

Tangential Flange Stress, Operating [STo]:
```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (5.91*283230/(110²*706))-3.07*29.9
  = 104.06 N./mm²
```
Tangential Flange Stress, Seating [STa]:
```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (5.91*242705/(110²*706))-3.07*25.6
  = 89.17 N./mm²
```

Average Flange Stress, Operating [SAo]:
```
  = ( SHo + max( SRo, STo ) ) / 2
  = (150+max(29.9,104))/2
  = 127.08 N./mm²
```
Average Flange Stress, Seating [SAa]:
```
  = ( SHa + max( SRa, STa ) ) / 2
  = (129+max(25.6,89.2))/2
  = 108.90 N./mm²
```

Bolt Stress, Operating [BSo]:
```
  = Wm1 / Ab
  = 3696/217
  = 170.54 N./mm²
```
Bolt Stress, Seating [BSa]:
```
  = ( Wm2 / Ab )
  = (1497/217)
  = 69.05 N./mm²
```

Flange Stress Analysis Results: N./mm²

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	150.10	206.85	128.63	206.85
Radial Flange	29.89	137.90	25.61	137.90
Tangential Flange	104.06	137.90	89.17	137.90
Maximum Average	127.08	137.90	108.90	137.90
Bolting	170.54	172.38	69.05	172.38

```
Minimum Required Flange Thickness                 103.734 mm.
Estimated M.A.W.P. ( Operating )                     62.8 bars
Estimated M.A.W.P. ( Gasket Seating )                62.8 bars
Estimated Finished Weight of Flange at given Thk.   350.9 kg.
Estimated Unfinished Weight of Forging at given Thk  498.4 kg.
```

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14*242705/1*1000*0.23/(2.06*202713*18²*113*0.3)
  = 0.623    (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*283230/1*1000*0.23/(2.06*195184*18²*113*0.3)
  = 0.755    (should be <= 1)
```

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14*242705/1*1000*0.23/(2.29*202713*18²*113*0.3)
  = 0.560    (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*283230/1*1000*0.23/(2.29*195184*18²*113*0.3)
  = 0.679    (should be <= 1)
```

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.82, Temperature Reduction per Fig. UCS 66.1 = 10 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -11 °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -20 °C
 Min Metal Temp. w/o impact per UG-20(f)                     -29 °C
```

Note: UCS-66(b)(-c) was considered in the flange MDMT calculation.

Flange Input Data Values **Description: New Flange :**

Item: Node 50 to 60

```
Description of Flange Geometry (Type)          Integral Weld Neck
Design Pressure                           P             62.10  bars
Design Temperature                                        148  °C
Internal Corrosion Allowance             ci            0.0000  mm.
External Corrosion Allowance             ce            0.0000  mm.
Use Corrosion Allowance in Thickness Calcs.               Yes
Flange Inside Diameter                    B           706.000  mm.
Flange Outside Diameter                   A           990.000  mm.
Flange Thickness                          t          110.0000  mm.
Thickness of Hub at Small End            go           18.0000  mm.
Thickness of Hub at Large End            g1           35.0000  mm.
Length of Hub                             h           60.0000  mm.

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

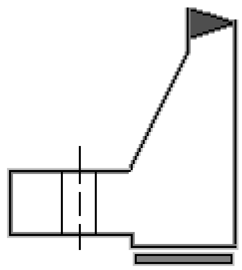
Bolt Material                                       SA-193 B7
Bolt Allowable Stress At Temperature     Sb            172.38  N./mm²
Bolt Allowable Stress At Ambient         Sa            172.38  N./mm²

Diameter of Bolt Circle                   C           900.000  mm.
Nominal Bolt Diameter                     a           41.2750  mm.
Type of Threads                          TEMA Thread Series
Number of Bolts                                            20

Flange Face Outside Diameter            Fod           800.000  mm.
Flange Face Inside Diameter             Fid           706.000  mm.
Flange Facing Sketch                      1, Code Sketch 1a

Gasket Outside Diameter                  Go           787.400  mm.
Gasket Inside Diameter                   Gi           736.600  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)
  = (62.1*(706/2+0))/(138*1-0.6*62.1)+Ca
  = 16.3397 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138 * 1 * 18 )/(353 + 0.6 * 18 )
  = 68.226 bars
```

```
 Corroded Flange ID,       Bcor = B+2*Fcor               706.000  mm.
 Corroded Large Hub,      g1Cor = g1-ci                   35.000  mm.
 Corroded Small Hub,      g0Cor = go-ci                   18.000  mm.
 Code R Dimension,            R = (C-B)/2 - g1            62.000  mm.

 Gasket Contact Width,        N = (Go - Gi) / 2           25.400  mm.
 Basic Gasket Width,         bo = N / 2                   12.700  mm.
 Effective Gasket Width,      b = Cb sqrt(bo)              8.980  mm.
 Gasket Reaction Diameter,    G = Go - 2 * b             769.440  mm.
```

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

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.79 * 769² * 62.1
  = 2887.614 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P
  = 2 * 8.98 * 3.14 * 769 * 3 * 62.1
  = 808.844 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.14 * 706² *62.1/4
  = 2431.082 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 2888 - 2431
  = 456.532 kN
```
Operating Bolt Load [Wm1]:

```
  = max( H + Hp + H'p, 0 )
  = max( 2888 + 809 + 0, 0 )
  = 3696.458 kN
```

Gasket Seating Bolt Load [Wm2]:

```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.9*8.98*3.141*769+0*0*0
  = 1496.617 kN
```

Required Bolt Area [Am]:

```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 3696/172, 1497/172
  = 214.461 cm²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:

```
  = 2a + 6t/(m + 0.5)
  = 2 * 41.3 + 6 * 110/(3 + 0.5)
  = 271.121 mm.
```

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 900 * sin( 3.14/20 )
  = 140.791 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:

```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 141/( 2 * 41.3 + 110 )), 1 )
  = 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area, cm²	214.461	216.774	
Radial Distance between Hub and Bolts:	53.975	62.000	
Radial Distance between Bolts and Edge:	41.275	45.000	
Circ. Spacing between the Bolts:	88.900	140.791	271.121

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:

```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 217  * 172/(68.9 * 3.14 * (787 + 737 ) )
  = 11.319 mm.
```

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :

```
  = 25.000 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * ( Am + Ab ) / 2
  = 172 * ( 214 + 217 )/2
  = 3716.39 kN
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 3696 - 2888
  = 808.84 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
```
  = (C - G ) / 2
  = ( 900 - 769 )/2
  = 65.2802 mm.
```
Distance to Face Pressure Reaction [ht]:
```
  = ( R + g1 + hg ) / 2
  = ( 62 + 35 + 65.3 )/2
  = 81.1401 mm.
```
Distance to End Pressure Reaction [hd]:
```
  = R + ( g1 / 2 )
  = 62  + ( 35/2.0 )
  = 79.5000 mm.
```

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	2431.	79.5000	1.0000	193349.
Face Pressure, Mt	457.	81.1401	1.0000	37058.
Gasket Load, Mg	809.	65.2802	1.0000	52823.
Gasket Seating, Matm	3716.	65.2802	1.0000	242705.

```
Total Moment for Operation,      Mop                         283230. N-m
Total Moment for Gasket seating, Matm                        242705. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor)          112.730  mm.
Hub Ratio,            h/h0 = HL / H0                   0.532
Thickness Ratio,     g1/g0 = (g1Cor/goCor)             1.944
```

Flange Factors for Integral Flange:
```
Factor F                                               0.820
Factor V                                               0.225
Factor f                                               1.051
Factors from Figure 2-7.1                    K =       1.402
                    T =       1.753          U =       6.492
                    Y =       5.908          Z =       3.070
                    d = 0.10517E+07 mm.³      e =      0.0073 mm.^-1
Stress Factors                           ALPHA =       1.801
                 BETA =       2.067      GAMMA =       1.027
                DELTA =       1.266      Lamda =       2.293
```

Longitudinal Hub Stress, Operating [SHo]:
```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.05*283230/706)/(2.29*35²)
  = 150.10 N./mm²
```
Longitudinal Hub Stress, Seating [SHa]:
```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.05*242705/706)/(2.29*35²)
  = 128.63 N./mm²
```

Radial Flange Stress, Operating [SRo]:

```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2.07*283230/706)/(2.29*110²)
  = 29.89 N./mm²
```
Radial Flange Stress, Seating [SRa]:
```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2.07*242705/706)/(2.29*110²)
  = 25.61 N./mm²
```

Tangential Flange Stress, Operating [STo]:
```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (5.91*283230/(110²*706))-3.07*29.9
  = 104.06 N./mm²
```
Tangential Flange Stress, Seating [STa]:
```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (5.91*242705/(110²*706))-3.07*25.6
  = 89.17 N./mm²
```

Average Flange Stress, Operating [SAo]:
```
  = ( SHo + max( SRo, STo ) ) / 2
  = (150+max(29.9,104))/2
  = 127.08 N./mm²
```
Average Flange Stress, Seating [SAa]:
```
  = ( SHa + max( SRa, STa ) ) / 2
  = (129+max(25.6,89.2))/2
  = 108.90 N./mm²
```

Bolt Stress, Operating [BSo]:
```
  = Wm1 / Ab
  = 3696/217
  = 170.54 N./mm²
```
Bolt Stress, Seating [BSa]:
```
  = ( Wm2 / Ab )
  = (1497/217)
  = 69.05 N./mm²
```

Flange Stress Analysis Results: N./mm²

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	150.10	206.85	128.63	206.85
Radial Flange	29.89	137.90	25.61	137.90
Tangential Flange	104.06	137.90	89.17	137.90
Maximum Average	127.08	137.90	108.90	137.90
Bolting	170.54	172.38	69.05	172.38

```
Minimum Required Flange Thickness                   103.734 mm.
Estimated M.A.W.P. ( Operating )                       62.8 bars
Estimated M.A.W.P. ( Gasket Seating )                  62.8 bars
Estimated Finished Weight of Flange at given Thk.     350.9 kg.
Estimated Unfinished Weight of Forging at given Thk   498.4 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*242705/1*1000*0.23/(2.06*202713*18²*113*0.3)
  = 0.623    (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*283230/1*1000*0.23/(2.06*195184*18²*113*0.3)
  = 0.755    (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*242705/1*1000*0.23/(2.29*202713*18²*113*0.3)
  = 0.560    (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*283230/1*1000*0.23/(2.29*195184*18²*113*0.3)
  = 0.679    (should be <= 1)
```

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.82, Temperature Reduction per Fig. UCS 66.1 = 10 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -11  °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -20  °C
 Min Metal Temp. w/o impact per UG-20(f)                     -29  °C
```

Note: UCS-66(b)(-c) was considered in the flange MDMT calculation.

Flange Input Data Values **Description: New Flange :**

Item: Node 70 to 80

```
Description of Flange Geometry (Type)            Integral Weld Neck
Design Pressure                             P             62.00  bars
Design Temperature                                          148  °C
Internal Corrosion Allowance               ci            0.0000  mm.
External Corrosion Allowance               ce            0.0000  mm.
Use Corrosion Allowance in Thickness Calcs.                 Yes
Flange Inside Diameter                      B           706.000  mm.
Flange Outside Diameter                     A           990.000  mm.
Flange Thickness                            t          110.0000  mm.
Thickness of Hub at Small End              go           18.0000  mm.
Thickness of Hub at Large End              g1           35.0000  mm.
Length of Hub                               h           60.0000  mm.

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

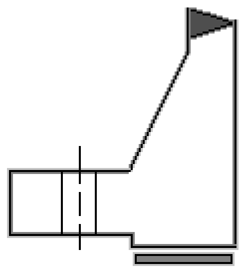
Bolt Material                                         SA-193 B7
Bolt Allowable Stress At Temperature       Sb            172.38  N./mm²
Bolt Allowable Stress At Ambient           Sa            172.38  N./mm²

Diameter of Bolt Circle                     C           900.000  mm.
Nominal Bolt Diameter                       a           41.2750  mm.
Type of Threads                            TEMA Thread Series
Number of Bolts                                              20

Flange Face Outside Diameter              Fod           800.000  mm.
Flange Face Inside Diameter               Fid           706.000  mm.
Flange Facing Sketch                        1, Code Sketch 1a

Gasket Outside Diameter                    Go           787.400  mm.
Gasket Inside Diameter                     Gi           736.600  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)
  = (62*(706/2+0))/(138*1-0.6*62)+Ca
  = 16.3119 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138 * 1 * 18 )/(353 + 0.6 * 18 )
  = 68.226 bars
```

```
 Corroded Flange ID,       Bcor = B+2*Fcor              706.000  mm.
 Corroded Large Hub,      g1Cor = g1-ci                  35.000  mm.
 Corroded Small Hub,      g0Cor = go-ci                  18.000  mm.
 Code R Dimension,            R = (C-B)/2 - g1           62.000  mm.

 Gasket Contact Width,        N = (Go - Gi) / 2          25.400  mm.
 Basic Gasket Width,         bo = N / 2                  12.700  mm.
 Effective Gasket Width,      b = Cb sqrt(bo)             8.980  mm.
 Gasket Reaction Diameter,    G = Go - 2 * b            769.440  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.79 * 769² * 62
  = 2882.829 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P
  = 2 * 8.98 * 3.14 * 769 * 3 * 62
  = 807.504 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.14 * 706² *62/4
  = 2427.053 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 2883 - 2427
  = 455.776 kN
```
Operating Bolt Load [Wm1]:

```
  = max( H + Hp + H'p, 0 )
  = max( 2883 + 808 + 0, 0 )
  = 3690.333 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.9*8.98*3.141*769+0*0*0
  = 1496.617 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 3690/172, 1497/172
  = 214.106 cm²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 41.3 + 6 * 110/(3 + 0.5)
  = 271.121 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 900 * sin( 3.14/20 )
  = 140.791 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 141/( 2 * 41.3 + 110 )), 1 )
  = 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area, cm²	214.106	216.774	
Radial Distance between Hub and Bolts:	53.975	62.000	
Radial Distance between Bolts and Edge:	41.275	45.000	
Circ. Spacing between the Bolts:	88.900	140.791	271.121

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 217  * 172/(68.9 * 3.14 * (787 + 737 ) )
  = 11.319 mm.
```

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :
```
  = 25.000 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa * ( Am + Ab ) / 2
  = 172 * ( 214 + 217 )/2
  = 3713.33 kN
```
Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 3690 - 2883
  = 807.50 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 900 - 769 )/2
  = 65.2802 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 62 + 35 + 65.3 )/2
  = 81.1401 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 62   + ( 35/2.0 )
  = 79.5000 mm.
```

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	2427.	79.5000	1.0000	193029.
Face Pressure, Mt	456.	81.1401	1.0000	36997.
Gasket Load, Mg	808.	65.2802	1.0000	52735.
Gasket Seating, Matm	3713.	65.2802	1.0000	242505.

```
Total Moment for Operation,      Mop                     282761. N-m
Total Moment for Gasket seating, Matm                    242505. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor)          112.730  mm.
Hub Ratio,            h/h0 = HL / H0                   0.532
Thickness Ratio,     g1/g0 = (g1Cor/goCor)             1.944
```

Flange Factors for Integral Flange:

```
Factor F                                               0.820
Factor V                                               0.225
Factor f                                               1.051
Factors from Figure 2-7.1                    K =       1.402
                    T =       1.753          U =       6.492
                    Y =       5.908          Z =       3.070
                    d = 0.10517E+07 mm.³      e =      0.0073 mm.^-1
Stress Factors                           ALPHA =       1.801
                 BETA =       2.067      GAMMA =       1.027
                DELTA =       1.266      Lamda =       2.293
```

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.05*282761/706)/(2.29*35²)
  = 149.86 N./mm²
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.05*242505/706)/(2.29*35²)
  = 128.52 N./mm²
```

Radial Flange Stress, Operating [SRo]:

```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2.07*282761/706)/(2.29*110²)
  = 29.84 N./mm²
```

Radial Flange Stress, Seating [SRa]:

```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2.07*242505/706)/(2.29*110²)
  = 25.59 N./mm²
```

Tangential Flange Stress, Operating [STo]:

```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (5.91*282761/(110²*706))-3.07*29.8
  = 103.89 N./mm²
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (5.91*242505/(110²*706))-3.07*25.6
  = 89.10 N./mm²
```

Average Flange Stress, Operating [SAo]:

```
  = ( SHo + max( SRo, STo ) ) / 2
  = (150+max(29.8,104))/2
  = 126.87 N./mm²
```

Average Flange Stress, Seating [SAa]:

```
  = ( SHa + max( SRa, STa ) ) / 2
  = (129+max(25.6,89.1))/2
  = 108.81 N./mm²
```

Bolt Stress, Operating [BSo]:

```
  = Wm1 / Ab
  = 3690/217
  = 170.25 N./mm²
```

Bolt Stress, Seating [BSa]:

```
  = ( Wm2 / Ab )
  = (1497/217)
  = 69.05 N./mm²
```

Flange Stress Analysis Results: N./mm²

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	149.86	206.85	128.52	206.85
Radial Flange	29.84	137.90	25.59	137.90
Tangential Flange	103.89	137.90	89.10	137.90
Maximum Average	126.87	137.90	108.81	137.90
Bolting	170.25	172.38	69.05	172.38

```
Minimum Required Flange Thickness                  103.607 mm.
Estimated M.A.W.P. ( Operating )                      62.8 bars
Estimated M.A.W.P. ( Gasket Seating )                 62.8 bars
Estimated Finished Weight of Flange at given Thk.    350.9 kg.
Estimated Unfinished Weight of Forging at given Thk  498.4 kg.
```

Flange Rigidity Based on Required Thickness [ASME]:

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

```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14*242505/1*1000*0.23/(2.06*201334*18²*113*0.3)
  = 0.628    (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*282761/1*1000*0.23/(2.06*193805*18²*113*0.3)
  = 0.761    (should be <= 1)
```

Flange Rigidity Based on Given Thickness [ASME]:

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

```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14*242505/1*1000*0.23/(2.29*201334*18²*113*0.3)
  = 0.563    (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*282761/1*1000*0.23/(2.29*193805*18²*113*0.3)
  = 0.683    (should be <= 1)
```

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.82, Temperature Reduction per Fig. UCS 66.1 = 10 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -11 °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -20 °C
 Min Metal Temp. w/o impact per UG-20(f)                     -29 °C
```

Note: UCS-66(b)(-c) was considered in the flange MDMT calculation.

Flange Input Data Values **Description: New Flange :**

Item: Node 80 to 90

```
Description of Flange Geometry (Type)          Integral Weld Neck
Design Pressure                            P          62.00  bars
Design Temperature                                      148  °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        700.000  mm.
Flange Outside Diameter                    A        990.000  mm.
Flange Thickness                           t       115.0000  mm.
Thickness of Hub at Small End             go        20.0000  mm.
Thickness of Hub at Large End             g1        35.0000  mm.
Length of Hub                              h        60.0000  mm.

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

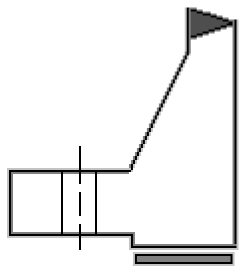
Bolt Material                                    SA-193 B7
Bolt Allowable Stress At Temperature      Sb         172.38  N./mm²
Bolt Allowable Stress At Ambient          Sa         172.38  N./mm²

Diameter of Bolt Circle                    C        900.000  mm.
Nominal Bolt Diameter                      a        41.2750  mm.
Type of Threads                           TEMA Thread Series
Number of Bolts                                          20

Flange Face Outside Diameter             Fod        800.000  mm.
Flange Face Inside Diameter              Fid        700.000  mm.
Flange Facing Sketch                       1, Code Sketch 1a

Gasket Outside Diameter                   Go        787.400  mm.
Gasket Inside Diameter                    Gi        736.600  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)
  = (62*(700/2+3))/(138*1-0.6*62)+Ca
  = 19.3119 mm.
```

Hub Small End Hub MAWP:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138 * 1 * 17 )/(353 + 0.6 * 17 )
  = 64.542 bars
```

```
 Corroded Flange Thickness, tc = T-ci                  112.000  mm.
 Corroded Flange ID,       Bcor = B+2*Fcor             706.000  mm.
 Corroded Large Hub,      g1Cor = g1-ci                 32.000  mm.
 Corroded Small Hub,      g0Cor = go-ci                 17.000  mm.
 Code R Dimension,            R = ((C-Bcor)/2)-g1cor    65.000  mm.

 Gasket Contact Width,        N = (Go - Gi) / 2         25.400  mm.
 Basic Gasket Width,         bo = N / 2                 12.700  mm.
 Effective Gasket Width,      b = Cb sqrt(bo)            8.980  mm.
 Gasket Reaction Diameter,    G = Go - 2 * b           769.440  mm.
```

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

Hydrostatic End Load due to Pressure [H]:

```
  = 0.785 * G² * Peq
  = 0.79 * 769² * 62
  = 2882.829 kN
```

Contact Load on Gasket Surfaces [Hp]:

```
  = 2 * b * Pi * G * m * P
  = 2 * 8.98 * 3.14 * 769 * 3 * 62
  = 807.504 kN
```

Hydrostatic End Load at Flange ID [Hd]:

```
  = Pi * Bcor² * P  / 4
  = 3.14 * 706² *62/4
  = 2427.053 kN
```

Pressure Force on Flange Face [Ht]:

```
  = H - Hd
  = 2883 - 2427
  = 455.776 kN
```

Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 2883 + 808 + 0, 0 )
  = 3690.333 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.9*8.98*3.141*769+0*0*0
  = 1496.617 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 3690/172, 1497/172
  = 214.106 cm²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 41.3 + 6 * 112/(3 + 0.5)
  = 274.550 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 900 * sin( 3.14/20 )
  = 140.791 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 141/( 2 * 41.3 + 112 )), 1 )
  = 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area, cm²	214.106	216.774	
Radial Distance between Hub and Bolts:	53.975	65.000	
Radial Distance between Bolts and Edge:	41.275	45.000	
Circ. Spacing between the Bolts:	88.900	140.791	274.550

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 217  * 172/(68.9 * 3.14 * (787 + 737 ) )
  = 11.319 mm.
```

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :
```
  = 25.000 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa * ( Am + Ab ) / 2
  = 172 * ( 214 + 217 )/2
  = 3713.33 kN
```
Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 3690 - 2883
```

```
  = 807.50 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 900 - 769 )/2
  = 65.2802 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 65 + 32 + 65.3 )/2
  = 81.1401 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 65  + ( 32/2.0 )
  = 81.0000 mm.
```

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

```
 Loading                  Force  |   Distance |  Bolt Corr |         Moment  |
 --------------------------------------------------------------------------
 End Pressure,    Md       2427. |    81.0000 |     1.0000 |        196671. |
 Face Pressure,   Mt        456. |    81.1401 |     1.0000 |         36997. |
 Gasket Load,     Mg        808. |    65.2802 |     1.0000 |         52735. |
 Gasket Seating, Matm      3713. |    65.2802 |     1.0000 |        242505. |

 Total Moment for Operation,      Mop                              286403. N-m
 Total Moment for Gasket seating, Matm                             242505. N-m

 Effective Hub Length, ho = sqrt(Bcor*goCor)          109.554  mm.
 Hub Ratio,           h/h0 = HL / H0                    0.548
 Thickness Ratio,    g1/g0 = (g1Cor/goCor)              1.882
```

Flange Factors for Integral Flange:

```
 Factor F                                               0.820
 Factor V                                               0.230
 Factor f                                               1.000
 Factors from Figure 2-7.1                     K =      1.402
                     T =      1.753            U =      6.492
                     Y =      5.908            Z =      3.070
                     d = 0.89401E+06 mm.³       e =     0.0075 mm.^-1
 Stress Factors                            ALPHA =      1.838
                  BETA =      2.117        GAMMA =      1.048
                 DELTA =      1.571        Lamda =      2.620
```

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1*286403/706)/(2.62*32²)
  = 151.17 N./mm²
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1*242505/706)/(2.62*32²)
  = 128.00 N./mm²
```

Radial Flange Stress, Operating [SRo]:
$= (Beta * Mop / Bcor) / (L * t^2)$
$= (2.12*286403/706)/(2.62*112^2)$
$= 26.13$ N./mm²

Radial Flange Stress, Seating [SRa]:
$= (Beta * Matm/Bcor) / (L * t^2)$
$= (2.12*242505/706)/(2.62*112^2)$
$= 22.12$ N./mm²

Tangential Flange Stress, Operating [STo]:
$= (Y * Mo / (t^2 * Bcor)) - Z * SRo$
$= (5.91*286403/(112^2*706))-3.07*26.1$
$= 110.79$ N./mm²

Tangential Flange Stress, Seating [STa]:
$= (y * Matm / (t^2 * Bcor)) - Z * SRa$
$= (5.91*242505/(112^2*706))-3.07*22.1$
$= 93.81$ N./mm²

Average Flange Stress, Operating [SAo]:
$= (SHo + max(SRo, STo)) / 2$
$= (151+max(26.1,111))/2$
$= 130.98$ N./mm²

Average Flange Stress, Seating [SAa]:
$= (SHa + max(SRa, STa)) / 2$
$= (128+max(22.1,93.8))/2$
$= 110.91$ N./mm²

Bolt Stress, Operating [BSo]:
$= Wm1 / Ab$
$= 3690/217$
$= 170.25$ N./mm²

Bolt Stress, Seating [BSa]:
$= (Wm2 / Ab)$
$= (1497/217)$
$= 69.05$ N./mm²

Flange Stress Analysis Results: N./mm²

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	151.17	206.85	128.00	206.85
Radial Flange	26.13	137.90	22.12	137.90
Tangential Flange	110.79	137.90	93.81	137.90
Maximum Average	130.98	137.90	110.91	137.90
Bolting	170.25	172.38	69.05	172.38

Minimum Required Flange Thickness	111.303 mm.
Estimated M.A.W.P. (Operating)	62.8 bars
Estimated Finished Weight of Flange at given Thk.	372.3 kg.
Estimated Unfinished Weight of Forging at given Thk	522.1 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*242505/1*1000*0.23/(2.45*201334*17²*110*0.3)
  = 0.620    (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*286403/1*1000*0.23/(2.45*193805*17²*110*0.3)
  = 0.760    (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*242505/1*1000*0.23/(2.62*201334*17²*110*0.3)
  = 0.580    (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*286403/1*1000*0.23/(2.62*193805*17²*110*0.3)
  = 0.712    (should be <= 1)
```

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.96, Temperature Reduction per Fig. UCS 66.1 = 2 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B               -7 °C
 Min Metal Temp. at Required thickness (UCS 66.1)             -9 °C
 Min Metal Temp. w/o impact per UG-20(f)                     -29 °C
```

Note: UCS-66(b)(-c) was considered in the flange MDMT calculation.

Flange Input Data Values **Description: New Flange :**

Item: Node 120 to 130

```
Description of Flange Geometry (Type)           Integral Weld Neck
Design Pressure                             P          62.00  bars
Design Temperature                                       148  °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        700.000  mm.
Flange Outside Diameter                     A        990.000  mm.
Flange Thickness                            t       115.0000  mm.
Thickness of Hub at Small End              go        20.0000  mm.
Thickness of Hub at Large End              g1        35.0000  mm.
Length of Hub                               h        60.0000  mm.

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

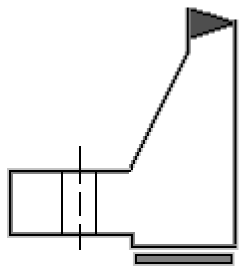
Bolt Material                                     SA-193 B7
Bolt Allowable Stress At Temperature       Sb         172.38  N./mm²
Bolt Allowable Stress At Ambient           Sa         172.38  N./mm²

Diameter of Bolt Circle                     C        900.000  mm.
Nominal Bolt Diameter                       a        41.2750  mm.
Type of Threads                            TEMA Thread Series
Number of Bolts                                           20

Flange Face Outside Diameter              Fod        800.000  mm.
Flange Face Inside Diameter               Fid        700.000  mm.
Flange Facing Sketch                        1, Code Sketch 1a

Gasket Outside Diameter                    Go        787.400  mm.
Gasket Inside Diameter                     Gi        736.600  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.
```



ASME Code, Section VIII Division 1, 2019

Hub Small End Required Thickness due to Internal Pressure:
```
  = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
  = (62*(700/2+3))/(138*1-0.6*62)+Ca
  = 19.3119 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138 * 1 * 17 )/(353 + 0.6 * 17 )
  = 64.542 bars
```

```
 Corroded Flange Thickness, tc = T-ci                    112.000  mm.
 Corroded Flange ID,       Bcor = B+2*Fcor               706.000  mm.
 Corroded Large Hub,      g1Cor = g1-ci                   32.000  mm.
 Corroded Small Hub,      g0Cor = go-ci                   17.000  mm.
 Code R Dimension,            R = ((C-Bcor)/2)-g1cor      65.000  mm.

 Gasket Contact Width,        N = (Go - Gi) / 2           25.400  mm.
 Basic Gasket Width,         bo = N / 2                   12.700  mm.
 Effective Gasket Width,      b = Cb sqrt(bo)              8.980  mm.
 Gasket Reaction Diameter,    G = Go - 2 * b             769.440  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.79 * 769² * 62
  = 2882.829 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P
  = 2 * 8.98 * 3.14 * 769 * 3 * 62
  = 807.504 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.14 * 706² *62/4
  = 2427.053 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 2883 - 2427
  = 455.776 kN
```

Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 2883 + 808 + 0, 0 )
  = 3690.333 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.9*8.98*3.141*769+0*0*0
  = 1496.617 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 3690/172, 1497/172
  = 214.106 cm²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 41.3 + 6 * 112/(3 + 0.5)
  = 274.550 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 900 * sin( 3.14/20 )
  = 140.791 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 141/( 2 * 41.3 + 112 )), 1 )
  = 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area, cm²	214.106	216.774	
Radial Distance between Hub and Bolts:	53.975	65.000	
Radial Distance between Bolts and Edge:	41.275	45.000	
Circ. Spacing between the Bolts:	88.900	140.791	274.550

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 217  * 172/(68.9 * 3.14 * (787 + 737 ) )
  = 11.319 mm.
```

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :
```
  = 25.000 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa * ( Am + Ab ) / 2
  = 172 * ( 214 + 217 )/2
  = 3713.33 kN
```
Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 3690 - 2883
```

```
  = 807.50 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 900 - 769 )/2
  = 65.2802 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 65 + 32 + 65.3 )/2
  = 81.1401 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 65  + ( 32/2.0 )
  = 81.0000 mm.
```

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

```
 Loading                  Force  |   Distance |  Bolt Corr |         Moment  |
 -----------------------------------------------------------------------------
 End Pressure,    Md       2427. |    81.0000 |     1.0000 |        196671. |
 Face Pressure,   Mt        456. |    81.1401 |     1.0000 |         36997. |
 Gasket Load,     Mg        808. |    65.2802 |     1.0000 |         52735. |
 Gasket Seating, Matm      3713. |    65.2802 |     1.0000 |        242505. |

 Total Moment for Operation,      Mop                              286403. N-m
 Total Moment for Gasket seating, Matm                             242505. N-m

 Effective Hub Length, ho = sqrt(Bcor*goCor)          109.554  mm.
 Hub Ratio,           h/h0 = HL / H0                     0.548
 Thickness Ratio,    g1/g0 = (g1Cor/goCor)               1.882
```

Flange Factors for Integral Flange:

```
 Factor F                                                0.820
 Factor V                                                0.230
 Factor f                                                1.000
 Factors from Figure 2-7.1                     K =       1.402
                    T =       1.753            U =       6.492
                    Y =       5.908            Z =       3.070
                    d = 0.89401E+06 mm.³        e =      0.0075 mm.^-1
 Stress Factors                            ALPHA =       1.838
                 BETA =       2.117        GAMMA =       1.048
                DELTA =       1.571        Lamda =       2.620
```

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1*286403/706)/(2.62*32²)
  = 151.17 N./mm²
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1*242505/706)/(2.62*32²)
  = 128.00 N./mm²
```

Radial Flange Stress, Operating [SRo]:
```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2.12*286403/706)/(2.62*112²)
  = 26.13 N./mm²
```
Radial Flange Stress, Seating [SRa]:
```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2.12*242505/706)/(2.62*112²)
  = 22.12 N./mm²
```

Tangential Flange Stress, Operating [STo]:
```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (5.91*286403/(112²*706))-3.07*26.1
  = 110.79 N./mm²
```
Tangential Flange Stress, Seating [STa]:
```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (5.91*242505/(112²*706))-3.07*22.1
  = 93.81 N./mm²
```

Average Flange Stress, Operating [SAo]:
```
  = ( SHo + max( SRo, STo ) ) / 2
  = (151+max(26.1,111))/2
  = 130.98 N./mm²
```
Average Flange Stress, Seating [SAa]:
```
  = ( SHa + max( SRa, STa ) ) / 2
  = (128+max(22.1,93.8))/2
  = 110.91 N./mm²
```

Bolt Stress, Operating [BSo]:
```
  = Wm1 / Ab
  = 3690/217
  = 170.25 N./mm²
```
Bolt Stress, Seating [BSa]:
```
  = ( Wm2 / Ab )
  = (1497/217)
  = 69.05 N./mm²
```

Flange Stress Analysis Results: N./mm²

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	151.17	206.85	128.00	206.85
Radial Flange	26.13	137.90	22.12	137.90
Tangential Flange	110.79	137.90	93.81	137.90
Maximum Average	130.98	137.90	110.91	137.90
Bolting	170.25	172.38	69.05	172.38

```
Minimum Required Flange Thickness                   111.303 mm.
Estimated M.A.W.P. ( Operating )                       62.8 bars
Estimated Finished Weight of Flange at given Thk.     372.3 kg.
Estimated Unfinished Weight of Forging at given Thk   522.1 kg.
```

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14*242505/1*1000*0.23/(2.45*202713*17²*110*0.3)
  = 0.615    (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*286403/1*1000*0.23/(2.45*195184*17²*110*0.3)
  = 0.755    (should be <= 1)
```

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14*242505/1*1000*0.23/(2.62*202713*17²*110*0.3)
  = 0.576    (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*286403/1*1000*0.23/(2.62*195184*17²*110*0.3)
  = 0.707    (should be <= 1)
```

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.96, Temperature Reduction per Fig. UCS 66.1 = 2 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -7 °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -9 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

Note: UCS-66(b)(-c) was considered in the flange MDMT calculation.

Flange Input Data Values **Description: New Flange :**

Item: Node 130 to 140

```
Description of Flange Geometry (Type)          Integral Weld Neck
Design Pressure                             P             62.00  bars
Design Temperature                                          148  °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           700.000  mm.
Flange Outside Diameter                     A           990.000  mm.
Flange Thickness                            t          115.0000  mm.
Thickness of Hub at Small End              go           20.0000  mm.
Thickness of Hub at Large End              g1           35.0000  mm.
Length of Hub                               h           60.0000  mm.

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

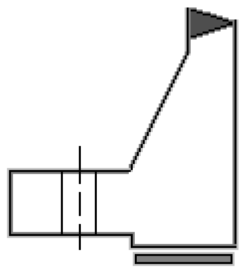
Bolt Material                                        SA-193 B7
Bolt Allowable Stress At Temperature       Sb           172.38  N./mm²
Bolt Allowable Stress At Ambient           Sa           172.38  N./mm²

Diameter of Bolt Circle                     C          900.000  mm.
Nominal Bolt Diameter                       a          41.2750  mm.
Type of Threads                            TEMA Thread Series
Number of Bolts                                             20

Flange Face Outside Diameter              Fod          800.000  mm.
Flange Face Inside Diameter               Fid          700.000  mm.
Flange Facing Sketch                        1, Code Sketch 1a

Gasket Outside Diameter                    Go          787.400  mm.
Gasket Inside Diameter                     Gi          736.600  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.
```



ASME Code, Section VIII Division 1, 2019

Hub Small End Required Thickness due to Internal Pressure:
```
  = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
  = (62*(700/2+3))/(138*1-0.6*62)+Ca
  = 19.3119 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138 * 1 * 17 )/(353 + 0.6 * 17 )
  = 64.542 bars
```

```
 Corroded Flange Thickness, tc = T-ci                   112.000  mm.
 Corroded Flange ID,       Bcor = B+2*Fcor              706.000  mm.
 Corroded Large Hub,      g1Cor = g1-ci                  32.000  mm.
 Corroded Small Hub,      g0Cor = go-ci                  17.000  mm.
 Code R Dimension,            R = ((C-Bcor)/2)-g1cor     65.000  mm.

 Gasket Contact Width,        N = (Go - Gi) / 2          25.400  mm.
 Basic Gasket Width,         bo = N / 2                  12.700  mm.
 Effective Gasket Width,      b = Cb sqrt(bo)             8.980  mm.
 Gasket Reaction Diameter,    G = Go - 2 * b            769.440  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.79 * 769² * 62
  = 2882.829 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P
  = 2 * 8.98 * 3.14 * 769 * 3 * 62
  = 807.504 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.14 * 706² *62/4
  = 2427.053 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 2883 - 2427
  = 455.776 kN
```

Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 2883 + 808 + 0, 0 )
  = 3690.333 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.9*8.98*3.141*769+0*0*0
  = 1496.617 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 3690/172, 1497/172
  = 214.106 cm²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 41.3 + 6 * 112/(3 + 0.5)
  = 274.550 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 900 * sin( 3.14/20 )
  = 140.791 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 141/( 2 * 41.3 + 112 )), 1 )
  = 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area, cm²	214.106	216.774	
Radial Distance between Hub and Bolts:	53.975	65.000	
Radial Distance between Bolts and Edge:	41.275	45.000	
Circ. Spacing between the Bolts:	88.900	140.791	274.550

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 217  * 172/(68.9 * 3.14 * (787 + 737 ) )
  = 11.319 mm.
```

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :
```
  = 25.000 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa * ( Am + Ab ) / 2
  = 172 * ( 214 + 217 )/2
  = 3713.33 kN
```
Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 3690 - 2883
```

```
  = 807.50 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 900 - 769 )/2
  = 65.2802 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 65 + 32 + 65.3 )/2
  = 81.1401 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 65   + ( 32/2.0 )
  = 81.0000 mm.
```

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	2427.	81.0000	1.0000	196671.
Face Pressure, Mt	456.	81.1401	1.0000	36997.
Gasket Load, Mg	808.	65.2802	1.0000	52735.
Gasket Seating, Matm	3713.	65.2802	1.0000	242505.

```
 Total Moment for Operation,      Mop                          286403. N-m
 Total Moment for Gasket seating, Matm                         242505. N-m

 Effective Hub Length, ho = sqrt(Bcor*goCor)          109.554  mm.
 Hub Ratio,            h/h0 = HL / H0                   0.548
 Thickness Ratio,     g1/g0 = (g1Cor/goCor)             1.882
```

Flange Factors for Integral Flange:

```
 Factor F                                               0.820
 Factor V                                               0.230
 Factor f                                               1.000
 Factors from Figure 2-7.1                     K =      1.402
                    T =       1.753            U =      6.492
                    Y =       5.908            Z =      3.070
                    d = 0.89401E+06 mm.³        e =     0.0075 mm.^-1
 Stress Factors                            ALPHA =      1.838
                 BETA =       2.117        GAMMA =      1.048
                DELTA =       1.571        Lamda =      2.620
```

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1*286403/706)/(2.62*32²)
  = 151.17 N./mm²
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1*242505/706)/(2.62*32²)
  = 128.00 N./mm²
```

Radial Flange Stress, Operating [SRo]:
```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2.12*286403/706)/(2.62*112²)
  = 26.13 N./mm²
```
Radial Flange Stress, Seating [SRa]:
```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2.12*242505/706)/(2.62*112²)
  = 22.12 N./mm²
```

Tangential Flange Stress, Operating [STo]:
```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (5.91*286403/(112²*706))-3.07*26.1
  = 110.79 N./mm²
```
Tangential Flange Stress, Seating [STa]:
```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (5.91*242505/(112²*706))-3.07*22.1
  = 93.81 N./mm²
```

Average Flange Stress, Operating [SAo]:
```
  = ( SHo + max( SRo, STo ) ) / 2
  = (151+max(26.1,111))/2
  = 130.98 N./mm²
```
Average Flange Stress, Seating [SAa]:
```
  = ( SHa + max( SRa, STa ) ) / 2
  = (128+max(22.1,93.8))/2
  = 110.91 N./mm²
```

Bolt Stress, Operating [BSo]:
```
  = Wm1 / Ab
  = 3690/217
  = 170.25 N./mm²
```
Bolt Stress, Seating [BSa]:
```
  = ( Wm2 / Ab )
  = (1497/217)
  = 69.05 N./mm²
```

Flange Stress Analysis Results: N./mm²

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	151.17	206.85	128.00	206.85
Radial Flange	26.13	137.90	22.12	137.90
Tangential Flange	110.79	137.90	93.81	137.90
Maximum Average	130.98	137.90	110.91	137.90
Bolting	170.25	172.38	69.05	172.38

```
Minimum Required Flange Thickness                    111.303 mm.
Estimated M.A.W.P. ( Operating )                        62.8 bars
Estimated Finished Weight of Flange at given Thk.      372.3 kg.
Estimated Unfinished Weight of Forging at given Thk    522.1 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*242505/1*1000*0.23/(2.45*202713*17²*110*0.3)
  = 0.615    (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*286403/1*1000*0.23/(2.45*195184*17²*110*0.3)
  = 0.755    (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*242505/1*1000*0.23/(2.62*202713*17²*110*0.3)
  = 0.576    (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*286403/1*1000*0.23/(2.62*195184*17²*110*0.3)
  = 0.707    (should be <= 1)
```

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.96, Temperature Reduction per Fig. UCS 66.1 = 2 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -7  °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -9  °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29  °C
```

Note: UCS-66(b)(-c) was considered in the flange MDMT calculation.

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
Skirt		...	...	...	736	...
Bottom Head		62.189	25	...	706	137.9
30	40	62.167	...	...	746	137.9
40	50	62.103	...	...	706	137.9
50	60	62.103	...	...	706	137.9
60	70	62.103	...	...	706	137.9
70	80	62	...	...	706	137.9
80	90	62	...	3	700	137.9
90	100	62	...	3	700	137.9
100	110	62	...	3	700	137.9
110	120	62	...	3	700	137.9
120	130	62	...	3	700	137.9
130	140	62	...	3	700	137.9
140	150	62	...	3	700	137.9
Top Head		62	25	3	700	137.9

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.
Skirt		...	No Calc	No Calc	25	No Calc
Bottom Head		62	77.5	77.7	20	15.9923
30	40	62	75.4	75.6	20	16.5183
40	50	62	62.7	62.8	110	103.734
50	60	62	62.7	62.8	110	103.734
60	70	62	75.5	75.6	20	16.3397
70	80	62	62.8	62.8	110	103.607
80	90	62	62.8	62.8	115	111.303
90	100	62	64.5	76.2	20	19.3119
100	110	62	64.5	76.2	20	19.3119
110	120	62	64.5	76.2	20	19.3119
120	130	62	62.8	62.8	115	111.303
130	140	62	62.8	62.8	115	111.303
140	150	62	64.5	76.2	20	19.3119
Top Head		62	66.8	78.3	20	18.7651
Minimum			62.7	62.8		

MAWP: 62.2 bars, limited by: Nozzle Reinforcement.

Elements Suitable for Design Internal Pressure.

Internal Pressure Calculation Results:

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Elliptical Head From 20 To 30 SA-516 70 , UCS-66 Crv. B at 148 °C

Bottom 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)
  = (62.2*706*1)/(2*138*1-0.2*62.2)
  = 15.9923 + 0.0000 = 15.9923 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.189 bars
```
  = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
  = (2*138*1*20)/(1*706+0.2*20)
  = 77.7 - 0.19 = 77.5  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
  = (2*138*1*20)/(1*706+0.2*20)
  = 77.7 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (62.2*(1*706+0.2*20))/(2*1*20)
  = 110.391 N./mm²
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (62.2*353)/(138*1-0.6*62.2)+0
  = 16.363 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.171 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138 * 1 * 25 )/(353 + 0.6 * 25 )
  = 93.7 - 0.17 = 93.5  bars
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 14.149 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 20, tr = 16, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.8, Temp. Reduction = 11 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -7 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -19 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 25, tr = 16.4, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.65, Temp. Reduction = 19 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -1 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -20 °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 30 To 40 SA-516 70 , UCS-66 Crv. B at 148 °C

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
= (P*Ro) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
= (62.2*373)/(138*1+0.4*62.2)
= 16.5183 + 0.0000 = 16.5183 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.167 bars

```
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (138*1*20)/(373-0.4*20)
= 75.6 - 0.17 = 75.4  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (138*1*20)/(373-0.4*20)
= 75.6 bars
```

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

```
= (P*(Ro-0.4*t))/(E*t)
= (62.2*((373-0.4*20))/(1*20)
= 113.461 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 2.755 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 20, tr = 16.6, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.83, Temp. Reduction = 10 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -7 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -17 °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 60 To 70 SA-516 70 , UCS-66 Crv. B at 148 °C
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (62.1*353)/(138*1-0.6*62.1)
= 16.3397 + 0.0000 = 16.3397 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.103 bars
```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (138*1*20)/(353+0.6*20)
= 75.6 - 0.1 = 75.5  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (138*1*20)/(353+0.6*20)
= 75.6 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
= (P*(R+0.6*t))/(E*t)
= (62.1*(353+0.6*20))/(1*20)
= 113.344 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 2.755 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 20, tr = 16.4, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.82, Temp. Reduction = 10 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -7 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -17 °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 90 To 100 SA-516 70 , UCS-66 Crv. B at 148 °C
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (62*353)/(138*1-0.6*62)
= 16.3119 + 3.0000 = 19.3119 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (138*1*17)/(353+0.6*17)
= 64.5 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138*1*20)/(350+0.6*20)
  = 76.2 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (62*(353+0.6*17))/(1*17)
  = 132.469 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 2.778 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 20, tr = 16.4, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.96, Temp. Reduction = 2 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -7 °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -9 °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 100 To 110 SA-516 70 , UCS-66 Crv. B at 148 °C
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 + 3.0000 = 19.3119 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138*1*17)/(353+0.6*17)
  = 64.5 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138*1*20)/(350+0.6*20)
  = 76.2 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (62*(353+0.6*17))/(1*17)
  = 132.469 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 2.778 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 20, tr = 16.4, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.96, Temp. Reduction = 2 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -7 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -9 °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 110 To 120 SA-516 70 , UCS-66 Crv. B at 148 °C
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 + 3.0000 = 19.3119 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138*1*17)/(353+0.6*17)
  = 64.5 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138*1*20)/(350+0.6*20)
  = 76.2 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (62*(353+0.6*17))/(1*17)
  = 132.469 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 2.778 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 20, tr = 16.4, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.96, Temp. Reduction = 2 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -7 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -9 °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 140 To 150 SA-516 70 , UCS-66 Crv. B at 148 °C

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 + 3.0000 = 19.3119 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138*1*17)/(353+0.6*17)
  = 64.5 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138*1*20)/(350+0.6*20)
  = 76.2 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (62*(353+0.6*17))/(1*17)
  = 132.469 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 2.778 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 20, tr = 16.4, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.96, Temp. Reduction = 2 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -7 °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -9 °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.

Elliptical Head From 150 To 160 SA-516 70 , UCS-66 Crv. B at 148 °C

Top 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)
  = (62*706*0.99)/(2*138*1-0.2*62)
  = 15.7651 + 3.0000 = 18.7651 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
  = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
  = (2*138*1*17)/(0.99*706+0.2*17)
  = 66.8 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
  = (2*138*1*20)/(1*700+0.2*20)
  = 78.3 bars
```

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

```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (62*(0.99*706+0.2*17))/(2*1*17)
  = 127.928 N./mm²
```

Straight Flange Required Thickness:

```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (62*353)/(138*1-0.6*62)+3
  = 19.312 mm.
```

Straight Flange Maximum Allowable Working Pressure:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138 * 1 * 22 )/(353 + 0.6 * 22 )
  = 82.8 bars
```

Factor K, corroded condition [Kcor]:

```
  = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
  = ( 2 + ( 706/( 2 * 178 ))²)/6
  = 0.988811
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 14.259 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 20, tr = 15.8, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.93, Temp. Reduction = 4 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -7 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -11 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 25, tr = 16.4, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.74, Temp. Reduction = 14 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -1 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -15 °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.

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        80.840  bars
Pressure per UG99b[36]  = 1.30 * Design Pres * Sa/S     80.600  bars
Pressure per UG99c      = 1.30 * M.A.P. - Head(Hyd)     81.480  bars
Pressure per UG100      = 1.10 * M.A.W.P. * Sa/S        68.403  bars
Pressure per PED        = max(1.43*DP, 1.25*DP*ratio)   88.660  bars
Pressure per App 27-4   = M.A.W.P.                      62.185  bars
```

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

```
  = Test Factor * Design Pressure * Stress Ratio
  = 1.3 * 62 * 1
  = 80.600 bars
```

Vertical 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
Bottom Head	145.0	235.8	0.615	81.67
30 40	149.0	235.8	0.632	81.65
60 70	148.6	235.8	0.630	81.42
90 100	173.5	235.8	0.736	81.19
100 110	173.2	235.8	0.734	81.04
110 120	172.8	235.8	0.733	80.90
140 150	172.4	235.8	0.731	80.71
Top Head	166.4	235.8	0.705	80.62

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
N07 (1in)	Nozzle	117.90	117.90	1.000
K07A (3in)	Nozzle	137.90	137.90	1.000
K09A (2in)	Nozzle	117.90	117.90	1.000
N01 (6in)	Nozzle	137.90	137.90	1.000
N09 (1in)	Nozzle	137.90	137.90	1.000
K07B (3in)	Nozzle	137.90	137.90	1.000
K08A (2in)	Nozzle	137.90	137.90	1.000
K08B (2in)	Nozzle	137.90	137.90	1.000
K09B (2in)	Nozzle	137.90	137.90	1.000
N10A (8in)	Nozzle	137.90	137.90	1.000
N05 (2in)	Nozzle	137.90	137.90	1.000
N04 (1in)	Nozzle	137.90	137.90	1.000
N10B (8in)	Nozzle	137.90	137.90	1.000
K2B (2in)	Nozzle	137.90	137.90	1.000
K2A (2in)	Nozzle	137.90	137.90	1.000

K3B (2in)	Nozzle	137.90	137.90	1.000
K3A (2in)	Nozzle	137.90	137.90	1.000
K4B (2in)	Nozzle	137.90	137.90	1.000
K4A (2in)	Nozzle	137.90	137.90	1.000
K10A (2in)	Nozzle	137.90	137.90	1.000
K05 (2in)	Nozzle	137.90	137.90	1.000
K10B (2in)	Nozzle	137.90	137.90	1.000
K1 (2in)	Nozzle	137.90	137.90	1.000
N06 (2in)	Nozzle	137.90	137.90	1.000
K6A (2in)	Nozzle	137.90	137.90	1.000
K6B (2in)	Nozzle	137.90	137.90	1.000
N03 (2in)	Nozzle	137.90	137.90	1.000
N10C (8in)	Nozzle	137.90	137.90	1.000
N02 (6in)	Nozzle	137.90	137.90	1.000
N08 (2in)	Nozzle	137.90	137.90	1.000
Minimum				1.000

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

Description	Ambient	Operating	Ratio
Bottom Head	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	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	137.90	1.000
	137.90	137.90	1.000
	137.90	137.90	1.000
Top Head	137.90	137.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
N07 (1in)	18.90	217.19	0.087
K07A (3in)	72.36	223.40	0.324
K09A (2in)	22.16	217.19	0.102
N01 (6in)	106.96	223.40	0.479
N09 (1in)	12.19	223.40	0.055
K07B (3in)	20.13	223.40	0.090
K08A (2in)	17.26	223.40	0.077
K08B (2in)	17.26	223.40	0.077
K09B (2in)	17.26	223.40	0.077
N10A (8in)	121.48	223.40	0.544

```
N05  (2in)                          |     17.27 |         223.40 |    0.077 |
N04  (1in)                          |     12.12 |         223.40 |    0.054 |
N10B  (8in)                         |     76.87 |         223.40 |    0.344 |
K2B  (2in)                          |     17.32 |         223.40 |    0.078 |
K2A  (2in)                          |     17.32 |         223.40 |    0.078 |
K3B  (2in)                          |     17.34 |         223.40 |    0.078 |
K3A  (2in)                          |     17.33 |         223.40 |    0.078 |
K4B  (2in)                          |     20.06 |         223.40 |    0.090 |
K4A  (2in)                          |     20.09 |         223.40 |    0.090 |
K10A  (2in)                         |     21.82 |         223.40 |    0.098 |
K05  (2in)                          |     21.82 |         223.40 |    0.098 |
K10B  (2in)                         |     21.71 |         223.40 |    0.097 |
K1  (2in)                           |     21.69 |         223.40 |    0.097 |
N06  (2in)                          |     21.69 |         223.40 |    0.097 |
K6A  (2in)                          |     21.69 |         223.40 |    0.097 |
K6B  (2in)                          |     21.68 |         223.40 |    0.097 |
N03  (2in)                          |     16.05 |         223.40 |    0.072 |
N10C  (8in)                         |    105.72 |         223.40 |    0.473 |
N02  (6in)                          |     99.54 |         223.40 |    0.446 |
N08  (2in)                          |     21.67 |         223.40 |    0.097 |
------------------------------------------------------------------------
```

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	1500	...	...	No Calc	No Calc
20	30	No Calc	746	20	0.0037236	115.451
30	40	2108.83	746	20	0.0019348	103.004
40	50	No Calc	...	110	No Calc	No Calc
50	60	No Calc	...	110	No Calc	No Calc
60	70	2000	746	20	0.0020523	104.333
70	80	No Calc	...	110	No Calc	No Calc
80	90	No Calc	...	112	No Calc	No Calc
90	100	4600	740	17	0.00069324	69.308
100	110	4600	740	17	0.00069324	69.308
110	120	4600	740	17	0.00069324	69.308
120	130	No Calc	...	112	No Calc	No Calc
130	140	No Calc	...	112	No Calc	No Calc
140	150	971.333	740	17	0.0035578	114.75
150	160	No Calc	740	17	0.0031907	112.973

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	...	No Calc	...	No Calc
20	30	20	1.93136	1.034	34.4
30	40	20	3.6997	1.034	36.8
40	50	110	64.6176	1.034	No Calc
50	60	110	64.6176	1.034	No Calc
60	70	20	3.61282	1.034	37.3
70	80	110	64.6176	1.034	No Calc
80	90	115	72.7456	1.034	No Calc
90	100	20	8.15391	1.034	21.2
100	110	20	8.15391	1.034	21.2
110	120	20	8.15391	1.034	21.2
120	130	115	72.7456	1.034	No Calc
130	140	115	72.7456	1.034	No Calc
140	150	20	5.65651	1.034	35.1
150	160	20	4.91581	1.034	28.8
Minimum					21.2

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	1500	No Calc	No Calc	No Calc
20	30	No Calc	No Calc	No Calc	No Calc
30	40	2108.83	65704.5	No Calc	No Calc
40	50	No Calc	No Calc	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc
60	70	2000	62721.3	No Calc	No Calc
70	80	No Calc	No Calc	No Calc	No Calc
80	90	No Calc	No Calc	No Calc	No Calc
90	100	4600	365050	No Calc	No Calc
100	110	4600	365050	No Calc	No Calc
110	120	4600	365050	No Calc	No Calc
120	130	No Calc	No Calc	No Calc	No Calc
130	140	No Calc	No Calc	No Calc	No Calc
140	150	971.333	24657.5	No Calc	No Calc
150	160	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

ASME Code, Section VIII Division 1, 2019

<u>Elliptical Head From 20 to 30 Ext. Chart: CS-2 at 100 °C</u>

Bottom Head

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
20.000	746.00	37.30	0.0037236	115.45

MAEP = B/(K0*Do/t) = 115/(0.9 *37.3) = 34.4 bars

Results for Required Thickness — Tca

Tca	Outer Dia	Do/t	Factor A	Factor B
1.931	746.00	386.26	0.0003596	35.95

MAEP = B/(K0*Do/t) = 35.9/(0.9 *386) = 1.03 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)
= (1.73*706*1)/(2*138*1-0.2*1.73)
= 0.4421 + 0.0000 = 0.4421 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*138*1*20)/(1*706+0.2*20))/1.67
= 46.5 bars
```

Maximum Allowable External Pressure [MAEP]:

```
= min( MAEP, MAWP )
= min( 34.4, 46.5 )
= 34.389 bars
```

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

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 |
 20.000 |     746.00 |     2108.83 |     37.30 |    2.8269 | 0.0019348 |   103.00 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*103 )/(3*37.3 ) = 36.8 bars

                                                 |                                    |
Results for Required Thickness                   |                                Tca |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |  Factor A | Factor B |
  3.700 |     746.00 |     2108.83 |    201.64 |    2.8269 | 0.0001564 |    15.64 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*15.6 )/(3*202 ) = 1.03 bars

                                                 |                                    |
Results for Maximum Stiffened Length             |                               Slen |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |  Factor A | Factor B |
 20.000 |     746.00 |    65704.55 |     37.30 |   50.0000 | 0.0008112 |    78.61 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*78.6 )/(3*37.3 ) = 28.1 bars
```

Cylindrical Shell From 60 to 70 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 |
 20.000 |     746.00 |     2000.00 |     37.30 |    2.6810 |  0.0020523 |   104.33 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*104 )/(3*37.3 ) = 37.3 bars

                                               |                                    |
Results for Required Thickness                 |                                Tca |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  3.613 |     746.00 |     2000.00 |    206.49 |    2.6810 |  0.0001602 |    16.01 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*16 )/(3*206 ) = 1.03 bars

                                               |                                    |
Results for Maximum Stiffened Length           |                               Slen |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
 20.000 |     746.00 |    62721.31 |     37.30 |   50.0000 |  0.0008112 |    78.61 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*78.6 )/(3*37.3 ) = 28.1 bars

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

Cylindrical Shell From 90 to 100 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 |
 17.000 |     740.00 |     4600.00 |     43.53 |    6.2162 |  0.0006932 |    69.31 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*69.3 )/(3*43.5 ) = 21.2 bars

                                               |                                    |
Results for Required Thickness                 |                                Tca |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  5.154 |     740.00 |     4600.00 |    143.58 |    6.2162 |  0.0001114 |    11.14 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*11.1 )/(3*144 ) = 1.03 bars

                                               |                                    |
Results for Maximum Stiffened Length           |                               Slen |
-------------------------------------------------------------------------------------
```

```
    Tca |  Outer Dia |         Slen |       Do/t |        L/D |   Factor A | Factor B |
 17.000 |     740.00 |    365050.28 |      43.53 |    50.0000 |  0.0005906 |    59.05 |
-----------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*59.1 )/(3*43.5 ) = 18.1 bars

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

Cylindrical Shell From 100 to 110 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 |
 17.000 |     740.00 |      4600.00 |      43.53 |     6.2162 |  0.0006932 |    69.31 |
-----------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*69.3 )/(3*43.5 ) = 21.2 bars

                                                |                                    |
Results for Required Thickness                 |                                Tca |
-----------------------------------------------------------------------------------
    Tca |  Outer Dia |         Slen |       Do/t |        L/D |   Factor A | Factor B |
  5.154 |     740.00 |      4600.00 |     143.58 |     6.2162 |  0.0001114 |    11.14 |
-----------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*11.1 )/(3*144 ) = 1.03 bars

                                                |                                    |
Results for Maximum Stiffened Length           |                               Slen |
-----------------------------------------------------------------------------------
    Tca |  Outer Dia |         Slen |       Do/t |        L/D |   Factor A | Factor B |
 17.000 |     740.00 |    365050.28 |      43.53 |    50.0000 |  0.0005906 |    59.05 |
-----------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*59.1 )/(3*43.5 ) = 18.1 bars

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

Cylindrical Shell From 110 to 120 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 |
 17.000 |     740.00 |      4600.00 |      43.53 |     6.2162 |  0.0006932 |    69.31 |
-----------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*69.3 )/(3*43.5 ) = 21.2 bars

                                                |                                    |
Results for Required Thickness                 |                                Tca |
-----------------------------------------------------------------------------------
    Tca |  Outer Dia |         Slen |       Do/t |        L/D |   Factor A | Factor B |
```

```
   5.154 |      740.00 |      4600.00 |      143.58 |      6.2162 |  0.0001114 |     11.14 |
 -------------------------------------------------------------------------------------
 MAEP = (4*B)/(3*(Do/t)) = (4*11.1 )/(3*144 ) = 1.03 bars

                                               |                                    |
 Results for Maximum Stiffened Length          |                               Slen |
 -------------------------------------------------------------------------------------
     Tca |  Outer Dia |         Slen |      Do/t |         L/D |   Factor A |  Factor B |
  17.000 |     740.00 |    365050.28 |      43.53 |     50.0000 |  0.0005906 |     59.05 |
 -------------------------------------------------------------------------------------
 MAEP = (4*B)/(3*(Do/t)) = (4*59.1 )/(3*43.5 ) = 18.1 bars

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

Cylindrical Shell From 140 to 150 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 |
  17.000 |     740.00 |       971.33 |      43.53 |      1.3126 |  0.0035578 |    114.75 |
 -------------------------------------------------------------------------------------
 MAEP = (4*B)/(3*(Do/t)) = (4*115 )/(3*43.5 ) = 35.1 bars

                                               |                                    |
 Results for Required Thickness                |                                Tca |
 -------------------------------------------------------------------------------------
     Tca |  Outer Dia |         Slen |      Do/t |         L/D |   Factor A |  Factor B |
   2.657 |     740.00 |       971.33 |     278.56 |      1.3126 |  0.0002161 |     21.61 |
 -------------------------------------------------------------------------------------
 MAEP = (4*B)/(3*(Do/t)) = (4*21.6 )/(3*279 ) = 1.03 bars

                                               |                                    |
 Results for Maximum Stiffened Length          |                               Slen |
 -------------------------------------------------------------------------------------
     Tca |  Outer Dia |         Slen |      Do/t |         L/D |   Factor A |  Factor B |
  17.000 |     740.00 |     24657.50 |      43.53 |     33.3209 |  0.0005914 |     59.13 |
 -------------------------------------------------------------------------------------
 MAEP = (4*B)/(3*(Do/t)) = (4*59.1 )/(3*43.5 ) = 18.1 bars

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

Elliptical Head From 150 to 160 Ext. Chart: CS-2 at 100 °C

Top Head

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 |
 17.000 |     740.00 |       43.53 | 0.0031907 |                            112.97 |
---------------------------------------------------------------------------------
MAEP = B/(K0*Do/t) = 113/(0.9 *43.5 ) = 28.8 bars

                                              |                                   |
Results for Required Thickness                |                               Tca |
---------------------------------------------------------------------------------
    Tca |  Outer Dia |        Do/t |  Factor A |                          Factor B |
  1.916 |     740.00 |      386.26 | 0.0003596 |                             35.95 |
---------------------------------------------------------------------------------
MAEP = B/(K0*Do/t) = 35.9/(0.9 *386 ) = 1.03 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)
  = (1.73*706*0.99)/(2*138*1-0.2*1.73)
  = 0.4372 + 3.0000 = 3.4372 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*138*1*17)/(0.99*706+0.2*17))/1.67
  = 40 bars
```

Maximum Allowable External Pressure [MAEP]:
```
  = min( MAEP, MAWP )
  = min( 28.8, 40 )
  = 28.835 bars
```

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

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	1264.54	...	1264.54	...	63.2269
20	30	146.17	65648.4	146.17	65648.4	7.3085
30	40	707.093	783082	707.093	783082	35.3546
40	50	350.879	66561.9	350.879	66561.9	17.5439
50	60	350.879	66561.9	350.879	66561.9	17.5439
60	70	707.093	783082	707.093	783082	35.3546
70	80	350.879	66561.9	350.879	66561.9	17.5439
80	90	372.313	68122	363.327	68519.7	18.6157
90	100	525.937	577371	448.909	587311	26.2968
100	110	525.937	577371	448.909	587311	26.2968
110	120	560.999	615862	478.836	626465	28.05
120	130	372.313	68122	363.327	68519.7	18.6157
130	140	372.313	68122	363.327	68519.7	18.6157
140	150	302.589	332181	258.272	337900	15.1295
150	160	143.961	64152.3	126.686	65648.4	7.19807
Total		7053	4202801.00	6729	4241693.00	352

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Insl	463.005	...	750	FIREPROOF
20	Liqd	68.5864	...	-87.5	Liquid: 20
20	Insl	6.46199	...	-62.5	Ins: 30
20	Lini	16.9035	...	-56.25	CLAD
20	Nozl	10.2662	...	-326.5	N07 (1in)
20	Nozl	23.447	...	-295.438	K07A (3in)
20	Nozl	15.3196	200	-631.997	K09A (2in)
20	Wght	50	...	-162.5	VORTEX BREAKER
30	Liqd	250.042	...	325	Liquid: 30
30	Insl	31.2597	...	1000	Ins: 30
30	Lini	106.37	...	1000	CLAD
30	Nozl	81.2937	430.914	1350	N01 (6in)
30	Nozl	9.87778	365.7	150	N09 (1in)
30	Nozl	19.8152	391.1	726	K07B (3in)
30	Nozl	11.0455	378.4	470	K08A (2in)
30	Nozl	11.0455	378.4	726	K08B (2in)
30	Nozl	11.0455	378.4	644	K09B (2in)
30	Nozl	150.448	455.381	1600	N10A (8in)
30	Nozl	11.0455	378.4	150	N05 (2in)
30	Wght	100	...	1800	DEMISTER PAD 1
30	Wght	100	...	1350	N01 INLET
40	Insl	3.23054	...	87.5	Ins: 40

50	Insl	3.23054	...	85	Ins: 50
60	Liqd	403.913	...	525	Liquid: 40
60	Insl	31.2597	...	1000	Ins: 30
60	Lini	106.37	...	1000	CLAD
60	Nozl	5.59574	365.7	100	N04 (1in)
60	Nozl	152.572	451.425	1493.7	N10B (8in)
60	Nozl	10.9749	378.4	1371	K2B (2in)
60	Nozl	10.9749	378.4	1115	K2A (2in)
60	Nozl	10.9749	378.4	293	K3B (2in)
60	Nozl	10.9749	378.4	549	K3A (2in)
60	Nozl	19.8152	391.1	1371	K4B (2in)
60	Nozl	19.9193	391.1	293	K4A (2in)
60	Wght	250	...	193	CHIMNEY
70	Insl	3.23054	...	85	Ins: 70
80	Insl	3.29633	...	87.5	Ins: 80
90	Pack	171.068	...	865	Pack: [1 of 1]
90	Insl	23.2681	...	750	Ins: 30
90	Nozl	10.9749	375.4	120	K10A (2in)
90	Nozl	10.9749	375.4	432.3	K05 (2in)
90	Wght	100	...	230	SUPPORT GRID
90	Wght	840	...	...	ATTACHMENTS
100	Pack	202.049	...	750	Pack: [1 of 1]
100	Insl	23.2681	...	750	Ins: 30
110	Plat	2245.02	0.14697E-04	800	PLAT:[1 OF 1]
110	Pack	185.885	...	690	Pack: [1 of 1]
110	Insl	24.8193	...	800	Ins: 30
110	Nozl	10.9749	375.4	1493	K10B (2in)
110	Wght	50	...	1380	BED LIMMITER
120	Insl	3.29633	...	87.5	Ins: 120
130	Insl	3.29633	...	87.5	Ins: 130
140	Insl	13.1852	...	425	Ins: 140
140	Nozl	10.9749	375.4	207	K1 (2in)
140	Nozl	10.9749	375.4	207	N06 (2in)
140	Nozl	10.9749	375.4	250	K6A (2in)
140	Nozl	10.9749	375.4	550	K6B (2in)
140	Nozl	5.21564	362.7	110	N03 (2in)
140	Nozl	152.572	448.425	250	N10C (8in)
140	Wght	100	...	400	DEMISTER PAD 2
150	Insl	6.36902	...	112.5	Ins: 30
150	Nozl	58.8148	...	325	N02 (6in)
150	Nozl	15.4001	...	240.139	N08 (2in)
150	Wght	1000	970	...	PIPING

90	Pliq	146.56	...	865.000
100	Pliq	173.11	...	750.000
110	Pliq	159.26	...	690.000

Total Weight of Each Detail Type:

Platforms	2245.0
Packing	559.0
Packing Liquid	478.9
Liquid	722.5
Insulation	642.5

```
Lining                          229.6
Nozzles                         905.3
Weights                        2590.0
-------------------------------------------
Sum of the Detail Weights       8372.9 kg.
```

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	7406.6	7406.6	7406.6	7406.6	7406.6	7406.6
Nozzles	905.3	905.3	905.3	905.3	905.3	905.3
Wld Weights	50.0	50.0	50.0	50.0	50.0	50.0
Platforms	...	...	2245.0	2245.0	2245.0	2245.0
Packing	...	...	559.0	559.0	559.0	559.0
Insulation	...	...	642.5	642.5	642.5	642.5
Lining	...	...	...	229.6	229.6	229.6
Empty Weights	...	...	...	2540.0	2540.0	...
Ope Weights	...	...	...	...	...	2440.0
Ope. Liquid	...	...	...	...	...	722.5
Packing Liq	...	...	...	...	...	478.9
Test Liquid	...	4200.2	...	...	...	...
Totals	8361.9	12562.1	12038.0	14578.0	14578.0	15679.5

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                 8361.9 kg.
Shop Test Wt.    - Fabricated Weight + Water ( Full )                     12562.1 kg.
Shipping Wt.     - Fab. Weight + removable Intls.+ Shipping App.          12038.0 kg.
Erected  Wt.     - Fab. Wt + or - loose items (trays,platforms etc.)      14578.0 kg.
Ope. Wt. no Liq  - Fab. Weight + Internals. + Details + Weights           14578.0 kg.
Operating Wt.    - Empty Weight + Operating Liq. Uncorroded               15679.5 kg.
Field Test Wt.   - Empty Weight + Water (Full)                            15348.5 kg.
Mass of the Upper 1/3 of the Vertical Vessel                               6426.2 kg.
```

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

Outside Surface Areas of Elements:

From	To	Surface Area cm^2
10	20	34683.2

20	30	7382.89
30	40	46872.6
40	50	8666.9
50	60	8666.9
60	70	46872.6
70	80	8666.9
80	90	8877.36
90	100	34871.7
100	110	34871.7
110	120	37196.5
120	130	8877.36
130	140	8877.36
140	150	20062.8
150	160	7275.52
Total		322722.125 cm²

Element and Detail Weights:

From	To	Total Ele. Empty Wgt. kg.	Total. Ele. Oper. Wgt. kg.	Total. Ele. Hydro. Wgt. kg.	Total Dtl. Offset Mom. N-m	Oper. Wgt. No Liquid kg.
10	20	1790.77	1790.77	1790.77	...	1790.77
20	30	275.877	344.463	341.485	30.057	275.877
30	40	1385.69	1635.74	1968.3	1291.21	1385.69
40	50	371.653	371.653	438.174	...	371.653
50	60	371.653	371.653	438.174	...	371.653
60	70	1371.88	1775.79	1904.48	1011.14	1371.88
70	80	371.653	371.653	438.174	...	371.653
80	90	394.225	394.225	453.267	...	394.225
90	100	1708.52	1855.08	1103.52	80.8338	1708.52
100	110	777.551	950.656	1081.58	...	777.551
110	120	3105.74	3265	3409.67	40.4172	3105.74
120	130	394.225	394.225	453.267	...	394.225
130	140	394.225	394.225	453.267	...	394.225
140	150	632.591	532.591	823.752	851.397	532.591
150	160	1231.74	1231.74	279.213	9515.67	1231.74

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid kg.	Cumulative Oper. Wgt. kg.	Cumulative Hydro. Wgt. kg.
10	20	14478	15679.5	15377.1
20	30	12687.2	13888.7	13586.3
30	40	12411.4	13544.2	13244.8
40	50	11025.7	11908.5	11276.5
50	60	10654	11536.9	10838.4
60	70	10282.4	11165.2	10400.2
70	80	8910.48	9389.4	8495.71

80	90	8538.83	9017.75	8057.54
90	100	8144.6	8623.53	7604.27
100	110	6436.08	6768.44	6500.75
110	120	5658.53	5817.79	5419.17
120	130	2552.79	2552.79	2009.5
130	140	2158.56	2158.56	1556.23
140	150	1764.33	1764.33	1102.96
150	160	1231.74	1231.74	279.213

Note: The cumulative operating weights no liquid in the column above are the cumulative operating weights minus the operating liquid weight minus any weights absent in the empty condition.

Cumulative Vessel Moment

From	To	Cumulative Empty Mom. N-m	Cumulative Oper. Mom. N-m	Cumulative Hydro. Mom. N-m
10	20	12820.7	12820.7	12820.7
20	30	12820.7	12820.7	12820.7
30	40	12790.7	12790.7	12790.7
40	50	11499.5	11499.5	11499.5
50	60	11499.5	11499.5	11499.5
60	70	11499.5	11499.5	11499.5
70	80	10488.3	10488.3	10488.3
80	90	10488.3	10488.3	10488.3
90	100	10488.3	10488.3	10488.3
100	110	10407.5	10407.5	10407.5
110	120	10407.5	10407.5	10407.5
120	130	10367.1	10367.1	10367.1
130	140	10367.1	10367.1	10367.1
140	150	10367.1	10367.1	10367.1
150	160	9515.67	9515.67	9515.67

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
N07 (1in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K07A (3in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K09A (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
N01 (6in)	90.32	102.10	148	600	GR 1.1	33.873	90.320	56.447	90.32
N09 (1in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K07B (3in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K08A (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K08B (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K09B (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
N10A (8in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
N05 (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
N04 (1in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
N10B (8in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K2B (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K2A (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K3B (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K3A (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K4B (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K4A (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K10A (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K05 (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K10B (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K1 (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
N06 (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K6A (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
K6B (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
N03 (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
N10C (8in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
N02 (6in)	90.32	102.10	148	600	GR 1.1	37.955	90.320	52.365	90.32
N08 (2in)	90.32	102.10	148	600	GR 1.1	...	...	...	...
Min Rating	90.320	102.100 bars [for Core Elements]					90.320	52.365	90.320

Selected Method for Derating ANSI B16.5 Flange MAWP: ASME UG-44(b)

The UG-44(b) Method is based on the paper PVP 2013-97814. PV Elite uses the maximum loads from each load category to determine ME and FE. In many cases, the computed maximum allowable pressure will be greater than the flange rating. In these cases, the minimum of the rating from the table and the UG-44(b) method will be used. SA-193 B8 Cl. 2 bolts or ones with higher allowable stresses at the specified bolt size shall be used.

The axial force FE must put the nozzle in tension (-P for 107/297; +Fr for PD 5500 AnnexG) to be considered.

Nozzle Description	Gasket Dimension	Fm Value	Resolved Moment	Axial Force	Design Pressure	Maximum Pressure	Pass Fail

	G mm.		ME N-m	FE kN	PD bars	Pmax bars	
N01 (6in)	192.151	0.50	4720	0	62.000	90.320	Pass
N02 (6in)	192.151	0.50	5289	0	62.000	90.320	Pass

Evaluating Flange on Nozzle [N01 (6in)]:

```
= 16*ME + 4*FE*G < pi*G^3[((PR - PD) + FM * PR)]
= 16(4720)+4*abs(0)192.151 < pi*192.151^3[(90.3-62.0)+.500*90.320]
= 75526.0 < 163836.8   Check Passes
```

Maximum Pressure for Flange on Nozzle N01 (6in) [Pmax]:

```
= min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
= min( 90.320, 0.500 * 90.320 + 90.320 - 75526.0/(pi * 192.151^3)
= min( 90.320, 101.607 )
= 90.320 bars
```

Evaluating Flange on Nozzle [N02 (6in)]:

```
= 16*ME + 4*FE*G < pi*G^3[((PR - PD) + FM * PR)]
= 16(5289)+4*abs(0)192.151 < pi*192.151^3[(90.3-62.0)+.500*90.320]
= 84626.5 < 163836.8   Check Passes
```

Maximum Pressure for Flange on Nozzle N02 (6in) [Pmax]:

```
= min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
= min( 90.320, 0.500 * 90.320 + 90.320 - 84626.5/(pi * 192.151^3)
= min( 90.320, 97.525 )
= 90.320 bars
```

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

The Natural Frequencies for the vessel have been computed iteratively by solving a system of matrices. These matrices describe the mass and the stiffness of the vessel. This is the generalized eigenvalue/ eigenvector problem and is referenced in some mathematical texts.

The Natural Frequency for the Vessel (Empty.) is 2.38486 Hz.

The Natural Frequency for the Vessel (Ope...) is 2.33622 Hz.

The Natural Frequency for the Vessel (Filled) is 2.52289 Hz.

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*0.21*0.94)/(1+1.7*3.4*0.21)))
  = min(0.85, 0.89 )
  = 0.850
```

```
Natural Frequency of Vessel (Operating)               2.336 Hz
Natural Frequency of Vessel (Empty)                   2.385 Hz
Natural Frequency of Vessel (Test)                    2.523 Hz

Force Coefficient                                [Cf] 0.644
Structure Height to Diameter ratio                    14.917
Height to top of Structure                            12371.574 mm.
```

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
  = 750 + 100 = 850 mm.
  = 2.79 ft. Imperial Units
```

Velocity Pressure coefficient evaluated at height z [Kz]:

```
  Because z (2.79 ft.) < 15 ft.
  = 2.01 * ( 15 / Zg ) 2 / Alpha
  = 2.01 * ( 15/900 )2/9.5
  = 0.85
```

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 )²
  = 1
```

Velocity Pressure evaluated at height z, Imperial Units [qz]:
```
  = max( 16, 0.00256 * Kz * Kzt * Kd * V(mph)² )
  = max( 16, 0.00256 * 0.85 * 1 * 0.95 * 74.6² )
  = 16 psf [78.1 ] Kgs/m²
```

Force on the first element [F]:
```
  = qz * G * Cf * WindArea
  = 16 * 0.85 * 0.64 * 16.2
  = 142 lbs. [0.63 ] kN
```

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m²
Skirt	850.0	0.000	0.000	0.000	0.849	1.000	78.120
Bottom Head	1625.0	0.000	0.000	0.000	0.849	1.000	78.120
Node 30 to 40	2650.0	0.000	0.000	0.000	0.849	1.000	78.120
Node 40 to 50	3735.0	0.000	0.000	0.000	0.849	1.000	78.120
Node 50 to 60	3914.5	0.000	0.000	0.000	0.849	1.000	78.120
Node 60 to 70	4999.5	0.000	0.000	0.000	0.865	1.000	78.120
Node 70 to 80	6084.5	0.000	0.000	0.000	0.902	1.000	78.120
Node 80 to 90	6266.5	0.000	0.000	0.000	0.907	1.000	78.120
Node 90 to 100	7104.0	0.000	0.000	0.000	0.931	1.000	78.120
Node 100 to 110	8604.0	0.000	0.000	0.000	0.970	1.000	78.120
Node 110 to 120	10154.0	0.000	0.000	0.000	1.004	1.000	78.120
Node 120 to 130	11041.5	0.000	0.000	0.000	1.022	1.000	78.120
Node 130 to 140	11226.1	0.000	0.000	0.000	1.026	1.000	78.120
Node 140 to 150	11745.1	0.000	0.000	0.000	1.035	1.000	78.120
Top Head	12304.0	0.000	0.000	0.000	1.046	1.000	78.120

Note:
The height/(avg. diameter) ratio [14.5], was less than or equal to 15,
therefore no wind vibration calculations have been performed.

Platform Load Calculations

ID	Wind Area cm²	Elevation mm.	Pressure Kgs/m²	Force kN	Cf
PLAT:[1 OF 1]	27720.00	10154.05	78.12	2.12	1.20

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm²	Elevation mm.	Pressure Kgs/m²	Force kN
VORTEX BREAKE	0.00	1437.50	78.12	0.00
DEMISTER PAD	0.00	3450.00	78.12	0.00
N01 INLET	0.00	3000.00	78.12	0.00
CHIMNEY	0.00	4192.53	78.12	0.00
SUPPORT GRID	0.00	6584.05	78.12	0.00
ATTACHMENTS	0.00	6354.05	78.12	0.00
BED LIMMITER	0.00	10734.05	78.12	0.00
DEMISTER PAD	0.00	11713.57	78.12	0.00
PIPING	0.00	12176.57	78.12	0.00

The Natural Frequency for the Vessel (Ope...) is 2.33622 Hz.

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm²	Wind Pressure Kgs/m²	Element Wind Load kN
10	20	850	1003.2	15048	78.12	0.3786
20	30	1625	1015.2	507.6	78.12	0.012771
30	40	2650	1015.2	20304	78.12	0.51084
40	50	3735	967.2	1644.24	78.12	0.041368
50	60	3914.53	967.2	1644.24	78.12	0.041368
60	70	4999.52	1015.2	20304	78.12	0.51084
70	80	6084.52	967.2	1644.24	78.12	0.041368
80	90	6266.55	960	1680	78.12	0.042268
90	100	7104.05	1008	15120	78.12	0.38041
100	110	8604.05	1008	15120	78.12	0.38041
110	120	10154	1008	16128	78.12	1.67986
120	130	11041.5	960	1680	78.12	0.042268
130	140	11226.1	960	1680	78.12	0.042268
140	150	11745.1	1006.19	8683.44	78.12	0.21847
150	160	12304	1008	2443.62	78.12	0.06148

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                                 2.000
Site Class                                                      C
Component Elevation Ratio            z/h                    0.000
Amplification Factor                  Ap                    0.000
Force Factor                                                0.000
Consider Vertical Acceleration                                 No
Minimum Acceleration Multiplier                             0.000
User Value of Sds (used if > 0 )                            1.020
User Value of Sd1 (used if > 0 )                            0.385
```

Seismic Analysis Results:

```
Sms = Fa * Ss = 1.11 * 1.38 = 1.53
Sm1 = Fv * S1 = 1.58 * 0.37 = 0.58
Sds = 2/3 * Sms = 2/3 * 1.53 = 1.02

Sds = Max( 0.8*Sds, SdsUser )
    = Max( 0.82, 1.02 )
    = 1.020

Sd1 = 2/3 * Sm1 = 2/3 * 0.58 = 0.39

Sd1 = Max( 0.8*Sd1, Sd1User )
    = Max( 0.31, 0.38 )
    = 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 * ( 40.4^0.75)
= 0.320 seconds
```

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

```
= ( 1/Natural Frequency ) = ( 1/2.34 )
= 0.428
```

Check the Value of T which is the smaller of Cu*Ta and T:

```
= Minimum Value of (1.4 * 0.32, 0.43 ) per 12.8.2
= 0.428
```

Compute the Seismic Response Coefficient per equation 12.8-2 [Cs]:
```
  = Sds / ( R / I )
  = 1.02/( 2/1.25 )
  = 0.637
```

Check the Maximum value of Cs per equation 12.8-3 [Cs]:
```
  = Sd1 / ( T * ( R / Ie ) )
  = 0.38/( 0.43 * ( 2/1.25 ) )
  = 0.562
```

Check the Minimum value of Cs per equation 15.4-1 [Cs]:
```
  = max( ( 0.044 * SDS * Ie ), 0.030 )
  = max( ( 0.044 * 1.02 * 1.25 ), 0.030 )
  = 0.056
```

Total Base Shear [V]:
```
  = Cs * W (Equation 12.8-1):
  = 0.56 * 154
  = 86.432 kN

 Final Base Shear,      V = 60.50 kN
```

Distribute the Base shear force to each element according to the equations
Fx = Cvx * V (eqn. 12.8-11) and the vertical distribution factor
Cvx = $Wx*hx^k$/(Sum of $Wi*hi^k$) and k is an exponent which is related
to the period of Vibration.

In this case, the value of k was 1

The Natural Frequency for the Vessel (Ope...) is 2.33622 Hz.

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN	Element Emp Load kN	Element Vertical Load kN
10	20	750	17.5603	0.7675	0.76956	...
20	30	1525	3.3778	0.30019	0.24106	...
30	40	2550	16.04	2.38359	2.02464	...
40	50	3635	3.64443	0.77201	0.77407	...
50	60	3814.53	3.64443	0.81013	0.8123	...
60	70	4899.53	17.4134	4.97193	3.85132	...
70	80	5984.53	3.64443	1.271	1.27441	...
80	90	6166.55	3.86577	1.3892	1.39292	...
90	100	7004.05	18.1909	7.42491	6.85661	...
100	110	8504.05	9.32213	4.61985	3.78874	...
110	120	10054	32.0166	18.7587	17.8915	...
120	130	10941.5	3.86577	2.46492	2.47152	...
130	140	11126.1	3.86577	2.50649	2.5132	...
140	150	11645.1	5.22259	3.54418	4.22091	...
150	160	12101.6	12.0785	8.51807	8.54087	...

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.

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The following table is for the Operating Case.

Wind/Earthquake Shear, Bending:

From	To	Distance to Support mm.	Cumulative Wind Shear kN	Earthquake Shear kN	Wind Bending N-m	Earthquake Bending N-m
10	20	750	4.38458	60.5027	31954.2	533734
20	30	1525	4.00598	59.7352	25658.8	443519
30	40	2550	3.99321	59.435	25458.7	440539
40	50	3635	3.48238	57.0514	17980.1	324005
50	60	3814.53	3.44101	56.2794	17358.6	313832
60	70	4899.53	3.39964	55.4693	16776.9	304329
70	80	5984.53	2.8888	50.4974	10485.9	198320
80	90	6166.55	2.84743	49.2263	9970.98	189371
90	100	7004.05	2.80517	47.8371	9476.18	180874
100	110	8504.05	2.42476	40.4122	5552.14	114660
110	120	10054	2.04434	35.7924	2198.96	57483.7
120	130	10941.5	0.36449	17.0336	271.113	15205.8
130	140	11126.1	0.32222	14.5687	207.932	12300.6
140	150	11645.1	0.27995	12.0622	155.221	9969.46
150	160	12101.6	0.06148	8.51807	7.83447	1085.47

Note:
The Wind Shears/Moments and the Earthquake Shears/Moments calculated and printed in the Wind/Earthquake Shear and Bending report have been factored by the input Scalar/Load reductions factors of;
Wind: 0.600; Earthquake: 0.700.

Wind Deflection Calculations:

The following table is for the Operating Case.

Wind Deflection:

From	To	Cumulative Wind Shear kN	Centroid Deflection mm.	Elem. End Deflection mm.	Elem. Ang. Rotation
10	20	4.38458	0.012586	0.048614	0.62537E-04
20	30	4.00598	0.050191	0.051795	0.64713E-04
30	40	3.99321	0.13707	0.25915	0.00013839
40	50	3.48238	0.27093	0.28273	0.00013904
50	60	3.44101	0.29456	0.30642	0.00013966
60	70	3.39964	0.45942	0.63545	0.0001858
70	80	2.8888	0.65125	0.66706	0.00018617
80	90	2.84743	0.68336	0.69968	0.00018653
90	100	2.80517	0.84459	0.998	0.00020925
100	110	2.42476	1.15777	1.32189	0.0002209
110	120	2.04434	1.49972	1.67879	0.00022418
120	130	0.36449	1.69841	1.71803	0.00022419
130	140	0.32222	1.73764	1.75726	0.0002242
140	150	0.27995	1.85402	1.95081	0.00022431
150	160	0.06148	1.95642	1.96203	0.00022431

Critical Wind Velocity for Tower Vibration:

From	To	1st Crit. Wind Speed Km/hr	2nd Crit. Wind Speed Km/hr
10	20	42.0728	262.955
20	30	42.5761	266.1
30	40	42.5761	266.1
40	50	40.563	253.519
50	60	40.563	253.519
60	70	42.5761	266.1
70	80	40.563	253.519
80	90	40.2611	251.632
90	100	42.2741	264.213
100	110	42.2741	264.213
110	120	42.2741	264.213
120	130	40.2611	251.632
130	140	40.2611	251.632
140	150	42.1983	263.739
150	160	42.2741	264.213

```
Allowable deflection at the Tower Top (Ope)(  6.000"/100ft. Criteria)
Allowable deflection : 60.633    Actual deflection : 1.962 mm.
```

Longitudinal Stress Constants:

From	To	Metal Area New cm²	Metal Area Corroded cm²	Section Modulus New mm.³	Section Modulus Corroded mm.³
10	20	558.418	558.418	9600579	9600579
20	30	456.159	456.159	8063436	8063436
30	40	456.159	456.159	8063436	8063436
40	50	456.159	456.159	8063436	8063436
50	60	456.159	456.159	8063436	8063436
60	70	456.159	456.159	8063436	8063436
70	80	456.159	456.159	8063436	8063436
80	90	452.389	386.133	7929036	6822780
90	100	452.389	386.133	7929036	6822780
100	110	452.389	386.133	7929036	6822780
110	120	452.389	386.133	7929036	6822780
120	130	452.389	386.133	7929036	6822780
130	140	452.389	386.133	7929036	6822780
140	150	452.389	386.133	7929036	6822780
150	160	452.389	386.133	7929036	6822780

Longitudinal Allowable Stresses:

From	To	Tensile N./mm²	Hydrotest Tensile N./mm²	Compressive N./mm²	Hydrotest Compressive N./mm²
10	20	75.845	129.695	-122.731	-147.277
20	30	137.9	235.809	-122.287	-146.745
30	40	137.9	235.8	-122.287	-146.745
40	50	137.9	223.4	-122.287	-146.745
50	60	137.9	223.4	-122.287	-146.745
60	70	137.9	235.809	-122.287	-146.745
70	80	137.9	223.4	-122.287	-146.745
80	90	137.9	223.4	-120.888	-145.066
90	100	137.9	235.809	-120.888	-145.066
100	110	137.9	235.809	-120.888	-145.066
110	120	137.9	235.809	-120.888	-145.066
120	130	137.9	223.4	-120.888	-145.066
130	140	137.9	223.4	-120.888	-145.066
140	150	137.9	235.809	-120.888	-145.066
150	160	137.9	235.809	-120.888	-145.066

Longitudinal Stress Report

Note: Longitudinal Operating and Empty Stresses are computed in the corroded condition. Stresses due to loads in the hydrostatic test cases have also been computed in the corroded condition.

Longitudinal Pressure Stresses due to:

From	To	Longitudinal Stress Internal Pressure N./mm²	Longitudinal Stress External Pressure N./mm²	Longitudinal Stress Hydrotest Pressure N./mm²
10	20	...	...	...
20	30	53.4781	-0.99082	69.5215
30	40	53.4781	-0.99082	69.5215
40	50	...	...	...
50	60	...	...	...
60	70	53.4781	-0.99082	69.5215
70	80	...	...	...
80	90	...	...	...
90	100	63.1343	-1.15176	82.0745
100	110	63.1343	-1.15176	82.0745
110	120	63.1343	-1.15176	82.0745
120	130	...	...	...
130	140	...	...	...
140	150	63.1343	-1.15176	82.0745
150	160	63.1343	-1.15176	82.0745

Longitudinal Stresses due to Weight Loads for these Conditions:

From	To	Wght. Str. Empty N./mm²	Wght. Str. Operating N./mm²	Wght. Str. Hydrotest N./mm²	Wght. Str. Emp. Mom. N./mm²	Wght. Str. Opr. Mom. N./mm²
10	20	-2.5426	-2.7536	-2.7005	1.33498	1.33498
20	30	-2.72759	-2.83055	-2.72759	1.58947	1.58947
30	40	-2.66828	-2.77124	-2.66828	1.58575	1.58575
40	50	-2.37037	-2.47334	-2.37037	1.42567	1.42567
50	60	-2.29047	-2.39344	-2.29047	1.42567	1.42567
60	70	-2.21057	-2.31354	-2.21057	1.42567	1.42567
70	80	-1.91564	-2.0186	-1.91564	1.30031	1.30031
80	90	-2.16865	-2.29029	-2.16865	1.53676	1.53676
90	100	-2.06853	-2.19017	-2.06853	1.53676	1.53676
100	110	-1.63461	-1.71902	-1.63461	1.52491	1.52491
110	120	-1.43713	-1.47758	-1.43713	1.52491	1.52491
120	130	-0.64835	-0.64835	-0.64835	1.51899	1.51899
130	140	-0.54822	-0.54822	-0.54822	1.51899	1.51899
140	150	-0.4481	-0.4481	-0.4481	1.51899	1.51899
150	160	-0.31283	-0.31283	-0.31283	1.39424	1.39424

Longitudinal Stresses due to Weight Loads and Bending for these Conditions:

From	To	Wght. Str. Hyd. Mom. N./mm²	Bend. Str. Oper. Wind N./mm²	Bend. Str. Oper. Equ. N./mm²	Bend. Str. Hyd. Wind N./mm²	Bend. Str. Hyd. Equ. N./mm²
10	20	1.33498	3.3273	55.5762	1.09801	...
20	30	1.58947	3.18109	54.9861	1.04976	...
30	40	1.58575	3.15629	54.6166	1.04158	...
40	50	1.42567	2.22911	40.1691	0.73561	...
50	60	1.42567	2.15206	38.9079	0.71018	...
60	70	1.42567	2.07995	37.7298	0.68638	...
70	80	1.30031	1.30001	24.5871	0.429	...
80	90	1.53676	1.46096	27.7468	0.48212	...
90	100	1.53676	1.38846	26.5019	0.45819	...
100	110	1.52491	0.8135	16.8001	0.26846	...
110	120	1.52491	0.32219	8.42256	0.10632	...
120	130	1.51899	0.039724	2.22796	0.013109	...
130	140	1.51899	0.030466	1.8023	0.010054	...
140	150	1.51899	0.022743	1.46073	0.0075052	...
150	160	1.39424	0.0011479	0.15904	0.00037881	...

Longitudinal Stresses due to these Conditions:

From	To	Vortex Shedding Operating Case N./mm²	Vortex Shedding Empty Case N./mm²	Vortex Shedding Test Case N./mm²	Earthquake Empty Case N./mm²
10	20	...	...	...	53.7118
20	30	...	...	...	53.3394
30	40	...	...	...	52.9889
40	50	...	...	...	39.2465
50	60	...	...	...	38.0446
60	70	...	...	...	36.9227
70	80	...	...	...	24.3026
80	90	...	...	...	27.4513
90	100	...	...	...	26.2462
100	110	...	...	...	16.8236
110	120	...	...	...	8.57138
120	130	...	...	...	2.31129
130	140	...	...	...	1.86644
140	150	...	...	...	1.50685
150	160	...	...	...	0.15947

Longitudinal Stresses due to Applied Axial Forces:

From	To	Longitudinal Stress Y Forces Wind N./mm²	Longitudinal Stress Y Forces Seismic N./mm²
10	20	...	...

```
  20|  30|                  ... |                  ... |
  30|  40|                  ... |                  ... |
  40|  50|                  ... |                  ... |
  50|  60|                  ... |                  ... |
  60|  70|                  ... |                  ... |
  70|  80|                  ... |                  ... |
  80|  90|                  ... |                  ... |
  90| 100|                  ... |                  ... |
 100| 110|                  ... |                  ... |
 110| 120|                  ... |                  ... |
 120| 130|                  ... |                  ... |
 130| 140|                  ... |                  ... |
 140| 150|                  ... |                  ... |
 150| 160|                  ... |                  ... |
-------------------------------------------------------
```

Longitudinal Stresses due to User Forces and Moments:

```
    |    |Wind For/Mom | Earthquake For/Mom |  Wind For/Mom | Earthquake For/Mom |
From| To |    Corroded |           Corroded |  No Corrosion |       No Corrosion |
    |    |     N./mm² |            N./mm² |       N./mm² |            N./mm² |
----------------------------------------------------------------------------------
  10|  20|         ... |                ... |           ... |                ... |
  20|  30|         ... |                ... |           ... |                ... |
  30|  40|         ... |                ... |           ... |                ... |
  40|  50|         ... |                ... |           ... |                ... |
  50|  60|         ... |                ... |           ... |                ... |
  60|  70|         ... |                ... |           ... |                ... |
  70|  80|         ... |                ... |           ... |                ... |
  80|  90|         ... |                ... |           ... |                ... |
  90| 100|         ... |                ... |           ... |                ... |
 100| 110|         ... |                ... |           ... |                ... |
 110| 120|         ... |                ... |           ... |                ... |
 120| 130|         ... |                ... |           ... |                ... |
 130| 140|         ... |                ... |           ... |                ... |
 140| 150|         ... |                ... |           ... |                ... |
 150| 160|         ... |                ... |           ... |                ... |
----------------------------------------------------------------------------------
```

Stress Combination Load Cases for Vertical Vessels:

Load Case Definition Key

```
IP = Longitudinal Stress due to Internal  Pressure
EP = Longitudinal Stress due to External  Pressure
HP = Longitudinal Stress due to Hydrotest Pressure
NP = No Pressure
EW = Longitudinal Stress due to Weight (No Liquid)
OW = Longitudinal Stress due to Weight (Operating)
HW = Longitudinal Stress due to Weight (Hydrotest)
WI = Bending Stress due to Wind Moment (Operating)
EQ = Bending Stress due to Earthquake Moment (Operating)
EE = Bending Stress due to Earthquake Moment (Empty)
HI = Bending Stress due to Wind Moment (Hydrotest)
HE = Bending Stress due to Earthquake Moment (Hydrotest)
WE = Bending Stress due to Wind Moment (Empty) (no CA)
WF = Bending Stress due to Wind Moment (Filled) (no CA)
CW = Longitudinal Stress due to Weight (Empty) (no CA)
VO = Bending Stress due to Vortex Shedding Loads ( Ope )
VE = Bending Stress due to Vortex Shedding Loads ( Emp )
VF = Bending Stress due to Vortex Shedding Loads ( Test No CA. )
FW = Axial Stress due to Vertical Forces for the Wind Case
FS = Axial Stress due to Vertical Forces for the Seismic Case
BW = Bending Stress due to Lat. Forces for the Wind Case, Corroded
BS = Bending Stress due to Lat. Forces for the Seismic Case, Corroded
BN = Bending Stress due to Lat. Forces for the Wind Case, UnCorroded
BU = Bending Stress due to Lat. Forces for the Seismic Case, UnCorroded
```

General Notes:

Case types HI and HE are in the Corroded condition.

Case types WE, WF, and CW are in the Un-Corroded condition.

A blank stress and stress ratio indicates that the corresponding stress comprising those components that did not contribute to that type of stress.

An asterisk (*) in the final column denotes overstress.

Analysis of Load Case 1 : NP+EW+WI+FW+BW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	2.12	75.85	-7.20	122.73	0.0279	0.0587
20	2.04	137.90	-7.50	122.29	0.0148	0.0613
30	2.07	137.90	-7.41	122.29	0.0150	0.0606
60	1.30	137.90	-5.72	122.29	0.0094	0.0467
90	0.86	137.90	-4.99	120.89	0.0062	0.0413
100	0.70	137.90	-3.97	120.89	0.0051	0.0329
110	0.41	137.90	-3.28	120.89	0.0030	0.0272

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
140	1.09	137.90	-1.99	120.89	0.0079	0.0165
150	1.08	137.90	-1.71	120.89	0.0079	0.0141

Analysis of Load Case 2 : NP+EW+EE+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	52.50	75.85	-57.59	122.73	0.6923	0.4692
20	52.20	137.90	-57.66	122.29	0.3785	0.4715
30	51.91	137.90	-57.24	122.29	0.3764	0.4681
60	36.14	137.90	-40.56	122.29	0.2621	0.3317
90	25.71	137.90	-29.85	120.89	0.1865	0.2469
100	16.71	137.90	-19.98	120.89	0.1212	0.1653
110	8.66	137.90	-11.53	120.89	0.0628	0.0954
140	2.58	137.90	-3.47	120.89	0.0187	0.0287
150	1.24	137.90	-1.87	120.89	0.0090	0.0154

Analysis of Load Case 3 : NP+OW+WI+FW+BW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	1.91	75.85	-7.42	122.73	0.0252	0.0604
20	1.94	137.90	-7.60	122.29	0.0141	0.0622
30	1.97	137.90	-7.51	122.29	0.0143	0.0614
60	1.19	137.90	-5.82	122.29	0.0086	0.0476
90	0.74	137.90	-5.12	120.89	0.0053	0.0423
100	0.62	137.90	-4.06	120.89	0.0045	0.0336
110	0.37	137.90	-3.32	120.89	0.0027	0.0275
140	1.09	137.90	-1.99	120.89	0.0079	0.0165
150	1.08	137.90	-1.71	120.89	0.0079	0.0141

Analysis of Load Case 4 : NP+OW+EQ+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	54.16	75.85	-59.66	122.73	0.7141	0.4861
20	53.75	137.90	-59.41	122.29	0.3897	0.4858
30	53.43	137.90	-58.97	122.29	0.3875	0.4823
60	36.84	137.90	-41.47	122.29	0.2672	0.3391
90	25.85	137.90	-30.23	120.89	0.1874	0.2501
100	16.61	137.90	-20.04	120.89	0.1204	0.1658
110	8.47	137.90	-11.43	120.89	0.0614	0.0945
140	2.53	137.90	-3.43	120.89	0.0184	0.0284
150	1.24	137.90	-1.87	120.89	0.0090	0.0154

Analysis of Load Case 5 : NP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		129.69	-5.13	147.28		0.0349
20		235.81	-5.37	146.74		0.0366
30		235.80	-5.30	146.74		0.0361
60		235.81	-4.32	146.74		0.0295

90		235.81	-4.06	145.07		0.0280
100	0.16	235.81	-3.43	145.07	0.0007	0.0236
110	0.19	235.81	-3.07	145.07	0.0008	0.0212
140	1.08	235.81	-1.97	145.07	0.0046	0.0136
150	1.08	235.81	-1.71	145.07	0.0046	0.0118

Analysis of Load Case 6 : NP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		129.69	-4.04	147.28		0.0274
20		235.81	-4.32	146.74		0.0294
30		235.80	-4.25	146.74		0.0290
60		235.81	-3.64	146.74		0.0248
90		235.81	-3.61	145.07		0.0249
100		235.81	-3.16	145.07		0.0218
110	0.09	235.81	-2.96	145.07	0.0004	0.0204
140	1.07	235.81	-1.97	145.07	0.0045	0.0136
150	1.08	235.81	-1.71	145.07	0.0046	0.0118

Analysis of Load Case 7 : IP+OW+WI+FW+BW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	1.91	75.85	-7.42	122.73	0.0252	0.0604
20	55.42	137.90		122.29	0.4019	
30	55.45	137.90		122.29	0.4021	
60	54.67	137.90		122.29	0.3964	
90	63.87	137.90		120.89	0.4632	
100	63.75	137.90		120.89	0.4623	
110	63.50	137.90		120.89	0.4605	
140	64.23	137.90		120.89	0.4658	
150	64.22	137.90		120.89	0.4657	

Analysis of Load Case 8 : IP+OW+EQ+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	54.16	75.85	-59.66	122.73	0.7141	0.4861
20	107.22	137.90	-5.93	122.29	0.7775	0.0485
30	106.91	137.90	-5.50	122.29	0.7753	0.0449
60	90.32	137.90		122.29	0.6550	
90	88.98	137.90		120.89	0.6453	
100	79.74	137.90		120.89	0.5782	
110	71.60	137.90		120.89	0.5192	
140	65.67	137.90		120.89	0.4762	
150	64.37	137.90		120.89	0.4668	

Analysis of Load Case 9 : EP+OW+WI+FW+BW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	1.91	75.85	-7.42	122.73	0.0252	0.0604

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
20	0.95	137.90	-8.59	122.29	0.0069	0.0703
30	0.98	137.90	-8.50	122.29	0.0071	0.0695
60	0.20	137.90	-6.81	122.29	0.0015	0.0557
90		137.90	-6.27	120.89		0.0518
100		137.90	-5.21	120.89		0.0431
110		137.90	-4.48	120.89		0.0370
140		137.90	-3.14	120.89		0.0260
150		137.90	-2.86	120.89		0.0237

Analysis of Load Case 10 : EP+OW+EQ+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	54.16	75.85	-59.66	122.73	0.7141	0.4861
20	52.75	137.90	-60.40	122.29	0.3826	0.4939
30	52.44	137.90	-59.96	122.29	0.3803	0.4904
60	35.85	137.90	-42.46	122.29	0.2600	0.3472
90	24.70	137.90	-31.38	120.89	0.1791	0.2596
100	15.45	137.90	-21.20	120.89	0.1121	0.1753
110	7.32	137.90	-12.58	120.89	0.0531	0.1040
140	1.38	137.90	-4.58	120.89	0.0100	0.0379
150	0.09	137.90	-3.02	120.89	0.0006	0.0250

Analysis of Load Case 11 : HP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		129.69	-5.13	147.28		0.0349
20	69.43	235.81		146.74	0.2944	
30	69.48	235.80		146.74	0.2947	
60	69.42	235.81		146.74	0.2944	
90	82.00	235.81		145.07	0.3477	
100	82.23	235.81		145.07	0.3487	
110	82.27	235.81		145.07	0.3489	
140	83.15	235.81		145.07	0.3526	
150	83.16	235.81		145.07	0.3526	

Analysis of Load Case 12 : HP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		129.69	-4.04	147.28		0.0274
20	68.38	235.81		146.74	0.2900	
30	68.44	235.80		146.74	0.2902	
60	68.74	235.81		146.74	0.2915	
90	81.54	235.81		145.07	0.3458	
100	81.96	235.81		145.07	0.3476	
110	82.16	235.81		145.07	0.3484	
140	83.15	235.81		145.07	0.3526	
150	83.16	235.81		145.07	0.3526	

Analysis of Load Case 13 : IP+WE+EW

From	Tensile	All. Tens.	Comp.	All. Comp.	Tens.	Comp.

Node	Stress	Stress	Stress	Stress	Ratio	Ratio
10		75.85	-3.88	122.73		0.0316
20	52.34	137.90		122.29	0.3796	
30	52.40	137.90		122.29	0.3800	
60	52.69	137.90		122.29	0.3821	
90	62.60	137.90		120.89	0.4540	
100	63.02	137.90		120.89	0.4570	
110	63.22	137.90		120.89	0.4585	
140	64.21	137.90		120.89	0.4656	
150	64.22	137.90		120.89	0.4657	

Analysis of Load Case 14 : IP+WF+CW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		75.85	-2.75	122.73		0.0224
20	50.65	137.90		122.29	0.3673	
30	50.71	137.90		122.29	0.3677	
60	51.16	137.90		122.29	0.3710	
90	61.26	137.90		120.89	0.4443	
100	61.67	137.90		120.89	0.4472	
110	61.87	137.90		120.89	0.4487	
140	62.75	137.90		120.89	0.4551	
150	62.87	137.90		120.89	0.4559	

Analysis of Load Case 15 : IP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		75.85	-4.09	122.73		0.0333
20	52.24	137.90		122.29	0.3788	
30	52.29	137.90		122.29	0.3792	
60	52.59	137.90		122.29	0.3814	
90	62.48	137.90		120.89	0.4531	
100	62.94	137.90		120.89	0.4564	
110	63.18	137.90		120.89	0.4582	
140	64.21	137.90		120.89	0.4656	
150	64.22	137.90		120.89	0.4657	

Analysis of Load Case 16 : IP+VE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		75.85	-3.88	122.73		0.0316
20	52.34	137.90		122.29	0.3796	
30	52.40	137.90		122.29	0.3800	
60	52.69	137.90		122.29	0.3821	
90	62.60	137.90		120.89	0.4540	
100	63.02	137.90		120.89	0.4570	
110	63.22	137.90		120.89	0.4585	
140	64.21	137.90		120.89	0.4656	
150	64.22	137.90		120.89	0.4657	

Analysis of Load Case 17 : NP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		75.85	-4.09	122.73		0.0333
20		137.90	-4.42	122.29		0.0361
30		137.90	-4.36	122.29		0.0356
60		137.90	-3.74	122.29		0.0306
90		137.90	-3.73	120.89		0.0308
100		137.90	-3.24	120.89		0.0268
110	0.05	137.90	-3.00	120.89	0.0003	0.0248
140	1.07	137.90	-1.97	120.89	0.0078	0.0163
150	1.08	137.90	-1.71	120.89	0.0078	0.0141

Analysis of Load Case 18 : FS+BS+IP+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		75.85	-4.09	122.73		0.0333
20	52.24	137.90		122.29	0.3788	
30	52.29	137.90		122.29	0.3792	
60	52.59	137.90		122.29	0.3814	
90	62.48	137.90		120.89	0.4531	
100	62.94	137.90		120.89	0.4564	
110	63.18	137.90		120.89	0.4582	
140	64.21	137.90		120.89	0.4656	
150	64.22	137.90		120.89	0.4657	

Analysis of Load Case 19 : FS+BS+EP+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		75.85	-4.09	122.73		0.0333
20		137.90	-5.41	122.29		0.0442
30		137.90	-5.35	122.29		0.0437
60		137.90	-4.73	122.29		0.0387
90		137.90	-4.88	120.89		0.0404
100		137.90	-4.40	120.89		0.0364
110		137.90	-4.15	120.89		0.0344
140		137.90	-3.12	120.89		0.0258
150		137.90	-2.86	120.89		0.0236

Absolute Maximum of the all of the Stress Ratio's 0.7775

Governing Element: Bottom Head
Governing Load Case 8 : IP+OW+EQ+FS+BS

Element Description	Long Pressure Stress	Weight + Axial Load Stress	Eccentric Moment Stress	Wind or Earthquake Stress	Combined Stress	Which Side
Skirt	...	-2.8	1.3	55.6	54.2	+ Tens

```
           Skirt |        ... |       -2.8 |       -1.3 |      -55.6 |      -59.7 | -  Comp |
-----------------------------------------------------------------------------------------------
     Bottom Head |       53.5 |       -2.8 |        1.6 |       55.0 |      107.2 | +  Tens |
     Bottom Head |       53.5 |       -2.8 |       -1.6 |      -55.0 |       -5.9 | -  Comp |
-----------------------------------------------------------------------------------------------
     Element # 3 |       53.5 |       -2.8 |        1.6 |       54.6 |      106.9 | +  Tens |
     Element # 3 |       53.5 |       -2.8 |       -1.6 |      -54.6 |       -5.5 | -  Comp |
-----------------------------------------------------------------------------------------------
     Element # 6 |       53.5 |       -2.3 |        1.4 |       37.7 |       90.3 | +  Tens |
     Element # 6 |       53.5 |       -2.3 |       -1.4 |      -37.7 |        ... | -  Comp |
-----------------------------------------------------------------------------------------------
     Element # 9 |       63.1 |       -2.2 |        1.5 |       26.5 |       89.0 | +  Tens |
     Element # 9 |       63.1 |       -2.2 |       -1.5 |      -26.5 |        ... | -  Comp |
-----------------------------------------------------------------------------------------------
    Element # 10 |       63.1 |       -1.7 |        1.5 |       16.8 |       79.7 | +  Tens |
    Element # 10 |       63.1 |       -1.7 |       -1.5 |      -16.8 |        ... | -  Comp |
-----------------------------------------------------------------------------------------------
    Element # 11 |       63.1 |       -1.5 |        1.5 |        8.4 |       71.6 | +  Tens |
    Element # 11 |       63.1 |       -1.5 |       -1.5 |       -8.4 |        ... | -  Comp |
-----------------------------------------------------------------------------------------------
    Element # 14 |       63.1 |       -0.4 |        1.5 |        1.5 |       65.7 | +  Tens |
    Element # 14 |       63.1 |       -0.4 |       -1.5 |       -1.5 |        ... | -  Comp |
-----------------------------------------------------------------------------------------------
        Top Head |       63.1 |       -0.3 |        1.4 |        0.2 |       64.4 | +  Tens |
        Top Head |       63.1 |       -0.3 |       -1.4 |       -0.2 |        ... | -  Comp |
-----------------------------------------------------------------------------------------------
```

Skirt Support Analysis Per EN 13445-3: 2009(E) Issue 1 (2009-07):

Item: Skirt

Type B Skirt per EN-13445 Figure 16.12-2:

```
 Design Pressure                          P          62.000  bars
 Total vessel (empty) weight             Fg         142.952  kN
 Head Weight below section 2-2      DeltaFg           2.705  kN
 Weight of vessel contents (liquid)      Ff          10.801  kN
 Vessel Gross Weight            Fg + Ff = F4        153.753  kN

 Skirt Mean Diameter                     Dz         711.000  mm.
 Skirt Analysis Thickness (Corroded)     ez          25.000  mm.
 Skirt Height                             H        1500.000  mm.

 Force  at section 1-1                   F1         151.048  kN
 Moment at section 1-1                   M1      443519.250  N-m
 Applied Moment - Bottom of Skirt        Mb      533734.312  N-m
 Weight Above the Skirt                   W         153.753  kN

                      Layout   Cntr. Dist.  Obround
Access No    Diameter  Angle   From Bottom  Cntr-Cntr
                mm.     Deg        mm.         mm.
-------------------------------------------------------
   1       202.0000    0.0000   800.0000     0.0000
   2       202.0000   90.0000   800.0000     0.0000
   3       255.0000  180.0000   800.0000     0.0000
   4       400.0000  280.0000   800.0000   200.0000

Access Opening Frame Dimension
Access No      Width    Thick
                mm.      mm.
-------------------------------
   1       150.0000    8.2000
   2       150.0000    8.2000
   3       150.0000    9.3000
   4       150.0000   10.0000

Interference check:
Access        Access        Pitch        Ligament
                             mm.           mm.
-----------------------------------------------
   1           2         558.4182      353.5970
   2           3         558.4182      325.6026
   3           4         620.4647      277.6440
   1           4        1737.3009     1422.4745

INTERFERENCE CHECK:  No Interference Detected between Openings

 Minimum Pitch between openings    is:    558.4182 mm.
 Minimum Ligament between Openings is:    277.6440 mm.
```

Recommended minimum Ligament:

```
  = 2 * Sqrt( D * t )
  = 2 * Sqrt( 711 * 25 ) = 267 mm.
    Please evaluate the suitability of this result
```

Section properties at least metal area [A]:

```
 Number of Openings At Critical Height = 4

 Access No          Layout Angle 1     Layout Angle 2
                         Deg.               Deg.
 ---------------------------------------------------
    1               -16.5055             16.5055
    2                73.4945            106.5055
    3               158.9827            201.0173
    4               245.7650            314.2350

 The points for integrating Ixx, Iyy is as follows:
 FROM THETA1       TO THETA2
      Deg               Deg
 --------------------------
    16.505           73.495
   106.505          158.983
   201.017          245.765
   -45.765          -16.505

 Height of Weakest Section           H             800.067  mm.
 Rotation of Principle Axes          a              18.095  Deg.
 Centroid Position in X direction    g              -2.056  mm.
 Centroid Position in Y direction    h              42.785  mm.
 Principle Moment of Inertia       Ixx          217626.703  cm**4
 Principle Moment of Inertia       Iyy          270912.688  cm**4
 Distance to Extreme Fiber        ybar             409.308  mm.
 Distance to Extreme Fiber        xbar             379.334  mm.
 Minimum Section Modulus            W4         5316947.000  mm.^3
 Metal Area at the Cutting Plane    A4             391.697  cm²
```

Half Opening Width Subtended Angle at Weakest Section: [Delta]:

```
  = Asin(Largest(Opening Width) / Dz)
  = Asin(400/711 ) = 0.6 rad (34.2 deg)
```

Skirt Mean Radius at Section 4-4 [r]:

```
  = Dz/2 = 711/2 = 356 mm.
```

Opening Ratio At Weakest Section: EN 13445 Equation 16.12-76 [ratio]:

```
  = Delta * Sqrt(r/ez)
  = 0.6 * Sqrt(356/25 ) = 2.25
    WARNING: ratio Exceeds 2 -  See EN 13445 16.12.76(a).
```

This equation is a precaution against radial bucking at the opening.
The frame (if there is one), may prevent this. The code does not
say what size this frame should be. Your judgement is required.

Analysis of the Section at Weakest Section Modulus [Section 4-4]:

Skirt Corroded Thickness [ez]:
```
  = ex(new) - ci - cext = 25 - 0 - 0 = 25 mm.
```

Please note:
There is more than one opening in the skirt
EN-13445 and AD-2000 considers only one opening per Figure 16.12-4
this skirt has 4 openings. Please check results

Find the moment acting at the Critical Height [M4]:
```
  = (Mbottom - Mtop)*(H - CutHeight)/H + Mtop
  = (533734 - 443519 )*(18000 - 9601 )/18000 + 443519
  = 485616 N-m

 Compute the section modulus [Zxx and Zyy]
  Zxx = Ixx/ybar = 217627/409 = 5316947 mm.³
  Zyy = Iyy/xbar = 270913/379 = 7141802 mm.³
  Z = Min(Zxx, Zyy) = Min(5316947,7141802 ) = 5316947 mm.³
```

The balance of the calculations are per EN-13445, and
they may be treated as academic if the designated code
is not EN-13445

Radius of Gyration of Skirt at 4-4 [rg]:
```
   (rg is not included in the analysis of EN 13445)
  = sqrt( Min( Ixx, Iyy ) / Area(A4) )
  = sqrt( Min( 217627, 270913 )/392 ) )
  = 236 mm.
```

Skirt Slenderness Ratio [r/L]:
```
  = 236/1500 = 0.16
```

Location of the Skirt Centroid at critical height [e]:
```
  ex = -2.06 : ey = 42.8
   e = Sqrt(ex² + ey²) = Sqrt(-2.06²+42.8²)
     = 42.8 mm.
```

Moment Increment at Centroid [DeltaM4]:
```
  = ( Fg + Ff ) * e = F4 * e
  = ( 143 + 10.8 ) * 42.8 = 6589 N-m
```

Nomenclature per EN-13445 (not AD-2000)

For the skirt at the opening/weakest part: Equations 16.12-70 & 71:
Actual Stresses:
```
  Sm4p = ( M4 + DeltaM4 ) / W4 - F4 / A4
       = (485616 + 6589 )/7141802 - 154/392
       = 65 N./mm² - Equation 16.12-70

  Sm4q = -( M4 + DeltaM4 ) / W4 - F4 / A4
       = -(485616 + 6589 )/7141802 - 154/392
```

```
       = -72.8 N./mm² - Equation 16.12-71
```

Allowable stresses at the opening/weakest part: Equations 16.12-72 & 73:
Max stress for Sm4p and Sm4q: Equations 16.12 72 & 73:

```
  = fz = 138 N./mm²
```

Skirt stress at the openings / critical section:

```
 Sm4p                  64.97            137.90        Pass        70
 Sm4q                 -72.82            137.90        Pass        71
```

The stresses are satisfactory in the region with the opening(s).

Shop/Field Installation Options :

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

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

```
Center of Gravity of the Platforms                     10054.050 mm.
Center of Gravity of the Packing                        8559.051 mm.
Center of Gravity of the Liquid                         3256.327 mm.
Center of Gravity of the Insulation                     2439.554 mm.
Center of Gravity of the Lining                         3556.864 mm.
Center of Gravity of the Nozzles                        6241.768 mm.
Center of Gravity of the Added Weights (Operating)       8122.526 mm.
Center of Gravity of the Added Weights (Empty)           8257.316 mm.

Center of Gravity of Bare Shell New and Cold            5895.865 mm.
Center of Gravity of Bare Shell Corroded                5734.581 mm.

Vessel CG in the Operating Condition                    6627.851 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition      6890.205 mm.
Vessel CG in the Test Condition                         6867.859 mm.
```

Skirt Data :

Skirt Outside Diameter at Base	SOD	736.0000	mm.
Skirt Thickness	STHK	25.0000	mm.
Skirt Internal Corrosion Allowance	SCA	0.0000	mm.
Skirt External Corrosion Allowance		0.0000	mm.
Skirt Material		SA-516 70	

Basering Input: Type of Geometry: Continuous Top Ring W/Gussets

Thickness of Basering	TBA	80.0000	mm.
Design Temperature of the Basering		85.00	°C
Basering Matl		SA-283 C	
Basering Operating All. Stress	BASOPE	108.25	N./mm²
Basering Yield Stress		191.06	N./mm²
Inside Diameter of Basering	DI	620.0000	mm.
Outside Diameter of Basering	DOU	1060.0000	mm.
Nominal Diameter of Bolts	BND	48.0000	mm.
Bolt Corrosion Allowance	BCA	0.0000	mm.
Bolt Material		SA-193 B7	
Bolt Material Class/Thickness Range		<= 2 1/2	
Bolt Operating Allowable Stress	SA	135.00	N./mm²
Number of Bolts	RN	12	
Diameter of Bolt Circle	DC	960.0000	mm.
Bolt Allowable Shear Stress		81.000	N./mm²
Thickness of Gusset Plates	TGA	12.0000	mm.
Width of Gussets at Top Plate	TWDT	200.0000	mm.
Width of Gussets at Base Plate	BWDT	162.0000	mm.
Gusset Plate Elastic Modulus	E	199042000.0	KPa.
Gusset Plate Yield Stress	SY	191.1	N./mm²
Height of Gussets	HG	265.0000	mm.
Distance between Gussets	RG	100.0000	mm.
Dist. from Bolt Center to Gusset (Rg/2)	CG	50.0000	mm.
Number of Gussets per bolt	NG	2	
Thickness of Top Plate or Ring	TTA	35.0000	mm.
Radial Width of the Top Plate	TOPWTH	200.0000	mm.
Anchor Bolt Hole Dia. in Top Plate	BHOLE	60.0000	mm.
External Corrosion Allowance	CA	1.6000	mm.
Dead Weight of Vessel	DW	143.0	kN
Operating Weight of Vessel	ROW	153.8	kN
Test Weight of Vessel	TW	150.5	kN
Earthquake Moment on Basering	EQMOM	543250.0	N-m
Wind Moment on Basering	WIMOM	41469.9	N-m
Test Moment on Basering	TM	20060.6	N-m
Percent Bolt Preload	ppl	100.0	
Use AISC A5.2 Increase in Fc and Bolt Stress		No	
Use Allowable Weld Stress per AISC J2.5		No	

```
Factor for Increase of Allowables     Fact           1.0000
```

Results for Basering Analysis : Analyze Option

Basering Thickness Calculation method used : Simplified (Steel on Steel)

Calculation of Bolt Loads for Multiple Loading Conditions:

Operating Bolt Load, Earthquake Operating Case:

```
  = (( 4 * M/DC ) - W ) / RN      per Jawad & Farr, Eq. 12.3
  = (( 4 * 543250/960 ) - 154 )/12
  = 175.7 kN
```

Operating Bolt Load, Windload Empty Case:

```
  = (( 4 * M/DC ) - W ) / RN      per Jawad & Farr, Eq. 12.3
  = (( 4 * 41470/960 ) - 143 )/12
  = 2.5 kN
```

Operating Bolt Load, Windload Vortex Shedding Case:

```
  = (( 4 * M/DC ) - W ) / RN      per Jawad & Farr, Eq. 12.3
  = (( 4 * 0/960 ) - 154 )/12
  = -12.8 kN
```

Operating Bolt Load, Test Moment Case:

```
  = (( 4 * M/DC ) - W ) / RN      per Jawad & Farr, Eq. 12.3
  = (( 4 * 20061/960 ) - 151 )/12
  = -5.6 kN
```

Calculation of Maximum Load per Bolt [W/Bolt], Earthquake + Operating Condition:
W = ROW - Yforce (from gy Accleration or user force), M = EQMOM

```
  = (( 4 * M/DC ) - W ) / RN      per Jawad & Farr, Eq. 12.3
  = (( 4 * 543250/960 ) - 154 )/12
  = 175.7 kN
```

```
Required Area for Each Bolt, Based on Max Load       13.0188   cm²
Area Available in a Single Bolt (Corr)               13.4296   cm²
Area Available in all the Bolts (Corr)              161.1551   cm²
Bolt Stress Based on Simplified Analysis               130.9   N./mm²
Allowable Bolt Stress       135.0   [Fact]            135.00   N./mm²
```

Shear Stress in a Single Bolt [taub]:

```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 60.5/( 2 * 13.4 * 12 )
  = 1.9 N./mm².  Must be less than 81.0 N./mm².
```

```
Concrete Contact Area of Base Ring             CCA     5805.66   cm²
Concrete Contact Section Modulus of Base Ring      0.1032E+09   mm.³
```

Concrete Load (Simplified method), Earthquake in Operating Condition [Sc]:

```
  = ((ppl/100*(Abt*Sa)+W)/Cca) + M/CZ per Jawad & Farr Eq. 12.1
  = (1 (161 *135 +154 )/5806 ) + 543250/103242232
```

```
  = 9.27 N./mm²
```

Concrete Allowable Stress *8.27 N./mm²*

Determine Maximum Bending Width of Basering Section [Rw1,Rw2]:
```
  Rw1 = (Dou - SkirtOD)/2,  Rw2 = ( SkirtID - Di + 2*Sca )/2
  Rw1 = (1060 -736 )/2, Rw2 = (686 -620 + 2*0 )/2
  Rw1 = 162, Rw2 = 33 mm.
```

Calculation of required Basering Thickness, (Simplified) [Tb]:
Allowable Bending Stress 1.5 Basope = 162.377 N./mm²
```
  = Max(Rw1,Rw2) * ( 3 * Sc / S )½ + CA per Jawad & Farr Eq. 12.12
  = Max(162,33 ) * ( 3 * 9.27/162 )½ + 1.6
  = 68.6517 mm.
```

Basering Stress at given Thickness [Sb]
```
  = 3 * Sc * ( Max[Rw1, Rw2]/(Tb - Ca) )²
  = 3 * 9.27 * ( Max[162, 33 ]/(80 - 1.6 ) )²
  = 119, must be less than 162 N./mm²
```

Required Thickness of Top Plate in Tension:
(Calculated as a fixed beam per Megyesy)
```
    P  = Wmax                Bolt Load
    Rm = (Ft * 2 * Cg)/8,    Bending Moment
    Sb                       Allowable Bending Stress
    Wt = (Topwth  -  Bnd),   Width of Section

  T = ( 6 * Rm / ( Sb * Wt ))½ + CA
  T = ( 6 * 2198/( 162 * 152 ))½ + 1.6
  T = 24.7100 mm.
```

Required Thickness of Continuous Top Ring per Moss:
```
  a  = ( Dc-SkirtOD )/2    Skirt Distance to Bolt Circle
  P  = Wmax                Bolt Load
  l  = Avgwdt              Average Gusset Width
  g1 = Gamma 1             Constant Term f( b/l )
  g2 = Gamma 2             Constant Term f( b/l )
  g  = Flat distance / 2   Nut 1/2 Dimension (from Tema)
  Fb =                     Allowable Bending Stress

  Mo = P/(4pi)[1.3(ln((2lsin(pia/l)/(pig)))+1]-[(0.7-g2)P/(4pi)] Moment Term
  Tc = ( 6 * Abs(Mo) / Fb )½  + CA  Required Thickness
  Tc = ( 6 * 576/162 )½ + 1.6
  Tc = 30.5480 mm.
```

<u>Required Thickness of Gusset in Compression, per AISC E2-1:</u>
1. Allowed Compression at Given Thickness:
```
    Factor Kl/r Per E2-1                          76.4976
    Factor Cc Per E2-1                           143.4044
    Allowable Buckling Str. per E2-1               88.69   N./mm²
    Actual Buckling Str. at Given Thickness        40.46   N./mm²
```

```
 Required Gusset thickness, + CA                      9.1608  mm.
```

2. Allowed Compression at Calculated Thickness:

```
    Factor Kl/r Per E2-1                            121.4116
    Factor Cc Per E2-1                              143.4044
    Allowable Buckling Str. per E2-1                   64.24  N./mm²
    Act. Buckling Str. at Calculated Thickness         64.21  N./mm²
```

Summary of Basering Thickness Calculations:

```
 Required Basering Thickness (simplified)            68.6517  mm.
 Actual Basering Thickness as entered by user        80.0000  mm.

 Required Top Ring/Plate Thickness as a Fixed Beam   24.7100  mm.
 Required Thickness of Continuous Top Ring (Moss)    30.5480  mm.
 Actual Top Ring Thickness as entered by user        35.0000  mm.

 Required Gusset thickness, + CA                      9.1608  mm.
 Actual Gusset Thickness as entered by user          12.0000  mm.
```

Weld Size Calculations per Steel Plate Engineering Data - Vol. 2

Compute the Weld load at the Skirt/Base Junction [W]

```
  = SkirtStress * ( SkirtThickness - CA )
  = 59.7 * ( 25 - 0 )
  = 1.49 kN/mm.
```

Results for Computed Minimum Basering Weld Size [BWeld]

```
  = W / [( 0.4 * Yield ) * 2 * 0.707]
  = 1.49/[( 0.4 * 191 ) * 2 * 0.707]
  = 13.8 mm.
```

Results for Computed Minimum Gusset and Top Plate to Skirt Weld Size

Vertical Plate Load [Wv]

```
  = Bolt Load / ( Cmwth + 2 * ( Hg + Tta ) )
  = 176/( 124 + 2 * ( 265 + 35 ) )
  = 0.24 kN/mm.
```

Horizontal Plate Load [Wh]

```
  = Bolt Load * e / ( Cmwth * (Hg+Tta) + 0.6667 * (Hg+Tta)² )
  = 176 * 112/(124 * (300 ) + 0.6667 * (300 )² )
  = 0.2 kN/mm.
```

Resultant Weld Load [Wr]

```
  = ( Wv² + Wh²)½
  = ( 0.24² + 0.2²)½
  = 0.32 kN/mm.
```

Results for Computed Min Gusset and Top Plate to Skirt Weld Size [GsWeld]

```
  = Wr / [( 0.4 * Yield ) * 2 * 0.707]
  = 0.32/[( 0.4 * 191 ) * 2 * 0.707]
  = 2.93 mm.
```

Results for Computed Minimum Gusset to Top Plate Weld Size

Weld Load [Wv]
```
  = Bolt Load / ( 2 * TopWth )
  = 176/( 2 * 200 )
  = 0.44 kN/mm.
```

Weld Load [Wh]
```
  = Bolt Load * e / ( 2 * Hgt * TopWth )
  = 176 * 112/( 2 * 300 * 200 )
  = 0.16 kN/mm.
```

Resultant Weld Load [Wr]
```
  = ( Wv² + Wh²)½
  = ( 0.44² + 0.16²)½
  = 0.47 kN/mm.
```

Results for Computed Min Gusset to Top Plate Weld Size [GtpWeld]
```
  = Wr / [( 0.4 * Yield ) * 2 * 0.707]
  = 0.47/[( 0.4 * 191 ) * 2 * 0.707]
  = 4.34 mm.
```

Note: The calculated weld sizes need not exceed the component thickness framing into the weld. At the same time, the weld must meet a minimum size specification which is 3/16 in. (4.76 mm) or 1/4 in. (6.35 mm), depending on the component thickness.

Summary of Required Weld Sizes:
```
 Required Basering to Skirt Double Fillet Weld Size      13.8030  mm.
 Required Gusset to Skirt Double Fillet Weld Size         4.7625  mm.
 Required Top Plate to Skirt Weld Size                    6.3500  mm.
 Required Gusset to Top Plate Double Fillet Weld Size     4.3401  mm.
```

Input, Nozzle Desc: N07 (1in) From: 20

```
Pressure for Reinforcement Calculations          P       62.189  bars
Temperature for Internal Pressure             Temp          148  °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       706.00  mm.
Aspect Ratio of Elliptical Head                 Ar         2.00
Head Finished (Minimum) Thickness                t      20.0000  mm.
Head Internal Corrosion Allowance                c       0.0000  mm.
Head External Corrosion Allowance               co       0.0000  mm.

Distance from Head Centerline                   L1       0.0000  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                                               0.00  deg
Diameter                                                 1.5000  in.

Size and Thickness Basis                                  Minimum
Nominal Thickness                               tn        XXS

Flange Material                                           SA-105
Flange Type                                   Weld Neck Flange

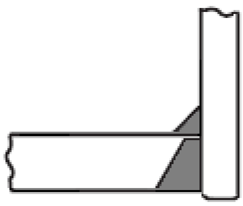
Corrosion Allowance                            can       0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

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      18.0000  mm.
Inside Projection                                h       0.0000  mm.
Weld leg size, Inside Element to Shell          Wi       0.0000  mm.

Flange Class                                         600
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: N07 (1in)

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

```
 Actual Inside Diameter Used in Calculation              1.200  in.
 Actual Thickness Used in Calculation                    0.350  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)
  = (62.2*0.9*706)/(2 *138*1-0.2*62.2)
  = 14.3930 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 15.2(exp([62.2/(118*1]-1)
  = 0.8255 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2795 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     88.2600  mm.
 Parallel to Vessel Wall                        Rn+tn+t     44.1300  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     22.2250  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 118/138 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 118/138 )
  = 0.855
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.86, 1 )
  = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	4.758	0.319	NA
Area in Shell	A1	3.095	9.974	NA
Area in Nozzle Wall	A2	3.065	3.272	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.855	0.855	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	7.015	14.102	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                 90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (30.5*14.4*1+2*8.89*14.4*1*(1-0.86))
  = 4.758 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 )
  = 57.8 ( 1 * 20 - 1 * 14.4 ) - 2 * 8.89
    ( 1 * 20 - 1 * 14.4 ) * ( 1 - 0.86 )
  = 3.095 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 22.2 )( 8.89 - 0.83 )0.86
  = 3.065 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 0.86 + ( 0 )² * 0.86
  = 0.855 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 0.8255 mm.
```

```
Wall Thickness per UG16(b),                          tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 15.9923 mm.
Wall Thickness                    tb1 = max(trb1, tr16b) = 15.9923 mm.
Wall Thickness, shell/head, external pressure         trb2 = 0.2647 mm.
Wall Thickness                    tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                          tb3 = 3.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 3.22, max( 16, 1.5 ) ]
  = 3.2200 mm.
```

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

```
  = max( ta, tb )
  = max( 0.83, 3.22 )
  = 3.2200 mm.
```

Available Nozzle Neck Thickness = 8.8900 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:B, Curve:A)

Govrn. thk, tg = 8.89, tr = 0.83, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.093, 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-Shell/Head Weld (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 8.89, tr = 0.83, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.093, 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 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)       -39 °C
```

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

```
Design Pressure/Ambient Rating = 62.19/102.10 = 0.609
```

<u>Weld Size Calculations, Description: N07 (1in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      8.8900  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,  (4.76 - 3.1 + 2 * 8.89 * 0.86 *
     (1 * 20 - 14.4 ) )138 )
  = 34.68 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.06 + 0 + 0.86 - 0 * 0.86 ) * 138
  = 54.05 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.06 + 0 + 0.86 + ( 3.04 ) ) * 138
  = 95.97 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.06 + 0 + 0.86 + 0 + ( 3.04 ) ) * 138
  = 95.97 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 48.3 * 10 * 0.49 * 118
  = 44. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 19.7 ) * ( 8.89 - 0 ) * 0.7 * 118
  = 45. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 48.3 * ( 18 - 0 ) * 0.74 * 138
  = 139. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 43.8 + 45.4 ) = 89.2 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 43.8 + 0 + 139 + 0 ) = 183 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 43.8 + 139 + 0 ) = 183 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 89 kN , must exceed W = 34 kN  or W1 = 54 kN
Path 2-2 = 183 kN , must exceed W = 34 kN  or W2 = 95 kN
Path 3-3 = 183 kN , must exceed W = 34 kN  or W3 = 95 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   72.9  bars

Nozzle is O.K. for the External Pressure           1.03  bars
```

The Drop for this Nozzle is : 0.4471 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 220.4471 mm.

Input, Nozzle Desc: K07A (3in) From: 20

```
Pressure for Reinforcement Calculations          P      62.186  bars
Temperature for Internal Pressure             Temp        148  °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     706.00  mm.
Aspect Ratio of Elliptical Head                 Ar       2.00
Head Finished (Minimum) Thickness                t    20.0000  mm.
Head Internal Corrosion Allowance                c     0.0000  mm.
Head External Corrosion Allowance               co     0.0000  mm.

Distance from Head Centerline                   L1   200.0000  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     137.90  N./mm²
Allowable Stress At Ambient                    Sna     137.90  N./mm²

Diameter Basis (for tr calc only)                           ID
Layout Angle                                           180.00  deg
Diameter                                               3.0000  in.

Size and Thickness Basis                                Minimum
Nominal Thickness                               tn      STD

Flange Material                                          SA-105
Flange Type                                    Weld Neck Flange

Hub Height of Integral Nozzle                    h    50.0000  mm.
Height of Beveled Transition                    L'    10.0000  mm.
Hub Thickness of Integral Nozzle  ( tn or x+tp )     20.0000  mm.
Style of FVC Nozzle                                Heavy Barrel

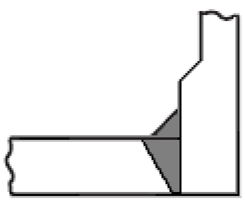
Corrosion Allowance                            can     0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1       1.00
Joint Efficiency of Nozzle Neck                 En       1.00

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     18.0000  mm.
Inside Projection                                h     0.0000  mm.
Weld leg size, Inside Element to Shell          Wi     0.0000  mm.
```

```
Flange Class                                          600
Flange Grade                                          GR 1.1
```

The Pressure Design option was Design Pressure + static head.

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



Hub Nozzle (Set-in)

Note : Checking Nozzle in the Meridional direction.

Reinforcement CALCULATION, Description: K07A (3in)

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

```
Actual Inside Diameter Used in Calculation               3.122   in.
Actual Thickness Used in Calculation                     0.189   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)
  = (62.2*0.9*706)/(2 *138*1-0.2*62.2)
  = 14.3923 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)
  = (62.2*39.6)/(138*1-0.6*62.2)
  = 1.8378 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3989 mm.

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):
```
  = 2.5 * Corroded Hub Thickness
```

```
  = 2.5 * 20 Note: less than the hub height, use (e-2)
  = 50.0000 mm.
```

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    168.1903  mm.
 Parallel to Vessel Wall, opening length              d     84.0951  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     50.0000  mm.
```

Note: Hub Height was >= 2.5 times Hub Thickness, using sketch UG-40 (e-2).

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	12.103	0.812	NA
Area in Shell	A1	4.716	15.195	NA
Area in Nozzle Wall	A2	18.670	20.149	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	24.386	36.344	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                    70.56   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (84.1*14.4*1+2*20*14.4*1*(1-1))
  = 12.103 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 )
```

```
  = 84.1 ( 1 * 20 - 1 * 14.4 ) - 2 * 20
     ( 1 * 20 - 1 * 14.4 ) * ( 1 - 1 )
  = 4.716 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 50 )( 20 - 1.84 )1/sin( 76.6 )
  = 18.670 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
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: A

Govrn. thk, tg = 4.8, tr = 1.84, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.38, Temp. Reduction = 55 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -48 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

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

Govrn. thk, tg = 20, tr = 14.4, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.72, Temp. Reduction = 16 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A              12 °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -3 °C

 Gov. MDMT of the nozzle to shell joint welded assembly :    -3 °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)       -39 °C
```

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

```
 Design Pressure/Ambient Rating = 62.19/102.10 = 0.609
```

Weld Size Calculations, Description: K07A (3in)

```
 Intermediate Calc. for nozzle/shell Welds    Tmin     19.0000  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, (12.1 - 4.72 + 2 * 20 * 1 *
     (1 * 20 - 14.4 ) )138 )
  = 132.79 kN
```

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:
```
  = (A2+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 18.7 + 1 - 0 * 1 ) * 138
  = 271.22 kN
```

Weld Load [W2]:
```
    = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
  = ( 18.7 + 0 + 1 + ( 8 ) ) * 138
  = 381.53 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
  = ( 18.7 + 0 + 1 + 0 ) * 138
  = 381.53 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 127 * 10 * 0.49 * 138
  = 134. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 52.7 ) * ( 20 - 0 ) * 0.7 * 138
  = 319. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 127 * ( 18 - 0 ) * 0.74 * 138
  = 365. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 134 + 319 ) = 454 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 134 + 0 + 365 + 0 ) = 499 kN
```

```
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 134 + 365 + 0 ) = 499 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 453 kN , must exceed W = 132 kN  or W1 = 271 kN
Path 2-2 = 499 kN , must exceed W = 132 kN  or W2 = 381 kN
Path 3-3 = 499 kN , must exceed W = 132 kN  or W3 = 381 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   77.7  bars
```

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

```
Nozzle is O.K. for the External Pressure           1.03  bars
```

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: K07A (3in)

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

```
Actual Inside Diameter Used in Calculation             3.122  in.
Actual Thickness Used in Calculation                   0.189  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)
= (62.2*0.9*706)/(2 *138*1-0.2*62.2)
= 14.3923 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)
= (62.2*39.6)/(138*1-0.6*62.2)
= 1.8378 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3989 mm.

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):

```
= 2.5 * Corroded Hub Thickness
= 2.5 * 20 Note: less than the hub height, use (e-2)
= 50.0000 mm.
```

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    159.2988  mm.
Parallel to Vessel Wall                         Rn+tn+t     79.6494  mm.
Normal to Vessel Wall (Thickness Limit), no pad    Tlnp     50.0000  mm.
```

Note: Hub Height was >= 2.5 times Hub Thickness, using sketch UG-40 (e-2).

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	11.413	0.766	NA
Area in Shell	A1	4.486	14.455	NA
Area in Nozzle Wall	A2	18.162	19.601	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	23.648	35.056	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (79.3*14.4*1+2*20*14.4*1*(1-1))
= 11.413 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)
= 80 (1 * 20 - 1 * 14.4) - 2 * 20
(1 * 20 - 1 * 14.4) * (1 - 1)
= 4.486 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 50)(20 - 1.84)1
= 18.162 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10² * 1 + (0)² * 1
= 1.000 cm²

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

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

```
Wall Thickness for Internal/External pressures        ta = 1.8378 mm.
Wall Thickness per UG16(b),                         tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure        trb1 = 15.9915 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 15.9915 mm.
Wall Thickness, shell/head, external pressure        trb2 = 0.2647 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                        tb3 = 4.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 4.8, max( 16, 1.5 ) ]
 = 4.8000 mm.
```

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

```
 = max( ta, tb )
 = max( 1.84, 4.8 )
 = 4.8000 mm.
```

Available Nozzle Neck Thickness = 4.8006 mm. --> OK

Weld Size Calculations, Description: K07A (3in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     19.0000  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, (11.4 - 4.49 + 2 * 20 * 1 *
   (1 * 20 - 14.4 ) )138 )
 = 126.44 kN
```

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:

```
 = (A2+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 18.2 + 1 - 0 * 1 ) * 138
 = 264.22 kN
```

Weld Load [W2]:

```
  = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
 = ( 18.2 + 0 + 1 + ( 8 ) ) * 138
 = 374.53 kN
```

Weld Load [W3]:

```
 = (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
 = ( 18.2 + 0 + 1 + 0 ) * 138
 = 374.53 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
 = (pi/2) * Dlo * Wo * 0.49 * Snw
 = ( 3.14/2.0 ) * 119 * 10 * 0.49 * 138
 = 127. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 49.6 ) * ( 20 - 0 ) * 0.7 * 138
  = 301. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 119 * ( 18 - 0 ) * 0.74 * 138
  = 344. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 127 + 301 ) = 428 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 127 + 0 + 344 + 0 ) = 471 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 127 + 344 + 0 ) = 471 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 427 kN , must exceed W = 126 kN  or W1 = 264 kN
 Path 2-2 = 470 kN , must exceed W = 126 kN  or W2 = 374 kN
 Path 3-3 = 470 kN , must exceed W = 126 kN  or W3 = 374 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   77.7  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1.03  bars
```

The Drop for this Nozzle is : 22.5225 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 243.5051 mm.

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Input, Nozzle Desc: K09A (2in) **From: 20**

```
Pressure for Reinforcement Calculations          P       62.186  bars
Temperature for Internal Pressure              Temp         148  °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       706.00  mm.
Aspect Ratio of Elliptical Head                 Ar         2.00
Head Finished (Minimum) Thickness                t      20.0000  mm.
Head Internal Corrosion Allowance                c       0.0000  mm.
Head External Corrosion Allowance               co       0.0000  mm.

Distance from Head Centerline                   L1     200.0000  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                                              90.00  deg
Diameter                                                 2.0000  in.

Size and Thickness Basis                                  Minimum
Nominal Thickness                               tn        XXS

Flange Material                                           SA-105
Flange Type                                    Weld Neck Flange

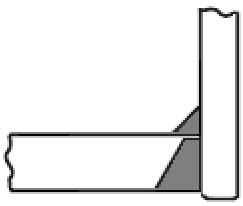
Corrosion Allowance                            can       0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     200.0000  mm.
Weld leg size between Nozzle and Pad/Shell      Wo      12.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv        18.0000  mm.
Inside Projection                                h       0.0000  mm.
Weld leg size, Inside Element to Shell          Wi       0.0000  mm.

Flange Class                                        600
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 in the Meridional direction.

Reinforcement CALCULATION, Description: K09A (2in)

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

```
 Actual Inside Diameter Used in Calculation              1.612  in.
 Actual Thickness Used in Calculation                    0.382  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)
  = (62.2*0.9*706)/(2 *138*1-0.2*62.2)
  = 14.3923 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)
  = (62.2*20.5)/(118*1-0.6*62.2)
  = 1.1151 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3185 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   102.7121  mm.
 Parallel to Vessel Wall                       Rn+tn+t     51.3560  mm.
 Normal to Vessel Wall (Thickness Limit), no pad  Tlnp     24.2253  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 118/138 )
```

```
  = 0.855
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 118/138 )
  = 0.855
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.86, 1 )
  = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	6.641	0.446	NA
Area in Shell	A1	3.172	10.221	NA
Area in Nozzle Wall	A2	3.684	4.026	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.231	1.231	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	8.087	15.479	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  70.89   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (43.3*14.4*1+2*9.69*14.4*1*(1-0.86))
  = 6.641 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 )
  = 59.4 ( 1 * 20 - 1 * 14.4 ) - 2 * 9.69
    ( 1 * 20 - 1 * 14.4 ) * ( 1 - 0.86 )
  = 3.172 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 24.2 )( 9.69 - 1.12 )0.86/sin( 74.6 )
  = 3.684 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
  = 12² * 0.86 + ( 0 )² * 0.86
```

```
  = 1.231 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:B, Curve:A)

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

Govrn. thk, tg = 9.69, tr = 1.12, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.12, 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-Shell/Head Weld (UCS-66(a)1(b)), Curve: B

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

Govrn. thk, tg = 9.69, tr = 1.12, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.12, 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 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)         -39 °C
```

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

```
 Design Pressure/Ambient Rating = 62.19/102.10 = 0.609
```

<u>Weld Size Calculations, Description: K09A (2in)</u>

```
 Intermediate Calc. for nozzle/shell Welds    Tmin      9.6901   mm.
```

Results Per UW-16.1:

```
                           Required Thickness    Actual Thickness
 Nozzle Weld              6.0000 = Min per Code 8.4840 = 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, (6.64 - 3.17 + 2 * 9.69 * 0.86 *
    (1 * 20 - 14.4 ) )138 )
  = 60.64 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.68 + 0 + 1.23 - 0 * 0.86 ) * 138
  = 67.77 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.68 + 0 + 1.23 + ( 3.31 ) ) * 138
  = 113.47 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.68 + 0 + 1.23 + 0 + ( 3.31 ) ) * 138
  = 113.47 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 63.8 * 12 * 0.49 * 118
  = 70. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 26.8 ) * ( 9.69 - 0 ) * 0.7 * 118
  = 67. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 63.8 * ( 18 - 0 ) * 0.74 * 138
  = 184. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 69.5 + 67.3 ) = 137 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 69.5 + 0 + 184 + 0 ) = 254 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 69.5 + 184 + 0 ) = 254 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 136 kN , must exceed W = 60 kN  or W1 = 67 kN
 Path 2-2 = 253 kN , must exceed W = 60 kN  or W2 = 113 kN
 Path 3-3 = 253 kN , must exceed W = 60 kN  or W3 = 113 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case    68   bars

 Nozzle is O.K. for the External Pressure          1.03   bars
```

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: K09A (2in)

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

```
 Actual Inside Diameter Used in Calculation             1.612   in.
```

```
Actual Thickness Used in Calculation                    0.382  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)
  = (62.2*0.9*706)/(2 *138*1-0.2*62.2)
  = 14.3923 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)
  = (62.2*20.5)/(118*1-0.6*62.2)
  = 1.1151 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3185 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    100.3250   mm.
 Parallel to Vessel Wall                         Rn+tn+t    50.1625   mm.
 Normal to Vessel Wall (Thickness Limit), no pad    Tlnp    24.2253   mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	6.297	0.423	NA
Area in Shell	A1	3.172	10.221	NA
Area in Nozzle Wall	A2	3.552	3.882	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.231	1.231	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	7.956	15.335	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (40.9*14.4*1+2*9.69*14.4*1*(1-0.86))
  = 6.297 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 )
  = 59.4 ( 1 * 20 - 1 * 14.4 ) - 2 * 9.69
    ( 1 * 20 - 1 * 14.4 ) * ( 1 - 0.86 )
  = 3.172 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 24.2 )( 9.69 - 1.12 )0.86
  = 3.552 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 12² * 0.86 + ( 0 )² * 0.86
  = 1.231 cm²
```

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

```
 Wall Thickness for Internal/External pressures      ta = 1.1151 mm.
 Wall Thickness per UG16(b),                       tr16b = 1.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 15.9915 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 15.9915 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 0.2647 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 1.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 3.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 3.42, max( 16, 1.5 ) ]
  = 3.4200 mm.
```

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

```
  = max( ta, tb )
  = max( 1.12, 3.42 )
  = 3.4200 mm.
```

Available Nozzle Neck Thickness = 9.6901 mm. --> OK

Weld Size Calculations, Description: K09A (2in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      9.6901  mm.
```

Results Per UW-16.1:

```
                           Required Thickness    Actual Thickness
 Nozzle Weld             6.0000 = Min per Code 8.4840 = 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, (6.3 - 3.17 + 2 * 9.69 * 0.86 *
    (1 * 20 - 14.4 ) )138 )
  = 55.90 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.55 + 0 + 1.23 - 0 * 0.86 ) * 138
  = 65.96 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.55 + 0 + 1.23 + ( 3.31 ) ) * 138
  = 111.65 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.55 + 0 + 1.23 + 0 + ( 3.31 ) ) * 138
  = 111.65 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 60.3 * 12 * 0.49 * 118
  = 66. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 25.3 ) * ( 9.69 - 0 ) * 0.7 * 118
  = 64. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 60.3 * ( 18 - 0 ) * 0.74 * 138
  = 174. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 65.7 + 63.6 ) = 129 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 65.7 + 0 + 174 + 0 ) = 240 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 65.7 + 174 + 0 ) = 240 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 129 kN , must exceed W = 55 kN  or W1 = 65 kN
 Path 2-2 = 239 kN , must exceed W = 55 kN  or W2 = 111 kN
 Path 3-3 = 239 kN , must exceed W = 55 kN  or W3 = 111 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case     69.1  bars

 Nozzle is O.K. for the External Pressure             1.03  bars
```

The Drop for this Nozzle is : 10.5544 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 231.5370 mm.

Input, Nozzle Desc: N01 (6in) **From: 30**

```
Pressure for Reinforcement Calculations          P       62.000  bars
Temperature for Internal Pressure             Temp          148  °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       706.00  mm.
Design Length of Section                         L    2108.8333  mm.
Shell Finished (Minimum) Thickness               t      20.0000  mm.
Shell Internal Corrosion Allowance               c       0.0000  mm.
Shell External Corrosion Allowance              co       0.0000  mm.

Distance from Bottom/Left Tangent                       1400.00  mm.

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

Type of Element Connected to the Shell : Nozzle

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

Flange Material                                            SA-105
Flange Type                                     Weld Neck Flange

Hub Height of Integral Nozzle                    h      90.0000  mm.
Height of Beveled Transition                    L'      18.0000  mm.
Hub Thickness of Integral Nozzle  ( tn or x+tp )       35.0000  mm.

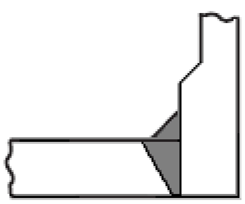
Corrosion Allowance                            can       0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

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       15.0000  mm.
Inside Projection                                h       0.0000  mm.
Weld leg size, Inside Element to Shell          Wi       0.0000  mm.
```

```
Flange Class                                          600
Flange Grade                                          GR 1.1
```

The Pressure Design option was Design Pressure + static head.

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



Hub Nozzle (Set-in)

Reinforcement CALCULATION, Description: N01 (6in)

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

```
Actual Inside Diameter Used in Calculation            6.135   in.
Actual Thickness Used in Calculation                  0.245   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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 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)
  = (62*77.9)/(138*1-0.6*62)
  = 3.6004 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5804 mm.

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):
```
  = 2.5 * Corroded Hub Thickness
  = 2.5 * 35 Note: less than the hub height, use (e-2)
  = 87.5000 mm.
```

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

```
Parallel to Vessel Wall (Diameter Limit)             Dl    311.6580  mm.
Parallel to Vessel Wall, opening length               d    155.8290  mm.
Normal to Vessel Wall (Thickness Limit), no pad    Tlnp     50.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 138/138 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 138/138 )
= 1.000
```

Weld Strength Reduction Factor [fr3]:

```
= min( fr2, fr4 )
= min( 1, 1 )
= 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	25.419	2.883	NA
Area in Shell	A1	5.747	25.401	NA
Area in Nozzle Wall	A2	31.400	34.420	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	38.147	60.820	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
= ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
= (156*16.3*1+2*35*16.3*1*(1-1))
= 25.419 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 )
= 156 ( 1 * 20 - 1 * 16.3 ) - 2 * 35
  ( 1 * 20 - 1 * 16.3 ) * ( 1 - 1 )
= 5.747 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 50 )( 35 - 3.6 )1
  = 31.400 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

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

```
 Wall Thickness for Internal/External pressures       ta = 3.6004 mm.
 Wall Thickness per UG16(b),                       tr16b = 1.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 16.3119 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 16.3119 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 0.2648 mm.
 Wall Thickness                 tb2 = max(trb2, tr16b) = 1.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 6.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.22, max( 16.3, 1.5 ) ]
  = 6.2200 mm.
```

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

```
  = max( ta, tb )
  = max( 3.6, 6.22 )
  = 6.2200 mm.
```

Available Nozzle Neck Thickness = 6.2230 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   :      78.5,  Allowable :     137.9 N./mm²   Passed
 Expansion   :       0.0,  Allowable :     266.3 N./mm²   Passed
 Occasional  :      37.3,  Allowable :     183.4 N./mm²   Passed
 Shear       :       7.9,  Allowable :      96.5 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: A
```
----------------------------------------------------------------------
```
Govrn. thk, tg = 6.22, tr = 3.6, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.58, Temp. Reduction = 24 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -32 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: B
```
----------------------------------------------------------------------
```
Govrn. thk, tg = 20, tr = 16.3, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.82, Temp. Reduction = 10 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -7 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -18 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -29 °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)       -40 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

<u>Weld Size Calculations, Description: N01 (6in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin     19.0000  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, (25.4 - 5.75 + 2 * 35 * 1 *
     (1 * 20 - 16.3 ) )138 )
  = 306.85 kN
```

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:
```
  = (A2+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 31.4 + 1 - 0 * 1 ) * 138
```

```
  = 446.75 kN
```

Weld Load [W2]:
```
   = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
  = ( 31.4 + 0 + 1 + ( 14 ) ) * 138
  = 639.80 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
  = ( 31.4 + 0 + 1 + 0 ) * 138
  = 639.80 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 226 * 10 * 0.49 * 138
  = 240. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 95.4 ) * ( 35 - 0 ) * 0.7 * 138
  = 1013. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 226 * ( 15 - 0 ) * 0.74 * 138
  = 543. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 240 + 1013 ) = 1252 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 240 + 0 + 543 + 0 ) = 783 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 240 + 543 + 0 ) = 783 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 1252 kN , must exceed W = 306 kN  or W1 = 446 kN
 Path 2-2 = 782 kN , must exceed W = 306 kN  or W2 = 639 kN
 Path 3-3 = 782 kN , must exceed W = 306 kN  or W3 = 639 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case    75.4   bars
```

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

```
 Nozzle is O.K. for the External Pressure           1.03   bars
```

The Drop for this Nozzle is : 18.5463 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 238.5462 mm.

Input Echo, WRC107/537 Item 1, Description: N01 (6in) :

```
Diameter Basis for Vessel                  Vbasis      ID
Cylindrical or Spherical Vessel            Cylsph      Cylindrical
Internal Corrosion Allowance                  Cas      0.0000   mm.
Vessel Diameter                                Dv     706.000   mm.
Vessel Thickness                               Tv      20.000   mm.

Design Temperature                             T1       148.0   °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      0.0000   mm.
Nozzle Diameter                                Dn     155.829   mm.
Nozzle Thickness                               Tn      35.000   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      137.90   N./mm²

Design Internal Pressure                       Dp      62.000   bars
Include Pressure Thrust                                    No
```

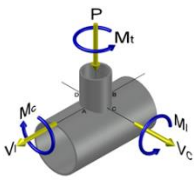
External Forces and Moments in WRC 107/537 Convention:

```
Radial Load              (SUS)                  P         9.6   kN
Longitudinal Shear       (SUS)                 Vl         9.6   kN
Circumferential Shear    (SUS)                 Vc        -7.2   kN
Circumferential Moment   (SUS)                 Mc     -2880.0   N-m
Longitudinal Moment      (SUS)                 Ml     -3740.0   N-m
Torsional Moment         (SUS)                 Mt     -4320.0   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 ) )
  = 225.829 + 2 * 1.65 * sqrt( 363.0 ( 20.0 - 0.0 ) )
  = 507.008 mm.
```

WRC 107 Stress Calculation for SUStained loads:
```
 Radial Load                                   P          9.6   kN
 Circumferential Shear                         VC        -7.2   kN
 Longitudinal Shear                            VL         9.6   kN
 Circumferential Moment                        MC     -2880.0   N-m
 Longitudinal Moment                           ML     -3740.0   N-m
 Torsional Moment                              MT     -4320.0   N-m

 Dimensionless Parameters used :    Gamma =    18.15
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.272	4C	2.613	(A,B)
N(PHI) / (P/Rm)	0.272	3C	1.798	(C,D)
M(PHI) / (P)	0.272	2C1	0.038	(A,B)
M(PHI) / (P)	0.272	1C !	0.067	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.272	3A	0.771	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.272	1A	0.082	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.272	3B	1.908	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.272	1B	0.028	(A,B,C,D)
N(x) / (P/Rm)	0.272	3C	1.798	(A,B)
N(x) / (P/Rm)	0.272	4C	2.613	(C,D)
M(x) / (P)	0.272	1C1	0.067	(A,B)
M(x) / (P)	0.272	2C !	0.038	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.272	4A	1.416	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.272	2A	0.041	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.272	4B	0.742	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.272	2B	0.046	(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
Circ. Memb. P	-3.5	-3.5	-3.5	-3.5	-2.4	-2.4	-2.4	-2.4
Circ. Bend. P	-5.5	5.5	-5.5	5.5	-9.6	9.6	-9.6	9.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	3.1	3.1	-3.1	-3.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	36.0	-36.0	-36.0	36.0
Circ. Memb. ML	9.9	9.9	-9.9	-9.9	0.0	0.0	0.0	0.0
Circ. Bend. ML	15.7	-15.7	-15.7	15.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	16.7	-3.8	-34.6	7.8	27.1	-25.7	-51.1	40.2
Long. Memb. P	-2.4	-2.4	-2.4	-2.4	-3.5	-3.5	-3.5	-3.5
Long. Bend. P	-9.6	9.6	-9.6	9.6	-5.5	5.5	-5.5	5.5
Long. Memb. MC	0.0	0.0	0.0	0.0	5.7	5.7	-5.7	-5.7
Long. Bend. MC	0.0	0.0	0.0	0.0	17.9	-17.9	-17.9	17.9
Long. Memb. ML	3.9	3.9	-3.9	-3.9	0.0	0.0	0.0	0.0
Long. Bend. ML	26.0	-26.0	-26.0	26.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	17.9	-14.9	-41.8	29.3	14.6	-10.1	-32.5	14.2
Shear VC	-1.0	-1.0	1.0	1.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.4	-1.4	1.4	1.4
Shear MT	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7
Tot. Shear	-3.7	-3.7	-1.7	-1.7	-4.0	-4.0	-1.3	-1.3
Str. Int.	21.1	16.0	42.2	29.5	28.3	26.7	51.2	40.2

Stress Intensity Values at

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)	106.4	112.6	106.4	112.6	106.4	112.6	106.4	112.6
Circ. Pl	(SUS)	6.5	6.5	-13.4	-13.4	0.7	0.7	-5.5	-5.5
Circ. Q	(SUS)	10.2	-10.2	-21.2	21.2	26.4	-26.4	-45.6	45.6
Long. Pm	(SUS)	53.2	53.2	53.2	53.2	53.2	53.2	53.2	53.2
Long. Pl	(SUS)	1.5	1.5	-6.2	-6.2	2.2	2.2	-9.1	-9.1
Long. Q	(SUS)	16.4	-16.4	-35.6	35.6	12.4	-12.4	-23.4	23.4
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	-1.0	-1.0	1.0	1.0	-1.4	-1.4	1.4	1.4
Shear Q	(SUS)	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7
Pm (SUS)		106.4	112.6	106.4	112.6	106.4	112.6	106.4	112.6
Pm+Pl (SUS)		112.9	119.1	93.0	99.2	107.2	113.4	101.0	107.2
Pm+Pl+Q (Total)		123.4	109.1	71.9	120.5	133.8	87.3	55.4	152.8

(Stress Intensity Values at)

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	112.62	137.90	Passed
Pm+Pl (SUS)	119.13	206.85	Passed
Pm+Pl+Q (TOTAL)	152.81	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: N09 (1in) **From: 30**

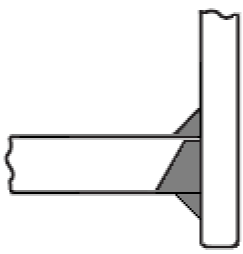
Pressure for Reinforcement Calculations	P	62.152	bars
Temperature for Internal Pressure	Temp	148	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	706.00	mm.
Design Length of Section	L	2108.8333	mm.
Shell Finished (Minimum) Thickness	t	20.0000	mm.
Shell Internal Corrosion Allowance	c	0.0000	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	137.90	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	14.2240	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.0000	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	18.0000	mm.
Inside Projection	h	325.0000	mm.
Weld leg size, Inside Element to Shell	Wi	15.0000	mm.
Flange Class		600	
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, with Inside projection

Reinforcement CALCULATION, Description: N09 (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                    0.560  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)
  = (62.2*353)/(138*1-0.6*62.2)
  = 16.3530 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 12.7(exp([62.2/(138*1]-1)
  = 0.5855 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2977 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl     93.8480  mm.
Parallel to Vessel Wall                        Rn+tn+t     46.9240  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     35.5600  mm.
Normal to Vessel Wall, Inward                              35.5600  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	4.154	0.470	NA
Area in Shell	A1	2.496	11.157	NA
Area in Nozzle Wall	A2	9.700	9.904	NA
Area in Inward Nozzle	A3	10.116	10.116	NA
Area in Welds	A41+A42+A43	3.250	3.250	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	25.562	34.428	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (25.4*16.4*1+2*14.2*16.4*1*(1-1))
  = 4.154 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 )
  = 68.4 ( 1 * 20 - 1 * 16.4 ) - 2 * 14.2
    ( 1 * 20 - 1 * 16.4 ) * ( 1 - 1 )
  = 2.496 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 35.6 )( 14.2 - 0.59 )1
  = 9.700 cm²
```

Area Available in Inward Nozzle [A3]:
```
  = 2 * ti * min( h, Tl, 2.5 * ti) * fr2
  = 2 * 14.2 * ( 35.6 ) * 1
  = 10.116 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 15 )² * 1
  = 3.250 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 0.5855 mm.
Wall Thickness per UG16(b),                       tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 16.3530 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 16.3530 mm.
Wall Thickness, shell/head, external pressure     trb2 = 0.2648 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                     tb3 = 3.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 3.42, max( 16.4, 1.5 ) ]
  = 3.4200 mm.
```

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

```
  = max( ta, tb )
  = max( 0.59, 3.42 )
  = 3.4200 mm.
```

Available Nozzle Neck Thickness = 14.2240 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 = 14.2, tr = 0.59, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.041, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              2 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)        -48 °C
```

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

```
Design Pressure/Ambient Rating = 62.15/102.10 = 0.609
```

Weld Size Calculations, Description: N09 (1in)

```
Intermediate Calc. for nozzle/shell Welds    Tmin      14.2240  mm.
Intermediate Calc. for Inward Weld        TminIns      14.2240  mm.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
Nozzle Weld           6.0000 = Min per Code 7.0700 = 0.7 * Wo mm.
```

```
Inward Weld          6.0000 = Min per Code10.6050 = 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,  (4.15 - 2.5 + 2 * 14.2 * 1 *
     (1 * 20 - 16.4 ) )138 )
  = 37.16 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 9.7 + 0 + 3.25 - 8.86 * 1 ) * 138
  = 147.54 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 9.7 + 10.1 + 3.25 + ( 5.69 ) ) * 138
  = 396.50 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 9.7 + 10.1 + 3.25 + 0 + ( 5.69 ) ) * 138
  = 396.50 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 53.8 * 10 * 0.49 * 138
  = 57. kN
```

Shear, Inward Nozzle Weld [Sinw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 53.8 * 15 * 0.49 * 138
  = 86. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 19.8 ) * ( 14.2 - 0 ) * 0.7 * 138
  = 85. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 53.8 * ( 18 - 0 ) * 0.74 * 138
  = 155. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 57.1 + 85.5 ) = 143 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
```

```
       = ( 57.1 + 0 + 155 + 85.7 ) = 298 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 57.1 + 155 + 85.7 ) = 298 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 142 kN , must exceed W = 37 kN  or W1 = 147 kN
Path 2-2 = 298 kN , must exceed W = 37 kN  or W2 = 396 kN
Path 3-3 = 298 kN , must exceed W = 37 kN  or W3 = 396 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   75.5  bars
```

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

```
Nozzle is O.K. for the External Pressure          1.03  bars
```

The Drop for this Nozzle is : 1.0283 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 545.0000 mm.

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Input, Nozzle Desc: K07B (3in) From: 30

```
Pressure for Reinforcement Calculations         P      62.000  bars
Temperature for Internal Pressure            Temp         148  °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      706.00  mm.
Design Length of Section                        L   2108.8333  mm.
Shell Finished (Minimum) Thickness              t     20.0000  mm.
Shell Internal Corrosion Allowance              c      0.0000  mm.
Shell External Corrosion Allowance             co      0.0000  mm.

Distance from Bottom/Left Tangent                      776.00  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      137.90  N./mm²
Allowable Stress At Ambient                   Sna      137.90  N./mm²

Diameter Basis (for tr calc only)                           ID
Layout Angle                                           180.00  deg
Diameter                                               3.0000  in.

Size and Thickness Basis                                Actual
Actual Thickness                               tn     20.4000  mm.

Flange Material                                         SA-105
Flange Type                                     Long Weld Neck

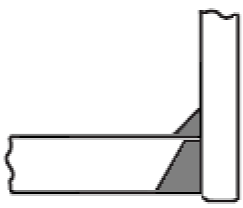
Corrosion Allowance                           can      0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle       E1        1.00
Joint Efficiency of Nozzle Neck                En        1.00

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      18.0000  mm.
Inside Projection                               h      0.0000  mm.
Weld leg size, Inside Element to Shell         Wi      0.0000  mm.

Flange Class                                         600
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: K07B (3in)

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

```
 Actual Inside Diameter Used in Calculation              3.000  in.
 Actual Thickness Used in Calculation                    0.803  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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 38.1(exp([62/(138*1]-1)
  = 1.7522 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4698 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl   157.0000  mm.
 Parallel to Vessel Wall                        Rn+tn+t    78.5000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    50.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	12.430	1.410	NA
Area in Shell	A1	2.980	13.171	NA
Area in Nozzle Wall	A2	18.648	19.930	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	22.628	34.101	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (76.2*16.3*1+2*20.4*16.3*1*(1-1))
  = 12.430 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 )
  = 80.8 ( 1 * 20 - 1 * 16.3 ) - 2 * 20.4
    ( 1 * 20 - 1 * 16.3 ) * ( 1 - 1 )
  = 2.980 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 50 )( 20.4 - 1.75 )1
  = 18.648 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 1.7522 mm.
```

```
Wall Thickness per UG16(b),                          tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 16.3119 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 16.3119 mm.
Wall Thickness, shell/head, external pressure         trb2 = 0.2648 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                         tb3 = 5.7300 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 5.73, max( 16.3, 1.5 ) ]
  = 5.7300 mm.
```

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

```
  = max( ta, tb )
  = max( 1.75, 5.73 )
  = 5.7300 mm.
```

Available Nozzle Neck Thickness = 20.4000 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 = 20, tr = 16.3, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.82, Temp. Reduction = 10 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              12 °C
Min Metal Temp. at Required thickness (UCS 66.1)             2 °C

Gov. MDMT of the nozzle to shell joint welded assembly :     2 °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)       -48 °C
```

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

```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

Weld Size Calculations, Description: K07B (3in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin     19.0000  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, (12.4 - 2.98 + 2 * 20.4 * 1 *
    (1 * 20 - 16.3 ) )138 )
```

```
  = 151.05 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 18.6 + 0 + 1 - 0 * 1 ) * 138
  = 270.92 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 18.6 + 0 + 1 + ( 8.16 ) ) * 138
  = 383.44 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 18.6 + 0 + 1 + 0 + ( 8.16 ) ) * 138
  = 383.44 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 117 * 10 * 0.49 * 138
  = 124. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 48.3 ) * ( 20.4 - 0 ) * 0.7 * 138
  = 299. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 117 * ( 18 - 0 ) * 0.74 * 138
  = 338. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 124 + 299 ) = 423 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 124 + 0 + 338 + 0 ) = 462 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 124 + 338 + 0 ) = 462 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 422 kN , must exceed W = 151 kN  or W1 = 270 kN
 Path 2-2 = 461 kN , must exceed W = 151 kN  or W2 = 383 kN
 Path 3-3 = 461 kN , must exceed W = 151 kN  or W3 = 383 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   75.4  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1.03  bars
```

The Drop for this Nozzle is : 4.8811 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 224.8811 mm.

Input, Nozzle Desc: K08A (2in) **From: 30**

```
Pressure for Reinforcement Calculations          P       62.121  bars
Temperature for Internal Pressure             Temp          148  °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       706.00  mm.
Design Length of Section                         L    2108.8333  mm.
Shell Finished (Minimum) Thickness               t      20.0000  mm.
Shell Internal Corrosion Allowance               c       0.0000  mm.
Shell External Corrosion Allowance              co       0.0000  mm.

Distance from Bottom/Left Tangent                        520.00  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       137.90  N./mm²
Allowable Stress At Ambient                    Sna       137.90  N./mm²

Diameter Basis (for tr calc only)                            ID
Layout Angle                                              45.00  deg
Diameter                                                 2.0000  in.

Size and Thickness Basis                                Actual
Actual Thickness                                tn      16.7640  mm.

Flange Material                                         SA-105
Flange Type                                     Long Weld Neck

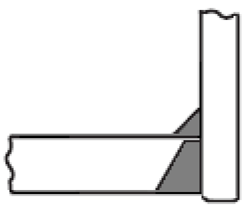
Corrosion Allowance                            can       0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

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        18.0000  mm.
Inside Projection                                h       0.0000  mm.
Weld leg size, Inside Element to Shell          Wi       0.0000  mm.

Flange Class                                         600
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: K08A (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                       0.660  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)
  = (62.1*353)/(138*1-0.6*62.1)
  = 16.3445 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 25.4(exp([62.1/(138*1]-1)
  = 1.1704 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3870 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    124.3280  mm.
 Parallel to Vessel Wall                         Rn+tn+t    62.1640  mm.
 Normal to Vessel Wall (Thickness Limit), no pad    Tlnp    41.9100  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.303	0.940	NA
Area in Shell	A1	2.688	11.985	NA
Area in Nozzle Wall	A2	13.071	13.727	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	16.758	26.712	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (50.8*16.3*1+2*16.8*16.3*1*(1-1))
  = 8.303 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 )
  = 73.5 ( 1 * 20 - 1 * 16.3 ) - 2 * 16.8
    ( 1 * 20 - 1 * 16.3 ) * ( 1 - 1 )
  = 2.688 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 41.9 )( 16.8 - 1.17 )1
  = 13.071 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 1.1704 mm.
```

```
Wall Thickness per UG16(b),                         tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure        trb1 = 16.3445 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 16.3445 mm.
Wall Thickness, shell/head, external pressure        trb2 = 0.2648 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                         tb3 = 4.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 4.8, max( 16.3, 1.5 ) ]
 = 4.8000 mm.
```

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

```
 = max( ta, tb )
 = max( 1.17, 4.8 )
 = 4.8000 mm.
```

Available Nozzle Neck Thickness = 16.7640 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 = 16.8, tr = 1.17, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.07, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              7 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)       -48 °C
```

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

```
Design Pressure/Ambient Rating = 62.12/102.10 = 0.608
```

Weld Size Calculations, Description: K08A (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin     16.7640  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, (8.3 - 2.69 + 2 * 16.8 * 1 *
   (1 * 20 - 16.3 ) )138 )
```

```
  = 94.33 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 13.1 + 0 + 1 - 0 * 1 ) * 138
  = 194.02 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 13.1 + 0 + 1 + ( 6.71 ) ) * 138
  = 286.48 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 13.1 + 0 + 1 + 0 + ( 6.71 ) ) * 138
  = 286.48 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84.3 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 33.8 ) * ( 16.8 - 0 ) * 0.7 * 138
  = 172. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84.3 * ( 18 - 0 ) * 0.74 * 138
  = 243. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.5 + 172 ) = 261 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.5 + 0 + 243 + 0 ) = 333 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.5 + 243 + 0 ) = 333 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 261 kN , must exceed W = 94 kN  or W1 = 194 kN
 Path 2-2 = 332 kN , must exceed W = 94 kN  or W2 = 286 kN
 Path 3-3 = 332 kN , must exceed W = 94 kN  or W3 = 286 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   75.5  bars
```

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

```
Nozzle is O.K. for the External Pressure          1.03   bars
```

The Drop for this Nozzle is : 2.5272 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5272 mm.

Input, Nozzle Desc: K08B (2in) **From: 30**

```
Pressure for Reinforcement Calculations         P       62.000  bars
Temperature for Internal Pressure            Temp          148  °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       706.00  mm.
Design Length of Section                        L    2108.8333  mm.
Shell Finished (Minimum) Thickness              t      20.0000  mm.
Shell Internal Corrosion Allowance              c       0.0000  mm.
Shell External Corrosion Allowance             co       0.0000  mm.

Distance from Bottom/Left Tangent                       776.00  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       137.90  N./mm²
Allowable Stress At Ambient                   Sna       137.90  N./mm²

Diameter Basis (for tr calc only)                          ID
Layout Angle                                             45.00  deg
Diameter                                                2.0000  in.

Size and Thickness Basis                               Actual
Actual Thickness                               tn      16.7640  mm.

Flange Material                                        SA-105
Flange Type                                    Long Weld Neck

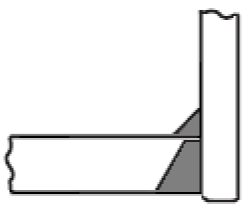
Corrosion Allowance                           can       0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle       E1         1.00
Joint Efficiency of Nozzle Neck                En         1.00

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      18.0000  mm.
Inside Projection                               h       0.0000  mm.
Weld leg size, Inside Element to Shell         Wi       0.0000  mm.

Flange Class                                        600
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: K08B (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                    0.660   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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 25.4(exp([62/(138*1]-1)
  = 1.1681 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3870 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   124.3280  mm.
 Parallel to Vessel Wall                        Rn+tn+t    62.1640  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    41.9100  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.286	0.940	NA
Area in Shell	A1	2.712	11.985	NA
Area in Nozzle Wall	A2	13.072	13.727	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	16.784	26.712	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (50.8*16.3*1+2*16.8*16.3*1*(1-1))
  = 8.286 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 )
  = 73.5 ( 1 * 20 - 1 * 16.3 ) - 2 * 16.8
    ( 1 * 20 - 1 * 16.3 ) * ( 1 - 1 )
  = 2.712 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 41.9 )( 16.8 - 1.17 )1
  = 13.072 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

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

```
 Wall Thickness for Internal/External pressures      ta = 1.1681 mm.
```

```
Wall Thickness per UG16(b),                            tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure           trb1 = 16.3119 mm.
Wall Thickness                    tb1 = max(trb1, tr16b) = 16.3119 mm.
Wall Thickness, shell/head, external pressure           trb2 = 0.2648 mm.
Wall Thickness                    tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                           tb3 = 4.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 4.8, max( 16.3, 1.5 ) ]
 = 4.8000 mm.
```

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

```
 = max( ta, tb )
 = max( 1.17, 4.8 )
 = 4.8000 mm.
```

Available Nozzle Neck Thickness = 16.7640 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 = 16.8, tr = 1.17, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.07, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A                7 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -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)        -48 °C
```

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

```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

<u>Weld Size Calculations, Description: K08B (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin     16.7640  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, (8.29 - 2.71 + 2 * 16.8 * 1 *
   (1 * 20 - 16.3 ) )138 )
```

```
  = 93.92 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 13.1 + 0 + 1 - 0 * 1 ) * 138
  = 194.04 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 13.1 + 0 + 1 + ( 6.71 ) ) * 138
  = 286.51 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 13.1 + 0 + 1 + 0 + ( 6.71 ) ) * 138
  = 286.51 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84.3 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 33.8 ) * ( 16.8 - 0 ) * 0.7 * 138
  = 172. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84.3 * ( 18 - 0 ) * 0.74 * 138
  = 243. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.5 + 172 ) = 261 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.5 + 0 + 243 + 0 ) = 333 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.5 + 243 + 0 ) = 333 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 261 kN , must exceed W = 93 kN  or W1 = 194 kN
 Path 2-2 = 332 kN , must exceed W = 93 kN  or W2 = 286 kN
 Path 3-3 = 332 kN , must exceed W = 93 kN  or W3 = 286 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   75.4  bars
```

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

```
Nozzle is O.K. for the External Pressure          1.03  bars
```

The Drop for this Nozzle is : 2.5272 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5272 mm.

Input, Nozzle Desc: K09B (2in) **From: 30**

```
Pressure for Reinforcement Calculations          P      62.104  bars
Temperature for Internal Pressure             Temp         148  °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      706.00  mm.
Design Length of Section                         L   2108.8333  mm.
Shell Finished (Minimum) Thickness               t     20.0000  mm.
Shell Internal Corrosion Allowance               c      0.0000  mm.
Shell External Corrosion Allowance              co      0.0000  mm.

Distance from Bottom/Left Tangent                       694.00  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      137.90  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     16.7640  mm.

Flange Material                                          SA-105
Flange Type                                      Long Weld Neck

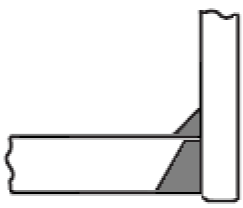
Corrosion Allowance                            can      0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1        1.00
Joint Efficiency of Nozzle Neck                 En        1.00

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     18.0000  mm.
Inside Projection                                h      0.0000  mm.
Weld leg size, Inside Element to Shell          Wi      0.0000  mm.

Flange Class                                          600
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: K09B (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                       0.660  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)
 = (62.1*353)/(138*1-0.6*62.1)
 = 16.3399 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
 = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
 = 25.4(exp([62.1/(138*1]-1)
 = 1.1701 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3870 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl   124.3280  mm.
Parallel to Vessel Wall                        Rn+tn+t    62.1640  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    41.9100  mm.
```

Weld Strength Reduction Factor [fr1]:
```
 = min( 1, Sn/Sv )
 = min( 1, 138/138 )
 = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.301	0.940	NA
Area in Shell	A1	2.691	11.985	NA
Area in Nozzle Wall	A2	13.071	13.727	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	16.762	26.712	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (50.8*16.3*1+2*16.8*16.3*1*(1-1))
  = 8.301 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 )
  = 73.5 ( 1 * 20 - 1 * 16.3 ) - 2 * 16.8
    ( 1 * 20 - 1 * 16.3 ) * ( 1 - 1 )
  = 2.691 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 41.9 )( 16.8 - 1.17 )1
  = 13.071 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 1.1701 mm.
```

```
Wall Thickness per UG16(b),                         tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure        trb1 = 16.3399 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 16.3399 mm.
Wall Thickness, shell/head, external pressure        trb2 = 0.2648 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                          tb3 = 4.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 4.8, max( 16.3, 1.5 ) ]
 = 4.8000 mm.
```

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

```
 = max( ta, tb )
 = max( 1.17, 4.8 )
 = 4.8000 mm.
```

Available Nozzle Neck Thickness = 16.7640 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 = 16.8, tr = 1.17, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.07, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              7 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)        -48 °C
```

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

```
Design Pressure/Ambient Rating = 62.10/102.10 = 0.608
```

Weld Size Calculations, Description: K09B (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin     16.7640  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, (8.3 - 2.69 + 2 * 16.8 * 1 *
   (1 * 20 - 16.3 ) )138 )
```

```
  = 94.27 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 13.1 + 0 + 1 - 0 * 1 ) * 138
  = 194.02 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 13.1 + 0 + 1 + ( 6.71 ) ) * 138
  = 286.48 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 13.1 + 0 + 1 + 0 + ( 6.71 ) ) * 138
  = 286.48 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84.3 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 33.8 ) * ( 16.8 - 0 ) * 0.7 * 138
  = 172. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84.3 * ( 18 - 0 ) * 0.74 * 138
  = 243. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.5 + 172 ) = 261 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.5 + 0 + 243 + 0 ) = 333 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.5 + 243 + 0 ) = 333 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 261 kN , must exceed W = 94 kN  or W1 = 194 kN
 Path 2-2 = 332 kN , must exceed W = 94 kN  or W2 = 286 kN
 Path 3-3 = 332 kN , must exceed W = 94 kN  or W3 = 286 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   75.5  bars
```

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

```
Nozzle is O.K. for the External Pressure          1.03  bars
```

The Drop for this Nozzle is : 2.5272 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5272 mm.

Input, Nozzle Desc: N10A (8in) From: 30

```
Pressure for Reinforcement Calculations          P        62.000  bars
Temperature for Internal Pressure              Temp          148  °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        706.00  mm.
Design Length of Section                         L     2108.8333  mm.
Shell Finished (Minimum) Thickness               t       20.0000  mm.
Shell Internal Corrosion Allowance               c        0.0000  mm.
Shell External Corrosion Allowance              co        0.0000  mm.

Distance from Bottom/Left Tangent                        1650.00  mm.

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

Type of Element Connected to the Shell : Nozzle

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

Diameter Basis (for tr calc only)                             ID
Layout Angle                                              180.00  deg
Diameter                                                  8.0000  in.

Size and Thickness Basis                                 Minimum
Nominal Thickness                               tn       STD

Flange Material                                           SA-105
Flange Type                                     Weld Neck Flange

Hub Height of Integral Nozzle                    h       80.0000  mm.
Height of Beveled Transition                    L'       22.0000  mm.
Hub Thickness of Integral Nozzle  ( tn or x+tp )         45.0000  mm.
Style of FVC Nozzle                                 Heavy Barrel

Corrosion Allowance                             can       0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle         E1         1.00
Joint Efficiency of Nozzle Neck                  En         1.00

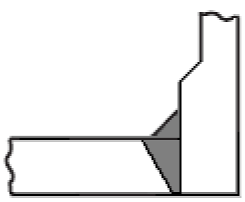
Outside Projection                               ho     200.0000  mm.
Weld leg size between Nozzle and Pad/Shell       Wo      10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv         18.0000  mm.
Inside Projection                                 h       0.0000  mm.
Weld leg size, Inside Element to Shell           Wi       0.0000  mm.
```

```
This is a Manway or Access Opening.

Flange Class                                              600
Flange Grade                                              GR 1.1
```

The Pressure Design option was Design Pressure + static head.

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



Hub Nozzle (Set-in)

Reinforcement CALCULATION, Description: N10A (8in)

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

```
Actual Inside Diameter Used in Calculation                  8.061   in.
Actual Thickness Used in Calculation                        0.282   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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 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)
  = (62*102)/(138*1-0.6*62)
  = 4.7310 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.6750 mm.

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):

Height value from sketch (e-1) [te]:

```
  = ( Hub Thickness - Neck Thickness ) / tan(30)
  = 37.8/0.5773
  = 65.5470 mm.
```

Note: Hub Height was < 2.5 times Hub Thickness, use sketch UG-40 (e-1).

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

```
 Parallel to Vessel Wall (Diameter Limit)             Dl   409.5242  mm.
 Parallel to Vessel Wall, opening length               d   204.7621  mm.
 Normal to Vessel Wall (Thickness Limit), no pad    Tlnp    50.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	33.401	3.788	NA
Area in Shell	A1	7.552	33.377	NA
Area in Nozzle Wall	A2	2.425	6.481	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	37.844	37.844	NA
TOTAL AREA AVAILABLE	Atot	48.821	78.702	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (205*16.3*1+2*45*16.3*1*(1-1))
  = 33.401 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 )
  = 205 ( 1 * 20 - 1 * 16.3 ) - 2 * 45
    ( 1 * 20 - 1 * 16.3 ) * ( 1 - 1 )
  = 7.552 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 50 )( 7.16 - 4.73 )1
  = 2.425 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

Area Available in the Hub Section [A6]:

```
  = ( 2 * min(Tlnp,ho,Hubht)) * (Hubtk - tn) * fr2
  = ( 2 * min(50,200,80 )) * (45 - 7.16 ) * 1 )
  = 37.844 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: A

Govrn. thk, tg = 7.16, tr = 4.73, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.66, Temp. Reduction = 19 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -27 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

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

Govrn. thk, tg = 20, tr = 16.3, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.82, Temp. Reduction = 10 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -7 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -18 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

 Gov. MDMT of the nozzle to shell joint welded assembly :   -29 °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)       -48 °C
```

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

```
 Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

<u>Weld Size Calculations, Description: N10A (8in)</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin    19.0000  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, (33.4 - 7.55 + 2 * 45 * 1 *
    (1 * 20 - 16.3 ) )138 )
  = 402.19 kN
```

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:

```
  = (A2+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 40.3 + 1 - 0 * 1 ) * 138
  = 569.05 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 40.3 + 0 + 1 + ( 18 ) ) * 138
  = 817.25 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 40.3 + 0 + 1 + 0 + ( 18 ) ) * 138
  = 817.25 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 295 * 10 * 0.49 * 138
  = 313. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 125 ) * ( 45 - 0 ) * 0.7 * 138
  = 1704. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 295 * ( 18 - 0 ) * 0.74 * 138
  = 850. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 313 + 1704 ) = 2017 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
```

```
       = ( 313 + 0 + 850 + 0 ) = 1163 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 313 + 850 + 0 ) = 1163 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 2016 kN , must exceed W = 402 kN  or W1 = 569 kN
Path 2-2 = 1163 kN , must exceed W = 402 kN  or W2 = 817 kN
Path 3-3 = 1163 kN , must exceed W = 402 kN  or W3 = 817 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   74.9  bars

Nozzle is O.K. for the External Pressure           1.03  bars
```

The Drop for this Nozzle is : 32.2387 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 252.2386 mm.

Input, Nozzle Desc: N05 (2in) **From: 30**

```
Pressure for Reinforcement Calculations         P       62.152  bars
Temperature for Internal Pressure            Temp          148  °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       706.00  mm.
Design Length of Section                        L    2108.8333  mm.
Shell Finished (Minimum) Thickness              t      20.0000  mm.
Shell Internal Corrosion Allowance              c       0.0000  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       137.90  N./mm²
Allowable Stress At Ambient                   Sna       137.90  N./mm²

Diameter Basis (for tr calc only)                           ID
Layout Angle                                            180.00  deg
Diameter                                                2.0000  in.

Size and Thickness Basis                                 Actual
Actual Thickness                               tn      16.7640  mm.

Flange Material                                          SA-105
Flange Type                                      Long Weld Neck

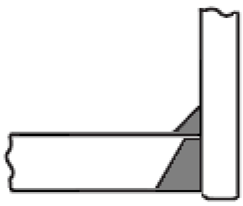
Corrosion Allowance                           can       0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle       E1         1.00
Joint Efficiency of Nozzle Neck                En         1.00

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      18.0000  mm.
Inside Projection                               h       0.0000  mm.
Weld leg size, Inside Element to Shell         Wi       0.0000  mm.

Flange Class                                          600
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                    0.660  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)
  = (62.2*353)/(138*1-0.6*62.2)
  = 16.3530 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 25.4(exp([62.2/(138*1]-1)
  = 1.1710 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3870 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   124.3280  mm.
 Parallel to Vessel Wall                        Rn+tn+t    62.1640  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    41.9100  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
= min( 1, Sn/Sv )
= min( 1, 138/138 )
= 1.000
```

Weld Strength Reduction Factor [fr3]:
```
= min( fr2, fr4 )
= min( 1, 1 )
= 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.307	0.940	NA
Area in Shell	A1	2.682	11.985	NA
Area in Nozzle Wall	A2	13.070	13.727	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	16.752	26.712	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                    90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
= ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
= (50.8*16.4*1+2*16.8*16.4*1*(1-1))
= 8.307 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 )
= 73.5 ( 1 * 20 - 1 * 16.4 ) - 2 * 16.8
  ( 1 * 20 - 1 * 16.4 ) * ( 1 - 1 )
= 2.682 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 41.9 )( 16.8 - 1.17 )1
= 13.070 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
= Wo² * fr2 + ( Wi-can/0.707 )² * fr2
= 10² * 1 + ( 0 )² * 1
= 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 1.1710 mm.
```

```
Wall Thickness per UG16(b),                        tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure       trb1 = 16.3530 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 16.3530 mm.
Wall Thickness, shell/head, external pressure       trb2 = 0.2648 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                        tb3 = 4.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 4.8, max( 16.4, 1.5 ) ]
 = 4.8000 mm.
```

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

```
 = max( ta, tb )
 = max( 1.17, 4.8 )
 = 4.8000 mm.
```

Available Nozzle Neck Thickness = 16.7640 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 = 16.8, tr = 1.17, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.07, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              7 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)        -48 °C
```

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

```
Design Pressure/Ambient Rating = 62.15/102.10 = 0.609
```

Weld Size Calculations, Description: N05 (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin     16.7640  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, (8.31 - 2.68 + 2 * 16.8 * 1 *
   (1 * 20 - 16.4 ) )138 )
```

```
  = 94.43 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 13.1 + 0 + 1 - 0 * 1 ) * 138
  = 194.01 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 13.1 + 0 + 1 + ( 6.71 ) ) * 138
  = 286.47 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 13.1 + 0 + 1 + 0 + ( 6.71 ) ) * 138
  = 286.47 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84.3 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 33.8 ) * ( 16.8 - 0 ) * 0.7 * 138
  = 172. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84.3 * ( 18 - 0 ) * 0.74 * 138
  = 243. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.5 + 172 ) = 261 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.5 + 0 + 243 + 0 ) = 333 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.5 + 243 + 0 ) = 333 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 261 kN , must exceed W = 94 kN  or W1 = 194 kN
 Path 2-2 = 332 kN , must exceed W = 94 kN  or W2 = 286 kN
 Path 3-3 = 332 kN , must exceed W = 94 kN  or W3 = 286 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case    75.5  bars
```

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

```
Nozzle is O.K. for the External Pressure          1.03  bars
```

The Drop for this Nozzle is : 2.5272 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5272 mm.

Input, Nozzle Desc: N04 (1in) **From: 60**

```
Pressure for Reinforcement Calculations          P      62.093  bars
Temperature for Internal Pressure             Temp         148  °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      706.00  mm.
Design Length of Section                         L   2000.0000  mm.
Shell Finished (Minimum) Thickness               t     20.0000  mm.
Shell Internal Corrosion Allowance               c      0.0000  mm.
Shell External Corrosion Allowance              co      0.0000  mm.

Distance from Bottom/Left Tangent                      2499.53  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      137.90  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     14.3000  mm.

Flange Material                                        SA-106 B
Flange Type                                      Long Weld Neck

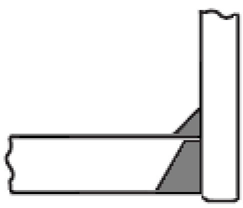
Corrosion Allowance                            can      0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1        1.00
Joint Efficiency of Nozzle Neck                 En        1.00

Outside Projection                              ho    226.1880  mm.
Weld leg size between Nozzle and Pad/Shell      Wo     10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv       18.0000  mm.
Inside Projection                                h      0.0000  mm.
Weld leg size, Inside Element to Shell          Wi      0.0000  mm.

Flange Class                                          600
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: N04 (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                    0.563   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)
  = (62.1*353)/(138*1-0.6*62.1)
  = 16.3371 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 12.7(exp([62.1/(138*1]-1)
  = 0.5850 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3143 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)              Dl     94.0000  mm.
Parallel to Vessel Wall                          Rn+tn+t     47.0000  mm.
Normal to Vessel Wall (Thickness Limit), no pad     Tlnp     35.7500  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	4.150	0.459	NA
Area in Shell	A1	2.513	11.242	NA
Area in Nozzle Wall	A2	9.806	10.000	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	13.319	22.241	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations              90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (25.4*16.3*1+2*14.3*16.3*1*(1-1))
  = 4.150 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 )
  = 68.6 ( 1 * 20 - 1 * 16.3 ) - 2 * 14.3
    ( 1 * 20 - 1 * 16.3 ) * ( 1 - 1 )
  = 2.513 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 35.8 )( 14.3 - 0.58 )1
  = 9.806 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 0.5850 mm.
```

```
Wall Thickness per UG16(b),                         tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure        trb1 = 16.3371 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 16.3371 mm.
Wall Thickness, shell/head, external pressure        trb2 = 0.2648 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                         tb3 = 3.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 3.42, max( 16.3, 1.5 ) ]
= 3.4200 mm.
```

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

```
= max( ta, tb )
= max( 0.58, 3.42 )
= 3.4200 mm.
```

Available Nozzle Neck Thickness = 14.3000 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 = 14.3, tr = 0.58, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.041, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              3 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)       -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.09/102.10 = 0.608
```

<u>Weld Size Calculations, Description: N04 (1in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin     14.3000  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, (4.15 - 2.51 + 2 * 14.3 * 1 *
  (1 * 20 - 16.3 ) )138 )
```

```
  = 37.02 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 9.81 + 0 + 1 - 0 * 1 ) * 138
  = 149.01 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 9.81 + 0 + 1 + ( 5.72 ) ) * 138
  = 227.88 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 9.81 + 0 + 1 + 0 + ( 5.72 ) ) * 138
  = 227.88 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 54 * 10 * 0.49 * 138
  = 57. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 19.8 ) * ( 14.3 - 0 ) * 0.7 * 138
  = 86. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 54 * ( 18 - 0 ) * 0.74 * 138
  = 156. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 57.3 + 86.1 ) = 143 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 57.3 + 0 + 156 + 0 ) = 213 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 57.3 + 156 + 0 ) = 213 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 143 kN , must exceed W = 37 kN  or W1 = 149 kN
 Path 2-2 = 213 kN , must exceed W = 37 kN  or W2 = 227 kN
 Path 3-3 = 213 kN , must exceed W = 37 kN  or W3 = 227 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   75.5  bars
```

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

```
Nozzle is O.K. for the External Pressure          1.03  bars
```

The Drop for this Nozzle is : 1.0341 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 247.2221 mm.

Input, Nozzle Desc: N10B (8in) **From: 60**

Pressure for Reinforcement Calculations	P	62.000	bars
Temperature for Internal Pressure	Temp	148	°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	706.00	mm.
Design Length of Section	L	2000.0000	mm.
Shell Finished (Minimum) Thickness	t	20.0000	mm.
Shell Internal Corrosion Allowance	c	0.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3893.23	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

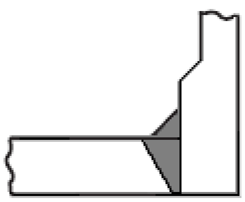
Material [Impact Tested]		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		180.00	deg
Diameter		8.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Hub Height of Integral Nozzle	h	80.0000	mm.
Height of Beveled Transition	L'	22.0000	mm.
Hub Thickness of Integral Nozzle (tn or x+tp)		45.0000	mm.
Corrosion Allowance	can	0.0000	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	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.

This is a Manway or Access Opening.

```
Flange Class                                            600
Flange Grade                                            GR 1.1
```

The Pressure Design option was Design Pressure + static head.

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



Hub Nozzle (Set-in)

Reinforcement CALCULATION, Description: N10B (8in)

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

```
Actual Inside Diameter Used in Calculation                 7.750   in.
Actual Thickness Used in Calculation                       0.438   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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 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)
  = (62*98.4)/(138*1-0.6*62)
  = 4.5482 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.6750 mm.

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):

Height value from sketch (e-1) [te]:
```
  = ( Hub Thickness - Neck Thickness ) / tan(30)
```

```
  = 33.9/0.5773
  = 58.6949 mm.
```

Note: Hub Height was < 2.5 times Hub Thickness, use sketch UG-40 (e-1).

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

```
 Parallel to Vessel Wall (Diameter Limit)           Dl    393.7000  mm.
 Parallel to Vessel Wall, opening length             d    196.8500  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    50.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	32.110	3.556	NA
Area in Shell	A1	7.260	32.258	NA
Area in Nozzle Wall	A2	6.564	10.437	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	33.887	33.887	NA
TOTAL AREA AVAILABLE	Atot	48.712	77.583	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (197*16.3*1+2*45*16.3*1*(1-1))
  = 32.110 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 ( 1 * 20 - 1 * 16.3 ) - 2 * 45
     ( 1 * 20 - 1 * 16.3 ) * ( 1 - 1 )
  = 7.260 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 50 )( 11.1 - 4.55 )1
  = 6.564 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

Area Available in the Hub Section [A6]:

```
  = ( 2 * min(Tlnp,ho,Hubht)) * (Hubtk - tn) * fr2
  = ( 2 * min(50,200,80 )) * (45 - 11.1 ) * 1 )
  = 33.887 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

Note: This Element/Detail was specified as being Impact Tested.

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

Govrn. thk, tg = 20, tr = 16.3, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.82, Temp. Reduction = 10 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -7 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -18 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

 Gov. MDMT of the nozzle to shell joint welded assembly :   -29 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 MDMT of ANSI B16.5/47 flange per Matl. Specification       -18 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2)           -40 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

```
 Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

Weld Size Calculations, Description: N10B (8in)

```
 Intermediate Calc. for nozzle/shell Welds    Tmin     19.0000   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, (32.1 - 7.26 + 2 * 45 * 1 *
     (1 * 20 - 16.3 ) )138 )
  = 388.42 kN
```

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:
```
  = (A2+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 40.5 + 1 - 0 * 1 ) * 138
  = 571.57 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 40.5 + 0 + 1 + ( 18 ) ) * 138
  = 819.77 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 40.5 + 0 + 1 + 0 + ( 18 ) ) * 138
  = 819.77 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 287 * 10 * 0.49 * 138
  = 304. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 121 ) * ( 45 - 0 ) * 0.7 * 138
  = 1650. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 287 * ( 18 - 0 ) * 0.74 * 138
  = 828. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 304 + 1650 ) = 1955 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 304 + 0 + 828 + 0 ) = 1132 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 304 + 828 + 0 ) = 1132 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 1954 kN , must exceed W = 388 kN  or W1 = 571 kN
Path 2-2 = 1132 kN , must exceed W = 388 kN  or W2 = 819 kN
Path 3-3 = 1132 kN , must exceed W = 388 kN  or W3 = 819 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   75.5   bars
```

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

```
Nozzle is O.K. for the External Pressure           1.03   bars
```

The Drop for this Nozzle is : 30.4504 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 250.4504 mm.

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Input, Nozzle Desc: K2B (2in) From: 60

```
Pressure for Reinforcement Calculations         P        62.000  bars
Temperature for Internal Pressure            Temp           148  °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        706.00  mm.
Design Length of Section                        L     2000.0000  mm.
Shell Finished (Minimum) Thickness              t       20.0000  mm.
Shell Internal Corrosion Allowance              c        0.0000  mm.
Shell External Corrosion Allowance             co        0.0000  mm.

Distance from Bottom/Left Tangent                       3770.53  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        137.90  N./mm²
Allowable Stress At Ambient                   Sna        137.90  N./mm²

Diameter Basis (for tr calc only)                           ID
Layout Angle                                             45.00  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

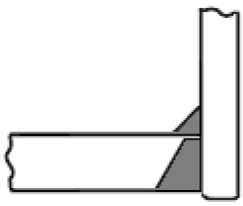
Corrosion Allowance                           can        0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle       E1          1.00
Joint Efficiency of Nozzle Neck                En          1.00

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       18.0000  mm.
Inside Projection                               h        0.0000  mm.
Weld leg size, Inside Element to Shell         Wi        0.0000  mm.

Flange Class                                         600
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: 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.
```

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)
 = (62*353)/(138*1-0.6*62)
 = 16.3119 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
 = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
 = 25.4(exp([62/(138*1]-1)
 = 1.1681 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    124.0000  mm.
Parallel to Vessel Wall                        Rn+tn+t     62.0000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     41.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
 = min( 1, Sn/Sv )
 = min( 1, 138/138 )
 = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.286	0.918	NA
Area in Shell	A1	2.700	11.995	NA
Area in Nozzle Wall	A2	12.808	13.457	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	16.508	26.453	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                    90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (50.8*16.3*1+2*16.6*16.3*1*(1-1))
  = 8.286 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 )
  = 73.2 ( 1 * 20 - 1 * 16.3 ) - 2 * 16.6
    ( 1 * 20 - 1 * 16.3 ) * ( 1 - 1 )
  = 2.700 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 41.5 )( 16.6 - 1.17 )1
  = 12.808 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 1.1681 mm.
```

```
Wall Thickness per UG16(b),                        tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure       trb1 = 16.3119 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 16.3119 mm.
Wall Thickness, shell/head, external pressure       trb2 = 0.2648 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                       tb3 = 4.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 4.8, max( 16.3, 1.5 ) ]
  = 4.8000 mm.
```

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

```
  = max( ta, tb )
  = max( 1.17, 4.8 )
  = 4.8000 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 = 16.6, tr = 1.17, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.07, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              7 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)       -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

<u>Weld Size Calculations, Description: K2B (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin     16.6000  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, (8.29 - 2.7 + 2 * 16.6 * 1 *
     (1 * 20 - 16.3 ) )138 )
```

```
  = 93.92 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 12.8 + 0 + 1 - 0 * 1 ) * 138
  = 190.40 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 12.8 + 0 + 1 + ( 6.64 ) ) * 138
  = 281.96 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 12.8 + 0 + 1 + 0 + ( 6.64 ) ) * 138
  = 281.96 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 33.7 ) * ( 16.6 - 0 ) * 0.7 * 138
  = 170. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84 * ( 18 - 0 ) * 0.74 * 138
  = 242. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.2 + 170 ) = 259 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.2 + 0 + 242 + 0 ) = 331 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.2 + 242 + 0 ) = 331 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 258 kN , must exceed W = 93 kN  or W1 = 190 kN
 Path 2-2 = 331 kN , must exceed W = 93 kN  or W2 = 281 kN
 Path 3-3 = 331 kN , must exceed W = 93 kN  or W3 = 281 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   75.5  bars
```

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

```
Nozzle is O.K. for the External Pressure          1.03  bars
```

The Drop for this Nozzle is : 2.5075 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5075 mm.

Input, Nozzle Desc: K2A (2in) **From: 60**

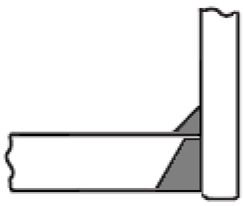
Pressure for Reinforcement Calculations	P	62.000	bars
Temperature for Internal Pressure	Temp	148	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	706.00	mm.
Design Length of Section	L	2000.0000	mm.
Shell Finished (Minimum) Thickness	t	20.0000	mm.
Shell Internal Corrosion Allowance	c	0.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3514.53	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	137.90	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		45.00	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	0.0000	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	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		600	
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: 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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 25.4(exp([62/(138*1]-1)
  = 1.1681 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    124.0000  mm.
 Parallel to Vessel Wall                        Rn+tn+t     62.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     41.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.286	0.918	NA
Area in Shell	A1	2.700	11.995	NA
Area in Nozzle Wall	A2	12.808	13.457	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	16.508	26.453	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                 90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (50.8*16.3*1+2*16.6*16.3*1*(1-1))
  = 8.286 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 )
  = 73.2 ( 1 * 20 - 1 * 16.3 ) - 2 * 16.6
    ( 1 * 20 - 1 * 16.3 ) * ( 1 - 1 )
  = 2.700 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 41.5 )( 16.6 - 1.17 )1
  = 12.808 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 1.1681 mm.
```

```
Wall Thickness per UG16(b),                        tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure       trb1 = 16.3119 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 16.3119 mm.
Wall Thickness, shell/head, external pressure       trb2 = 0.2648 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                         tb3 = 4.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 4.8, max( 16.3, 1.5 ) ]
  = 4.8000 mm.
```

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

```
  = max( ta, tb )
  = max( 1.17, 4.8 )
  = 4.8000 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 = 16.6, tr = 1.17, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.07, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              7 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)       -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

<u>Weld Size Calculations, Description: K2A (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin     16.6000  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, (8.29 - 2.7 + 2 * 16.6 * 1 *
    (1 * 20 - 16.3 ) )138 )
```

```
  = 93.92 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 12.8 + 0 + 1 - 0 * 1 ) * 138
  = 190.40 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 12.8 + 0 + 1 + ( 6.64 ) ) * 138
  = 281.96 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 12.8 + 0 + 1 + 0 + ( 6.64 ) ) * 138
  = 281.96 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 33.7 ) * ( 16.6 - 0 ) * 0.7 * 138
  = 170. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84 * ( 18 - 0 ) * 0.74 * 138
  = 242. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.2 + 170 ) = 259 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.2 + 0 + 242 + 0 ) = 331 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.2 + 242 + 0 ) = 331 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 258 kN , must exceed W = 93 kN  or W1 = 190 kN
 Path 2-2 = 331 kN , must exceed W = 93 kN  or W2 = 281 kN
 Path 3-3 = 331 kN , must exceed W = 93 kN  or W3 = 281 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case    75.5  bars
```

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

```
Nozzle is O.K. for the External Pressure          1.03  bars
```

The Drop for this Nozzle is : 2.5075 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5075 mm.

Input, Nozzle Desc: K3B (2in) From: 60

```
Pressure for Reinforcement Calculations          P       62.074  bars
Temperature for Internal Pressure             Temp          148  °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       706.00  mm.
Design Length of Section                         L    2000.0000  mm.
Shell Finished (Minimum) Thickness               t      20.0000  mm.
Shell Internal Corrosion Allowance               c       0.0000  mm.
Shell External Corrosion Allowance              co       0.0000  mm.

Distance from Bottom/Left Tangent                       2692.53  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       137.90  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

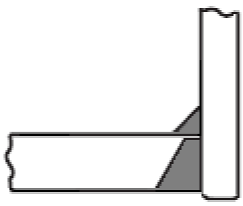
Corrosion Allowance                            can       0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

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        18.0000  mm.
Inside Projection                                h       0.0000  mm.
Weld leg size, Inside Element to Shell          Wi       0.0000  mm.

Flange Class                                          600
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: K3B (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)
  = (62.1*353)/(138*1-0.6*62.1)
  = 16.3320 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 25.4(exp([62.1/(138*1]-1)
  = 1.1695 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    124.0000  mm.
 Parallel to Vessel Wall                        Rn+tn+t     62.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     41.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.297	0.918	NA
Area in Shell	A1	2.685	11.995	NA
Area in Nozzle Wall	A2	12.807	13.457	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	16.492	26.453	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (50.8*16.3*1+2*16.6*16.3*1*(1-1))
  = 8.297 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 )
  = 73.2 ( 1 * 20 - 1 * 16.3 ) - 2 * 16.6
    ( 1 * 20 - 1 * 16.3 ) * ( 1 - 1 )
  = 2.685 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 41.5 )( 16.6 - 1.17 )1
  = 12.807 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 1.1695 mm.
```

```
Wall Thickness per UG16(b),                           tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure          trb1 = 16.3320 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 16.3320 mm.
Wall Thickness, shell/head, external pressure          trb2 = 0.2648 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                           tb3 = 4.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 4.8, max( 16.3, 1.5 ) ]
= 4.8000 mm.
```

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

```
= max( ta, tb )
= max( 1.17, 4.8 )
= 4.8000 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 = 16.6, tr = 1.17, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.07, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              7 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)       -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.07/102.10 = 0.608
```

Weld Size Calculations, Description: K3B (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin     16.6000  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, (8.3 - 2.69 + 2 * 16.6 * 1 *
   (1 * 20 - 16.3 ) )138 )
```

```
  = 94.17 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 12.8 + 0 + 1 - 0 * 1 ) * 138
  = 190.39 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 12.8 + 0 + 1 + ( 6.64 ) ) * 138
  = 281.94 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 12.8 + 0 + 1 + 0 + ( 6.64 ) ) * 138
  = 281.94 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 33.7 ) * ( 16.6 - 0 ) * 0.7 * 138
  = 170. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84 * ( 18 - 0 ) * 0.74 * 138
  = 242. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.2 + 170 ) = 259 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.2 + 0 + 242 + 0 ) = 331 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.2 + 242 + 0 ) = 331 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 258 kN , must exceed W = 94 kN  or W1 = 190 kN
 Path 2-2 = 331 kN , must exceed W = 94 kN  or W2 = 281 kN
 Path 3-3 = 331 kN , must exceed W = 94 kN  or W3 = 281 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   75.5  bars
```

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

```
Nozzle is O.K. for the External Pressure          1.03  bars
```

The Drop for this Nozzle is : 2.5075 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5075 mm.

Input, Nozzle Desc: K3A (2in) From: 60

```
Pressure for Reinforcement Calculations          P      62.049  bars
Temperature for Internal Pressure             Temp         148  °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      706.00  mm.
Design Length of Section                         L   2000.0000  mm.
Shell Finished (Minimum) Thickness               t     20.0000  mm.
Shell Internal Corrosion Allowance               c      0.0000  mm.
Shell External Corrosion Allowance              co      0.0000  mm.

Distance from Bottom/Left Tangent                      2948.53  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      137.90  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

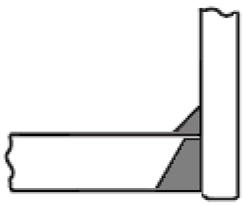
Corrosion Allowance                            can      0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1        1.00
Joint Efficiency of Nozzle Neck                 En        1.00

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     18.0000  mm.
Inside Projection                                h      0.0000  mm.
Weld leg size, Inside Element to Shell          Wi      0.0000  mm.

Flange Class                                          600
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: K3A (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)
  = (62*353)/(138*1-0.6*62)
  = 16.3252 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 25.4(exp([62/(138*1]-1)
  = 1.1691 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    124.0000  mm.
 Parallel to Vessel Wall                          Rn+tn+t     62.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad     Tlnp     41.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.293	0.918	NA
Area in Shell	A1	2.690	11.995	NA
Area in Nozzle Wall	A2	12.808	13.457	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	16.498	26.453	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                 90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (50.8*16.3*1+2*16.6*16.3*1*(1-1))
  = 8.293 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 )
  = 73.2 ( 1 * 20 - 1 * 16.3 ) - 2 * 16.6
    ( 1 * 20 - 1 * 16.3 ) * ( 1 - 1 )
  = 2.690 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 41.5 )( 16.6 - 1.17 )1
  = 12.808 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 1.1691 mm.
```

```
Wall Thickness per UG16(b),                          tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 16.3252 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 16.3252 mm.
Wall Thickness, shell/head, external pressure         trb2 = 0.2648 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                          tb3 = 4.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 4.8, max( 16.3, 1.5 ) ]
= 4.8000 mm.
```

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

```
= max( ta, tb )
= max( 1.17, 4.8 )
= 4.8000 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 = 16.6, tr = 1.17, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.07, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              7 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)       -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.05/102.10 = 0.608
```

<u>Weld Size Calculations, Description: K3A (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin     16.6000  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, (8.29 - 2.69 + 2 * 16.6 * 1 *
   (1 * 20 - 16.3 ) )138 )
```

```
  = 94.08 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 12.8 + 0 + 1 - 0 * 1 ) * 138
  = 190.39 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 12.8 + 0 + 1 + ( 6.64 ) ) * 138
  = 281.95 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 12.8 + 0 + 1 + 0 + ( 6.64 ) ) * 138
  = 281.95 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 33.7 ) * ( 16.6 - 0 ) * 0.7 * 138
  = 170. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84 * ( 18 - 0 ) * 0.74 * 138
  = 242. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.2 + 170 ) = 259 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.2 + 0 + 242 + 0 ) = 331 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.2 + 242 + 0 ) = 331 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 258 kN , must exceed W = 94 kN  or W1 = 190 kN
 Path 2-2 = 331 kN , must exceed W = 94 kN  or W2 = 281 kN
 Path 3-3 = 331 kN , must exceed W = 94 kN  or W3 = 281 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case    75.5  bars
```

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

```
Nozzle is O.K. for the External Pressure          1.03  bars
```

The Drop for this Nozzle is : 2.5075 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5075 mm.

Input, Nozzle Desc: K4B (2in) **From: 60**

```
Pressure for Reinforcement Calculations          P       62.000  bars
Temperature for Internal Pressure             Temp          148  °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       706.00  mm.
Design Length of Section                         L    2000.0000  mm.
Shell Finished (Minimum) Thickness               t      20.0000  mm.
Shell Internal Corrosion Allowance               c       0.0000  mm.
Shell External Corrosion Allowance              co       0.0000  mm.

Distance from Bottom/Left Tangent                       3770.53  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       137.90  N./mm²
Allowable Stress At Ambient                    Sna       137.90  N./mm²

Diameter Basis (for tr calc only)                           ID
Layout Angle                                             315.00  deg
Diameter                                                 3.0000  in.

Size and Thickness Basis                                Actual
Actual Thickness                                tn      20.4000  mm.

Flange Material                                         SA-105
Flange Type                                     Long Weld Neck

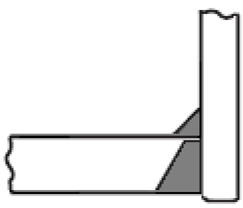
Corrosion Allowance                            can       0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

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       18.0000  mm.
Inside Projection                                h       0.0000  mm.
Weld leg size, Inside Element to Shell          Wi       0.0000  mm.

Flange Class                                         600
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: K4B (2in)

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

```
Actual Inside Diameter Used in Calculation              3.000  in.
Actual Thickness Used in Calculation                    0.803  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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 38.1(exp([62/(138*1]-1)
  = 1.7522 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4698 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    157.0000  mm.
Parallel to Vessel Wall                         Rn+tn+t     78.5000  mm.
Normal to Vessel Wall (Thickness Limit), no pad    Tlnp     50.0000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	12.430	1.376	NA
Area in Shell	A1	2.980	13.241	NA
Area in Nozzle Wall	A2	18.648	19.930	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	22.628	34.171	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (76.2*16.3*1+2*20.4*16.3*1*(1-1))
  = 12.430 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 )
  = 80.8 ( 1 * 20 - 1 * 16.3 ) - 2 * 20.4
    ( 1 * 20 - 1 * 16.3 ) * ( 1 - 1 )
  = 2.980 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 50 )( 20.4 - 1.75 )1
  = 18.648 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 1.7522 mm.
```

```
Wall Thickness per UG16(b),                          tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 16.3119 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 16.3119 mm.
Wall Thickness, shell/head, external pressure         trb2 = 0.2648 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                          tb3 = 5.7300 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 5.73, max( 16.3, 1.5 ) ]
 = 5.7300 mm.
```

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

```
 = max( ta, tb )
 = max( 1.75, 5.73 )
 = 5.7300 mm.
```

Available Nozzle Neck Thickness = 20.4000 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 = 20, tr = 16.3, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.82, Temp. Reduction = 10 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A               12 °C
Min Metal Temp. at Required thickness (UCS 66.1)               2 °C

Gov. MDMT of the nozzle to shell joint welded assembly :       2 °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)        -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

Weld Size Calculations, Description: K4B (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin     19.0000   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, (12.4 - 2.98 + 2 * 20.4 * 1 *
   (1 * 20 - 16.3 ) )138 )
```

```
  = 151.05 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 18.6 + 0 + 1 - 0 * 1 ) * 138
  = 270.92 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 18.6 + 0 + 1 + ( 8.16 ) ) * 138
  = 383.44 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 18.6 + 0 + 1 + 0 + ( 8.16 ) ) * 138
  = 383.44 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 117 * 10 * 0.49 * 138
  = 124. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 48.3 ) * ( 20.4 - 0 ) * 0.7 * 138
  = 299. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 117 * ( 18 - 0 ) * 0.74 * 138
  = 338. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 124 + 299 ) = 423 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 124 + 0 + 338 + 0 ) = 462 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 124 + 338 + 0 ) = 462 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 422 kN , must exceed W = 151 kN  or W1 = 270 kN
 Path 2-2 = 461 kN , must exceed W = 151 kN  or W2 = 383 kN
 Path 3-3 = 461 kN , must exceed W = 151 kN  or W3 = 383 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case    75.5   bars
```

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

```
Nozzle is O.K. for the External Pressure          1.03  bars
```

The Drop for this Nozzle is : 4.8811 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 224.8811 mm.

Input, Nozzle Desc: K4A (2in) **From: 60**

```
Pressure for Reinforcement Calculations          P      62.074  bars
Temperature for Internal Pressure             Temp         148  °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      706.00  mm.
Design Length of Section                         L   2000.0000  mm.
Shell Finished (Minimum) Thickness               t     20.0000  mm.
Shell Internal Corrosion Allowance               c      0.0000  mm.
Shell External Corrosion Allowance              co      0.0000  mm.

Distance from Bottom/Left Tangent                      2692.53  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      137.90  N./mm²
Allowable Stress At Ambient                    Sna      137.90  N./mm²

Diameter Basis (for tr calc only)                           ID
Layout Angle                                            315.00  deg
Diameter                                                3.0000  in.

Size and Thickness Basis                                 Actual
Actual Thickness                                tn     20.4000  mm.

Flange Material                                            SA-105
Flange Type                                      Long Weld Neck

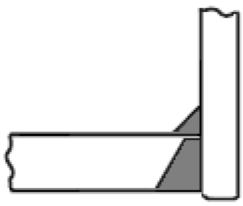
Corrosion Allowance                            can      0.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1        1.00
Joint Efficiency of Nozzle Neck                 En        1.00

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       18.0000  mm.
Inside Projection                                h      0.0000  mm.
Weld leg size, Inside Element to Shell          Wi      0.0000  mm.

Flange Class                                            600
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: K4A (2in)

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

```
Actual Inside Diameter Used in Calculation               3.000   in.
Actual Thickness Used in Calculation                     0.803   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)
 = (62.1*353)/(138*1-0.6*62.1)
 = 16.3320 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
 = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
 = 38.1(exp([62.1/(138*1]-1)
 = 1.7543 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4698 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    157.0000  mm.
Parallel to Vessel Wall                        Rn+tn+t     78.5000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     50.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
 = min( 1, Sn/Sv )
 = min( 1, 138/138 )
 = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	12.445	1.376	NA
Area in Shell	A1	2.964	13.241	NA
Area in Nozzle Wall	A2	18.646	19.930	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	22.609	34.171	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (76.2*16.3*1+2*20.4*16.3*1*(1-1))
  = 12.445 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 )
  = 80.8 ( 1 * 20 - 1 * 16.3 ) - 2 * 20.4
    ( 1 * 20 - 1 * 16.3 ) * ( 1 - 1 )
  = 2.964 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 50 )( 20.4 - 1.75 )1
  = 18.646 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 1.7543 mm.
```

```
Wall Thickness per UG16(b),                          tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 16.3320 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 16.3320 mm.
Wall Thickness, shell/head, external pressure         trb2 = 0.2648 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                          tb3 = 5.7300 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 5.73, max( 16.3, 1.5 ) ]
= 5.7300 mm.
```

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

```
= max( ta, tb )
= max( 1.75, 5.73 )
= 5.7300 mm.
```

Available Nozzle Neck Thickness = 20.4000 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 = 20, tr = 16.3, c = 0 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.82, Temp. Reduction = 10 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              12 °C
Min Metal Temp. at Required thickness (UCS 66.1)             2 °C

Gov. MDMT of the nozzle to shell joint welded assembly :     2 °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)       -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.07/102.10 = 0.608
```

<u>Weld Size Calculations, Description: K4A (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin     19.0000  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, (12.4 - 2.96 + 2 * 20.4 * 1 *
  (1 * 20 - 16.3 ) )138 )
```

```
  = 151.37 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 18.6 + 0 + 1 - 0 * 1 ) * 138
  = 270.89 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 18.6 + 0 + 1 + ( 8.16 ) ) * 138
  = 383.41 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 18.6 + 0 + 1 + 0 + ( 8.16 ) ) * 138
  = 383.41 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 117 * 10 * 0.49 * 138
  = 124. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 48.3 ) * ( 20.4 - 0 ) * 0.7 * 138
  = 299. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 117 * ( 18 - 0 ) * 0.74 * 138
  = 338. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 124 + 299 ) = 423 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 124 + 0 + 338 + 0 ) = 462 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 124 + 338 + 0 ) = 462 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 422 kN , must exceed W = 151 kN  or W1 = 270 kN
 Path 2-2 = 461 kN , must exceed W = 151 kN  or W2 = 383 kN
 Path 3-3 = 461 kN , must exceed W = 151 kN  or W3 = 383 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case    75.5  bars
```

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

```
Nozzle is O.K. for the External Pressure          1.03  bars
```

The Drop for this Nozzle is : 4.8811 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 224.8811 mm.

Input, Nozzle Desc: K10A (2in) From: 90

```
Pressure for Reinforcement Calculations         P       62.000  bars
Temperature for Internal Pressure            Temp          148  °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       700.00  mm.
Design Length of Section                        L    4600.0000  mm.
Shell Finished (Minimum) Thickness              t      20.0000  mm.
Shell Internal Corrosion Allowance              c       3.0000  mm.
Shell External Corrosion Allowance             co       0.0000  mm.

Distance from Bottom/Left Tangent                      4874.05  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       137.90  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

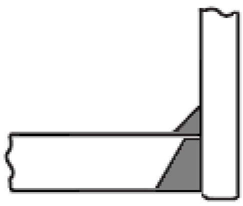
Corrosion Allowance                           can       3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle       E1         1.00
Joint Efficiency of Nozzle Neck                En         1.00

Outside Projection                             ho     200.0000  mm.
Weld leg size between Nozzle and Pad/Shell     Wo      10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv      18.0000  mm.
Inside Projection                               h       0.0000  mm.
Weld leg size, Inside Element to Shell         Wi       0.0000  mm.

Flange Class                                         600
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: 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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 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)
  = (62*28.4)/(138*1-0.6*62)
  = 1.3123 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   118.0000  mm.
 Parallel to Vessel Wall                        Rn+tn+t    59.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    34.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	9.265	1.464	NA
Area in Shell	A1	0.421	7.250	NA
Area in Nozzle Wall	A2	8.356	8.985	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	9.777	17.235	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*16.3*1+2*13.6*16.3*1*(1-1))
  = 9.265 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 )
  = 61.2 ( 1 * 17 - 1 * 16.3 ) - 2 * 13.6
    ( 1 * 17 - 1 * 16.3 ) * ( 1 - 1 )
  = 0.421 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34 )( 13.6 - 1.31 )1
  = 8.356 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 4.3123 mm.
```

```
Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure       trb1 = 19.3119 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 19.3119 mm.
Wall Thickness, shell/head, external pressure       trb2 = 3.2648 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( 19.3, 4.5 ) ]
= 7.8000 mm.
```

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

```
= max( ta, tb )
= max( 4.31, 7.8 )
= 7.8000 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 = 16.6, tr = 1.31, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.096, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              7 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)        -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

<u>Weld Size Calculations, Description: K10A (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000   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, (9.27 - 0.42 + 2 * 13.6 * 1 *
   (1 * 17 - 16.3 ) )138 )
```

```
  = 124.53 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.36 + 0 + 1 - 0 * 1 ) * 138
  = 129.00 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.36 + 0 + 1 + ( 4.62 ) ) * 138
  = 192.76 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.36 + 0 + 1 + 0 + ( 4.62 ) ) * 138
  = 192.76 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 35.2 ) * ( 16.6 - 3 ) * 0.7 * 138
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84 * ( 18 - 3 ) * 0.74 * 138
  = 202. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.2 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.2 + 0 + 202 + 0 ) = 291 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.2 + 202 + 0 ) = 291 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 234 kN , must exceed W = 124 kN  or W1 = 129 kN
 Path 2-2 = 291 kN , must exceed W = 124 kN  or W2 = 192 kN
 Path 3-3 = 291 kN , must exceed W = 124 kN  or W3 = 192 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   63.5  bars

 Nozzle is O.K. for the External Pressure           1.03  bars
```

The Drop for this Nozzle is : 2.5291 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5291 mm.

Input, Nozzle Desc: K05 (2in)   **From: 90**

```
Pressure for Reinforcement Calculations         P       62.000  bars
Temperature for Internal Pressure            Temp          148  °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       700.00  mm.
Design Length of Section                        L    4600.0000  mm.
Shell Finished (Minimum) Thickness              t      20.0000  mm.
Shell Internal Corrosion Allowance              c       3.0000  mm.
Shell External Corrosion Allowance             co       0.0000  mm.

Distance from Bottom/Left Tangent                      5186.35  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       137.90  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      16.6000  mm.

Flange Material                                        SA-105
Flange Type                                    Long Weld Neck

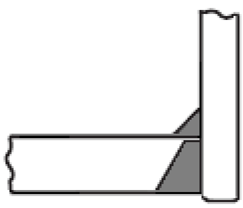
Corrosion Allowance                           can       3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle       E1         1.00
Joint Efficiency of Nozzle Neck                En         1.00

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      18.0000  mm.
Inside Projection                               h       0.0000  mm.
Weld leg size, Inside Element to Shell         Wi       0.0000  mm.

Flange Class                                       600
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: K05 (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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 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)
  = (62*28.4)/(138*1-0.6*62)
  = 1.3123 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    118.0000  mm.
 Parallel to Vessel Wall                        Rn+tn+t     59.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     34.0000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	9.265	1.464	NA
Area in Shell	A1	0.421	7.250	NA
Area in Nozzle Wall	A2	8.356	8.985	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	9.777	17.235	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*16.3*1+2*13.6*16.3*1*(1-1))
  = 9.265 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 )
  = 61.2 ( 1 * 17 - 1 * 16.3 ) - 2 * 13.6
    ( 1 * 17 - 1 * 16.3 ) * ( 1 - 1 )
  = 0.421 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34 )( 13.6 - 1.31 )1
  = 8.356 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 4.3123 mm.
```

```
Wall Thickness per UG16(b),                          tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 19.3119 mm.
Wall Thickness                    tb1 = max(trb1, tr16b) = 19.3119 mm.
Wall Thickness, shell/head, external pressure         trb2 = 3.2648 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( 19.3, 4.5 ) ]
= 7.8000 mm.
```

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

```
= max( ta, tb )
= max( 4.31, 7.8 )
= 7.8000 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 = 16.6, tr = 1.31, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.096, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              7 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)       -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

Weld Size Calculations, Description: K05 (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000   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, (9.27 - 0.42 + 2 * 13.6 * 1 *
  (1 * 17 - 16.3 ) )138 )
```

```
  = 124.53 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.36 + 0 + 1 - 0 * 1 ) * 138
  = 129.00 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.36 + 0 + 1 + ( 4.62 ) ) * 138
  = 192.76 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.36 + 0 + 1 + 0 + ( 4.62 ) ) * 138
  = 192.76 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 35.2 ) * ( 16.6 - 3 ) * 0.7 * 138
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84 * ( 18 - 3 ) * 0.74 * 138
  = 202. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.2 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.2 + 0 + 202 + 0 ) = 291 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.2 + 202 + 0 ) = 291 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 234 kN , must exceed W = 124 kN  or W1 = 129 kN
 Path 2-2 = 291 kN , must exceed W = 124 kN  or W2 = 192 kN
 Path 3-3 = 291 kN , must exceed W = 124 kN  or W3 = 192 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case    63.5  bars

 Nozzle is O.K. for the External Pressure            1.03  bars
```

The Drop for this Nozzle is : 2.5291 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5291 mm.

Input, Nozzle Desc: K10B (2in) **From: 110**

```
Pressure for Reinforcement Calculations          P       62.000  bars
Temperature for Internal Pressure             Temp          148  °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       700.00  mm.
Design Length of Section                         L    4600.0000  mm.
Shell Finished (Minimum) Thickness               t      20.0000  mm.
Shell Internal Corrosion Allowance               c       3.0000  mm.
Shell External Corrosion Allowance              co       0.0000  mm.

Distance from Bottom/Left Tangent                       9247.05  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       137.90  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

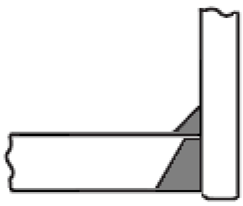
Corrosion Allowance                            can       3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     200.0000  mm.
Weld leg size between Nozzle and Pad/Shell      Wo      10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv        18.0000  mm.
Inside Projection                                h       0.0000  mm.
Weld leg size, Inside Element to Shell          Wi       0.0000  mm.

Flange Class                                           600
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: 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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 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)
  = (62*28.4)/(138*1-0.6*62)
  = 1.3123 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   118.0000  mm.
 Parallel to Vessel Wall                       Rn+tn+t     59.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     34.0000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	9.265	1.464	NA
Area in Shell	A1	0.421	7.250	NA
Area in Nozzle Wall	A2	8.356	8.985	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	9.777	17.235	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                    90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*16.3*1+2*13.6*16.3*1*(1-1))
  = 9.265 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 )
  = 61.2 ( 1 * 17 - 1 * 16.3 ) - 2 * 13.6
    ( 1 * 17 - 1 * 16.3 ) * ( 1 - 1 )
  = 0.421 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34 )( 13.6 - 1.31 )1
  = 8.356 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 4.3123 mm.
```

```
Wall Thickness per UG16(b),                          tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 19.3119 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 19.3119 mm.
Wall Thickness, shell/head, external pressure         trb2 = 3.2648 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( 19.3, 4.5 ) ]
= 7.8000 mm.
```

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

```
= max( ta, tb )
= max( 4.31, 7.8 )
= 7.8000 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 = 16.6, tr = 1.31, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.096, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              7 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)       -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

<u>Weld Size Calculations, Description: K10B (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  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, (9.27 - 0.42 + 2 * 13.6 * 1 *
  (1 * 17 - 16.3 ) )138 )
```

```
  = 124.53 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.36 + 0 + 1 - 0 * 1 ) * 138
  = 129.00 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.36 + 0 + 1 + ( 4.62 ) ) * 138
  = 192.76 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.36 + 0 + 1 + 0 + ( 4.62 ) ) * 138
  = 192.76 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 35.2 ) * ( 16.6 - 3 ) * 0.7 * 138
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84 * ( 18 - 3 ) * 0.74 * 138
  = 202. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.2 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.2 + 0 + 202 + 0 ) = 291 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.2 + 202 + 0 ) = 291 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 234 kN , must exceed W = 124 kN  or W1 = 129 kN
 Path 2-2 = 291 kN , must exceed W = 124 kN  or W2 = 192 kN
 Path 3-3 = 291 kN , must exceed W = 124 kN  or W3 = 192 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case    63.5  bars

 Nozzle is O.K. for the External Pressure            1.03  bars
```

The Drop for this Nozzle is : 2.5291 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5291 mm.

Input, Nozzle Desc: K1 (2in) From: 140

```
Pressure for Reinforcement Calculations         P      62.000  bars
Temperature for Internal Pressure            Temp         148  °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      700.00  mm.
Design Length of Section                        L    971.3333  mm.
Shell Finished (Minimum) Thickness              t     20.0000  mm.
Shell Internal Corrosion Allowance              c      3.0000  mm.
Shell External Corrosion Allowance             co      0.0000  mm.

Distance from Bottom/Left Tangent                     9920.57  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      137.90  N./mm²
Allowable Stress At Ambient                   Sna      137.90  N./mm²

Diameter Basis (for tr calc only)                          ID
Layout Angle                                           225.00  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

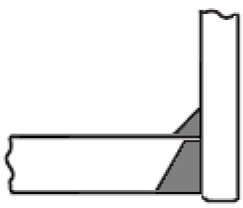
Corrosion Allowance                           can      3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle       E1        1.00
Joint Efficiency of Nozzle Neck                En        1.00

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      20.0000  mm.
Inside Projection                               h      0.0000  mm.
Weld leg size, Inside Element to Shell         Wi      0.0000  mm.

Flange Class                                       600
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: 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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 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)
  = (62*28.4)/(138*1-0.6*62)
  = 1.3123 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   118.0000  mm.
 Parallel to Vessel Wall                        Rn+tn+t    59.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    34.0000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	9.265	0.754	NA
Area in Shell	A1	0.421	8.778	NA
Area in Nozzle Wall	A2	8.356	8.985	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	9.777	18.764	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*16.3*1+2*13.6*16.3*1*(1-1))
  = 9.265 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 )
  = 61.2 ( 1 * 17 - 1 * 16.3 ) - 2 * 13.6
    ( 1 * 17 - 1 * 16.3 ) * ( 1 - 1 )
  = 0.421 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34 )( 13.6 - 1.31 )1
  = 8.356 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 4.3123 mm.
```

```
Wall Thickness per UG16(b),                          tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 19.3119 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 19.3119 mm.
Wall Thickness, shell/head, external pressure         trb2 = 3.2648 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( 19.3, 4.5 ) ]
 = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
 = max( ta, tb )
 = max( 4.31, 7.8 )
 = 7.8000 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 = 16.6, tr = 1.31, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.096, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              7 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)       -40 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

<u>Weld Size Calculations, Description: K1 (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  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, (9.27 - 0.42 + 2 * 13.6 * 1 *
    (1 * 17 - 16.3 ) )138 )
```

```
  = 124.53 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.36 + 0 + 1 - 0 * 1 ) * 138
  = 129.00 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.36 + 0 + 1 + ( 4.62 ) ) * 138
  = 192.76 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.36 + 0 + 1 + 0 + ( 4.62 ) ) * 138
  = 192.76 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 35.2 ) * ( 16.6 - 3 ) * 0.7 * 138
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84 * ( 20 - 3 ) * 0.74 * 138
  = 229. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.2 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.2 + 0 + 229 + 0 ) = 318 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.2 + 229 + 0 ) = 318 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 234 kN , must exceed W = 124 kN  or W1 = 129 kN
 Path 2-2 = 318 kN , must exceed W = 124 kN  or W2 = 192 kN
 Path 3-3 = 318 kN , must exceed W = 124 kN  or W3 = 192 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   63.5  bars

 Nozzle is O.K. for the External Pressure           1.03  bars
```

The Drop for this Nozzle is : 2.5291 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5291 mm.

Input, Nozzle Desc: N06 (2in) From: 140

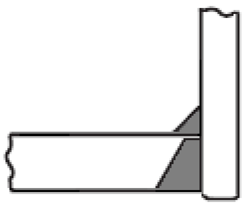
Pressure for Reinforcement Calculations	P	62.000	bars
Temperature for Internal Pressure	Temp	148	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	700.00	mm.
Design Length of Section	L	971.3333	mm.
Shell Finished (Minimum) Thickness	t	20.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		9920.57	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	137.90	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	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	20.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		600	
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: N06 (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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 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)
  = (62*28.4)/(138*1-0.6*62)
  = 1.3123 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   118.0000  mm.
Parallel to Vessel Wall                        Rn+tn+t    59.0000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    34.0000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	9.265	0.754	NA
Area in Shell	A1	0.421	8.778	NA
Area in Nozzle Wall	A2	8.356	8.985	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	9.777	18.764	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                 90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*16.3*1+2*13.6*16.3*1*(1-1))
  = 9.265 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 )
  = 61.2 ( 1 * 17 - 1 * 16.3 ) - 2 * 13.6
    ( 1 * 17 - 1 * 16.3 ) * ( 1 - 1 )
  = 0.421 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34 )( 13.6 - 1.31 )1
  = 8.356 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 4.3123 mm.
```

```
Wall Thickness per UG16(b),                          tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 19.3119 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 19.3119 mm.
Wall Thickness, shell/head, external pressure         trb2 = 3.2648 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( 19.3, 4.5 ) ]
= 7.8000 mm.
```

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

```
= max( ta, tb )
= max( 4.31, 7.8 )
= 7.8000 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 = 16.6, tr = 1.31, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.096, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              7 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)       -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

<u>Weld Size Calculations, Description: N06 (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  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, (9.27 - 0.42 + 2 * 13.6 * 1 *
  (1 * 17 - 16.3 ) )138 )
```

```
  = 124.53 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.36 + 0 + 1 - 0 * 1 ) * 138
  = 129.00 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.36 + 0 + 1 + ( 4.62 ) ) * 138
  = 192.76 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.36 + 0 + 1 + 0 + ( 4.62 ) ) * 138
  = 192.76 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 35.2 ) * ( 16.6 - 3 ) * 0.7 * 138
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84 * ( 20 - 3 ) * 0.74 * 138
  = 229. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.2 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.2 + 0 + 229 + 0 ) = 318 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.2 + 229 + 0 ) = 318 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 234 kN , must exceed W = 124 kN  or W1 = 129 kN
 Path 2-2 = 318 kN , must exceed W = 124 kN  or W2 = 192 kN
 Path 3-3 = 318 kN , must exceed W = 124 kN  or W3 = 192 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case    63.5  bars

 Nozzle is O.K. for the External Pressure            1.03  bars
```

The Drop for this Nozzle is : 2.5291 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5291 mm.

Input, Nozzle Desc: K6A (2in) From: 140

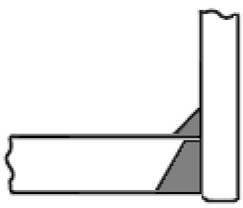
Pressure for Reinforcement Calculations	P	62.000	bars
Temperature for Internal Pressure	Temp	148	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	700.00	mm.
Design Length of Section	L	971.3333	mm.
Shell Finished (Minimum) Thickness	t	20.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		9963.57	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	137.90	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	20.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		600	
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: K6A (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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 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)
  = (62*28.4)/(138*1-0.6*62)
  = 1.3123 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   118.0000  mm.
Parallel to Vessel Wall                       Rn+tn+t    59.0000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    34.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	9.265	0.754	NA
Area in Shell	A1	0.421	8.778	NA
Area in Nozzle Wall	A2	8.356	8.985	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	9.777	18.764	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*16.3*1+2*13.6*16.3*1*(1-1))
  = 9.265 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 )
  = 61.2 ( 1 * 17 - 1 * 16.3 ) - 2 * 13.6
    ( 1 * 17 - 1 * 16.3 ) * ( 1 - 1 )
  = 0.421 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34 )( 13.6 - 1.31 )1
  = 8.356 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 4.3123 mm.
```

```
Wall Thickness per UG16(b),                          tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 19.3119 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 19.3119 mm.
Wall Thickness, shell/head, external pressure         trb2 = 3.2648 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( 19.3, 4.5 ) ]
 = 7.8000 mm.
```

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

```
 = max( ta, tb )
 = max( 4.31, 7.8 )
 = 7.8000 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 = 16.6, tr = 1.31, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.096, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A               7 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -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)        -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

<u>Weld Size Calculations, Description: K6A (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  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, (9.27 - 0.42 + 2 * 13.6 * 1 *
   (1 * 17 - 16.3 ) )138 )
```

```
  = 124.53 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.36 + 0 + 1 - 0 * 1 ) * 138
  = 129.00 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.36 + 0 + 1 + ( 4.62 ) ) * 138
  = 192.76 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.36 + 0 + 1 + 0 + ( 4.62 ) ) * 138
  = 192.76 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 35.2 ) * ( 16.6 - 3 ) * 0.7 * 138
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84 * ( 20 - 3 ) * 0.74 * 138
  = 229. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.2 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.2 + 0 + 229 + 0 ) = 318 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.2 + 229 + 0 ) = 318 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 234 kN , must exceed W = 124 kN  or W1 = 129 kN
 Path 2-2 = 318 kN , must exceed W = 124 kN  or W2 = 192 kN
 Path 3-3 = 318 kN , must exceed W = 124 kN  or W3 = 192 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   63.5  bars

 Nozzle is O.K. for the External Pressure           1.03  bars
```

The Drop for this Nozzle is : 2.5291 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5291 mm.

Input, Nozzle Desc: K6B (2in) **From: 140**

```
Pressure for Reinforcement Calculations         P       62.000  bars
Temperature for Internal Pressure            Temp          148  °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       700.00  mm.
Design Length of Section                        L     971.3333  mm.
Shell Finished (Minimum) Thickness              t      20.0000  mm.
Shell Internal Corrosion Allowance              c       3.0000  mm.
Shell External Corrosion Allowance             co       0.0000  mm.

Distance from Bottom/Left Tangent                     10263.57  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       137.90  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

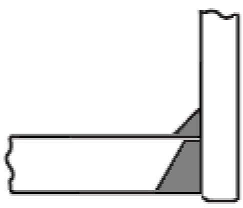
Corrosion Allowance                           can       3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle       E1         1.00
Joint Efficiency of Nozzle Neck                En         1.00

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      20.0000  mm.
Inside Projection                               h       0.0000  mm.
Weld leg size, Inside Element to Shell         Wi       0.0000  mm.

Flange Class                                           600
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: K6B (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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 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)
  = (62*28.4)/(138*1-0.6*62)
  = 1.3123 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   118.0000  mm.
 Parallel to Vessel Wall                        Rn+tn+t    59.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    34.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	9.265	0.754	NA
Area in Shell	A1	0.421	8.778	NA
Area in Nozzle Wall	A2	8.356	8.985	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	9.777	18.764	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*16.3*1+2*13.6*16.3*1*(1-1))
  = 9.265 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 )
  = 61.2 ( 1 * 17 - 1 * 16.3 ) - 2 * 13.6
    ( 1 * 17 - 1 * 16.3 ) * ( 1 - 1 )
  = 0.421 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34 )( 13.6 - 1.31 )1
  = 8.356 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 4.3123 mm.
```

```
Wall Thickness per UG16(b),                          tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 19.3119 mm.
Wall Thickness                   tb1 = max(trb1, tr16b) = 19.3119 mm.
Wall Thickness, shell/head, external pressure         trb2 = 3.2648 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( 19.3, 4.5 ) ]
 = 7.8000 mm.
```

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

```
 = max( ta, tb )
 = max( 4.31, 7.8 )
 = 7.8000 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 = 16.6, tr = 1.31, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.096, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              7 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)        -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

Weld Size Calculations, Description: K6B (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000   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, (9.27 - 0.42 + 2 * 13.6 * 1 *
   (1 * 17 - 16.3 ) )138 )
```

```
  = 124.53 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.36 + 0 + 1 - 0 * 1 ) * 138
  = 129.00 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.36 + 0 + 1 + ( 4.62 ) ) * 138
  = 192.76 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.36 + 0 + 1 + 0 + ( 4.62 ) ) * 138
  = 192.76 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84 * 10 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 35.2 ) * ( 16.6 - 3 ) * 0.7 * 138
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84 * ( 20 - 3 ) * 0.74 * 138
  = 229. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.2 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.2 + 0 + 229 + 0 ) = 318 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.2 + 229 + 0 ) = 318 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 234 kN , must exceed W = 124 kN  or W1 = 129 kN
 Path 2-2 = 318 kN , must exceed W = 124 kN  or W2 = 192 kN
 Path 3-3 = 318 kN , must exceed W = 124 kN  or W3 = 192 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case    63.5   bars

 Nozzle is O.K. for the External Pressure            1.03   bars
```

The Drop for this Nozzle is : 2.5291 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.5291 mm.

Input, Nozzle Desc: N03 (2in) **From: 140**

```
Pressure for Reinforcement Calculations         P        62.000  bars
Temperature for Internal Pressure            Temp           148  °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        700.00  mm.
Design Length of Section                        L      971.3333  mm.
Shell Finished (Minimum) Thickness              t       20.0000  mm.
Shell Internal Corrosion Allowance              c        3.0000  mm.
Shell External Corrosion Allowance             co        0.0000  mm.

Distance from Bottom/Left Tangent                       9823.57  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        137.90  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       14.3000  mm.

Flange Material                                        SA-106 B
Flange Type                                       Long Weld Neck

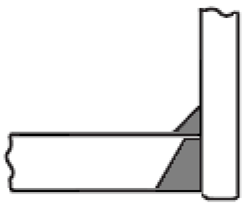
Corrosion Allowance                           can        3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle       E1          1.00
Joint Efficiency of Nozzle Neck                En          1.00

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       20.0000  mm.
Inside Projection                               h        0.0000  mm.
Weld leg size, Inside Element to Shell         Wi        0.0000  mm.

Flange Class                                           600
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: N03 (2in)

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                    0.563  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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 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([62/(138*1]-1)
  = 0.7220 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2982 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     88.0000  mm.
 Parallel to Vessel Wall                        Rn+tn+t     44.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     28.2500  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	5.122	0.417	NA
Area in Shell	A1	0.389	8.118	NA
Area in Nozzle Wall	A2	5.977	6.216	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	7.366	15.334	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (31.4*16.3*1+2*11.3*16.3*1*(1-1))
  = 5.122 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 )
  = 56.6 ( 1 * 17 - 1 * 16.3 ) - 2 * 11.3
    ( 1 * 17 - 1 * 16.3 ) * ( 1 - 1 )
  = 0.389 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 28.3 )( 11.3 - 0.72 )1
  = 5.977 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.7220 mm.
```

```
Wall Thickness per UG16(b),                          tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 19.3119 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 19.3119 mm.
Wall Thickness, shell/head, external pressure         trb2 = 3.2648 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( 19.3, 4.5 ) ]
= 6.4200 mm.
```

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

```
= max( ta, tb )
= max( 3.72, 6.42 )
= 6.4200 mm.
```

Available Nozzle Neck Thickness = 14.3000 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 = 14.3, tr = 0.72, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.064, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A               3 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -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)        -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

Weld Size Calculations, Description: N03 (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin     11.3000  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, (5.12 - 0.39 + 2 * 11.3 * 1 *
   (1 * 17 - 16.3 ) )138 )
```

```
  = 67.40 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 5.98 + 0 + 1 - 0 * 1 ) * 138
  = 96.20 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 5.98 + 0 + 1 + ( 3.84 ) ) * 138
  = 149.18 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 5.98 + 0 + 1 + 0 + ( 3.84 ) ) * 138
  = 149.18 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 54 * 10 * 0.49 * 138
  = 57. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 21.3 ) * ( 14.3 - 3 ) * 0.7 * 138
  = 73. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 54 * ( 20 - 3 ) * 0.74 * 138
  = 147. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 57.3 + 73.2 ) = 130 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 57.3 + 0 + 147 + 0 ) = 204 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 57.3 + 147 + 0 ) = 204 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 130 kN , must exceed W = 67 kN  or W1 = 96 kN
 Path 2-2 = 204 kN , must exceed W = 67 kN  or W2 = 149 kN
 Path 3-3 = 204 kN , must exceed W = 67 kN  or W3 = 149 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   64.5  bars
```

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

```
Nozzle is O.K. for the External Pressure          1.03  bars
```

The Drop for this Nozzle is : 1.0430 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 221.0430 mm.

Input, Nozzle Desc: N10C (8in) From: 140

```
Pressure for Reinforcement Calculations          P       62.000  bars
Temperature for Internal Pressure             Temp          148  °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       700.00  mm.
Design Length of Section                         L     971.3333  mm.
Shell Finished (Minimum) Thickness               t      20.0000  mm.
Shell Internal Corrosion Allowance               c       3.0000  mm.
Shell External Corrosion Allowance              co       0.0000  mm.

Distance from Bottom/Left Tangent                       9963.57  mm.

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

Type of Element Connected to the Shell : Nozzle

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

Diameter Basis (for tr calc only)                           ID
Layout Angle                                             180.00  deg
Diameter                                                 8.0000  in.

Size and Thickness Basis                                  Minimum
Nominal Thickness                               tn        80

Flange Material                                           SA-105
Flange Type                                     Weld Neck Flange

Hub Height of Integral Nozzle                    h      80.0000  mm.
Height of Beveled Transition                    L'      22.0000  mm.
Hub Thickness of Integral Nozzle  ( tn or x+tp )      45.0000  mm.

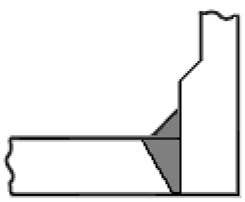
Corrosion Allowance                            can       3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

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      20.0000  mm.
Inside Projection                                h       0.0000  mm.
Weld leg size, Inside Element to Shell          Wi       0.0000  mm.
This is a Manway or Access Opening.
```

```
Flange Class                                                600
Flange Grade                                                GR 1.1
```

The Pressure Design option was Design Pressure + static head.

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



Hub Nozzle (Set-in)

Reinforcement CALCULATION, Description: N10C (8in)

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

```
Actual Inside Diameter Used in Calculation              7.750   in.
Actual Thickness Used in Calculation                    0.438   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)
  = (62*353)/(138*1-0.6*62)
  = 16.3119 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)
  = (62*101)/(138*1-0.6*62)
  = 4.6868 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.6751 mm.

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):

Height value from sketch (e-1) [te]:
```
  = ( Hub Thickness - Neck Thickness ) / tan(30)
```

```
  = 33.9/0.5773
  = 58.6949 mm.
```

Note: Hub Height was < 2.5 times Hub Thickness, use sketch UG-40 (e-1).

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    405.7000  mm.
 Parallel to Vessel Wall, opening length              d    202.8500  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     42.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	33.089	2.694	NA
Area in Shell	A1	1.396	29.096	NA
Area in Nozzle Wall	A2	2.912	6.322	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	28.804	28.804	NA
TOTAL AREA AVAILABLE	Atot	34.112	65.222	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                    90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (203*16.3*1+2*42*16.3*1*(1-1))
  = 33.089 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 )
```

```
  = 203 ( 1 * 17 - 1 * 16.3 ) - 2 * 42
     ( 1 * 17 - 1 * 16.3 ) * ( 1 - 1 )
  = 1.396 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 42.5 )( 8.11 - 4.69 )1
  = 2.912 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

Area Available in the Hub Section [A6]:

```
  = ( 2 * min(Tlnp,ho,Hubht)) * (Hubtk - tn) * fr2
  = ( 2 * min(42.5,200,80 )) * (45 - 11.1 ) * 1 )
  = 28.804 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

Note: This Element/Detail was specified as being Impact Tested.

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

Govrn. thk, tg = 20, tr = 16.3, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.96, Temp. Reduction = 2 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -7 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -10 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

 Gov. MDMT of the nozzle to shell joint welded assembly :   -19 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 MDMT of ANSI B16.5/47 flange per Matl. Specification       -18 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2)           -40 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

```
 Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

<u>Weld Size Calculations, Description: N10C (8in)</u>

```
 Intermediate Calc. for nozzle/shell Welds    Tmin     17.0000   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, (33.1 - 1.4 + 2 * 42 * 1 *
    (1 * 17 - 16.3 ) )138 )
  = 444.98 kN
```

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:
```
  = (A2+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 31.7 + 1 - 0 * 1 ) * 138
  = 451.12 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 31.7 + 0 + 1 + ( 14.3 ) ) * 138
  = 648.02 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 31.7 + 0 + 1 + 0 + ( 14.3 ) ) * 138
  = 648.02 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 287 * 10 * 0.49 * 138
  = 304. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 122 ) * ( 45 - 3 ) * 0.7 * 138
  = 1559. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 287 * ( 20 - 3 ) * 0.74 * 138
  = 782. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 304 + 1559 ) = 1864 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 304 + 0 + 782 + 0 ) = 1086 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 304 + 782 + 0 ) = 1086 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 1863 kN , must exceed W = 444 kN  or W1 = 451 kN
Path 2-2 = 1086 kN , must exceed W = 444 kN  or W2 = 648 kN
Path 3-3 = 1086 kN , must exceed W = 444 kN  or W3 = 648 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case    62.9   bars

Nozzle is O.K. for the External Pressure            1.03   bars
```

The Drop for this Nozzle is : 30.7364 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 250.7363 mm.

Input, Nozzle Desc: N02 (6in) **From: 150**

```
Pressure for Reinforcement Calculations         P       62.000  bars
Temperature for Internal Pressure            Temp          148  °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       700.00  mm.
Aspect Ratio of Elliptical Head                Ar         2.00
Head Finished (Minimum) Thickness               t      20.0000  mm.
Head Internal Corrosion Allowance               c       3.0000  mm.
Head External Corrosion Allowance              co       0.0000  mm.

Distance from Head Centerline                  L1       0.0000  mm.

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

Type of Element Connected to the Shell : Nozzle

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

Diameter Basis (for tr calc only)                         ID
Layout Angle                                              0.00  deg
Diameter                                                6.0000  in.

Size and Thickness Basis                               Minimum
Nominal Thickness                              tn      80

Flange Material                                        SA-105
Flange Type                                   Weld Neck Flange

Hub Height of Integral Nozzle                   h      90.0000  mm.
Height of Beveled Transition                   L'      18.0000  mm.
Hub Thickness of Integral Nozzle  ( tn or x+tp )      35.0000  mm.

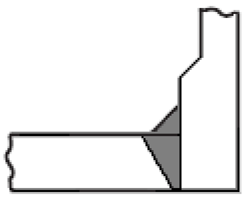
Corrosion Allowance                           can       3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle       E1         1.00
Joint Efficiency of Nozzle Neck                En         1.00

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      15.0000  mm.
Inside Projection                               h       0.0000  mm.
Weld leg size, Inside Element to Shell         Wi       0.0000  mm.
```

```
Flange Class                                         600
Flange Grade                                         GR 1.1
```

The Pressure Design option was Design Pressure + static head.

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



Hub Nozzle (Set-in)

Reinforcement CALCULATION, Description: N02 (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 Elliptical Head, Tr [Int. Press]

```
  = (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
  = (62*0.89*706)/(2 *138*1-0.2*62)
  = 14.2338 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)
  = (62*77.5)/(138*1-0.6*62)
  = 3.5829 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5804 mm.

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):

```
  = 2.5 * Corroded Hub Thickness
  = 2.5 * 32 Note: less than the hub height, use (e-2)
  = 80.0000 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), no pad   Tlnp     42.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 138/138 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 138/138 )
= 1.000
```

Weld Strength Reduction Factor [fr3]:

```
= min( fr2, fr4 )
= min( 1, 1 )
= 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	22.073	1.485	NA
Area in Shell	A1	4.290	23.391	NA
Area in Nozzle Wall	A2	24.155	26.707	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	29.444	51.098	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  90.00   Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
= ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
= (155*14.2*1+2*32*14.2*1*(1-1))
= 22.073 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 ( 1 * 17 - 1 * 14.2 ) - 2 * 32
  ( 1 * 17 - 1 * 14.2 ) * ( 1 - 1 )
= 4.290 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 42.5 )( 32 - 3.58 )1
  = 24.155 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10² * 1 + ( 0 )² * 1
  = 1.000 cm²
```

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

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

```
 Wall Thickness for Internal/External pressures       ta = 6.5829 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 18.7651 mm.
 Wall Thickness                tb1 = max(trb1, tr16b) = 18.7651 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.2618 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( 18.8, 4.5 ) ]
  = 9.2200 mm.
```

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

```
  = max( ta, tb )
  = max( 6.58, 9.22 )
  = 9.2200 mm.
```

Available Nozzle Neck Thickness = 9.6012 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  :      78.3,  Allowable :    137.9 N./mm²  Passed
 Expansion  :       0.0,  Allowable :    266.4 N./mm²  Passed
 Occasional :      34.9,  Allowable :    183.4 N./mm²  Passed
 Shear      :       8.4,  Allowable :     96.5 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: A

Govrn. thk, tg = 9.6, tr = 3.58, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.54, Temp. Reduction = 28 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -35 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

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

Govrn. thk, tg = 20, tr = 14.2, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.84, Temp. Reduction = 9 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B             -7 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -16 °C
Min Metal Temp. w/o impact per UG-20(f)                   -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -29 °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)      -40 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

Weld Size Calculations, Description: N02 (6in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin     19.0000  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, (22.1 - 4.29 + 2 * 32 * 1 *
    (1 * 17 - 14.2 ) )138 )
  = 269.62 kN
```

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:
```
  = (A2+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 24.2 + 1 - 0 * 1 ) * 138
  = 346.85 kN
```

Weld Load [W2]:
```
   = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
  = ( 24.2 + 0 + 1 + ( 10.9 ) ) * 138
  = 496.87 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
  = ( 24.2 + 0 + 1 + 0 ) * 138
  = 496.87 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 219 * 10 * 0.49 * 138
  = 233. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 93.5 ) * ( 35 - 3 ) * 0.7 * 138
  = 908. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 219 * ( 15 - 3 ) * 0.74 * 138
  = 421. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 233 + 908 ) = 1140 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 233 + 0 + 421 + 0 ) = 654 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 233 + 421 + 0 ) = 654 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 1140 kN , must exceed W = 269 kN  or W1 = 346 kN
 Path 2-2 = 653 kN , must exceed W = 269 kN  or W2 = 496 kN
 Path 3-3 = 653 kN , must exceed W = 269 kN  or W3 = 496 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   66.8  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1.03  bars
```

The Drop for this Nozzle is : 9.3543 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 229.3543 mm.

Input Echo, WRC107/537 Item 1, Description: N02 (6in) :

```
 Diameter Basis for Vessel                  Vbasis      ID
 Cylindrical or Spherical Vessel            Cylsph      Spherical
 Internal Corrosion Allowance                  Cas      3.0000  mm.
 Vessel Diameter                                Dv    1260.000  mm.
 Vessel Thickness                               Tv      20.000  mm.

 Design Temperature                             T1       148.0  °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
WRC107 Attachment Classification                  Holsol       Hollow

Diameter Basis for Nozzle                         Nbasis       ID
Corrosion Allowance for Nozzle                       Can       3.0000   mm.
Nozzle Diameter                                       Dn     149.073   mm.
Nozzle Thickness                                      Tn      35.000   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       137.90   N./mm²

Design Internal Pressure                              Dp      62.000   bars
Include Pressure Thrust                                            No
```

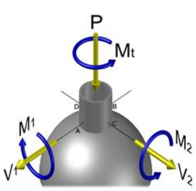
External Forces and Moments in WRC 107/537 Convention:

```
Radial Load              (SUS)                         P          9.6   kN
Longitudinal Shear       (SUS)                 (Vl)   V1          9.6   kN
Circumferential Shear    (SUS)                 (Vc)   V2         -9.6   kN
Circumferential Moment   (SUS)                 (Mc)   M1      -3740.0   N-m
Longitudinal Moment      (SUS)                 (Ml)   M2      -3740.0   N-m
Torsional Moment         (SUS)                        Mt      -4320.0   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 ) )
 = 219.073 + 2 * 1.65 * sqrt( 641.5 ( 20.0 - 3.0 ) )
 = 563.690 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load		P	9.6	kN
Circumferential Shear	(VC)	V2	-9.6	kN
Longitudinal Shear	(VL)	V1	9.6	kN
Circumferential Moment	(MC)	M1	-3740.0	N-m
Longitudinal Moment	(ML)	M2	-3740.0	N-m
Torsional Moment		MT	-4320.0	N-m

Dimensionless Param: U = 1.05 TAU = 5.00 (2.92) RHO = 0.53

Dimensionless Loads for Spherical Shells at Attachment Junction:

Curves read for 1979	Figure	Value	Location
N(x) * T / P	SP 1	0.03873	(A,B,C,D)
M(x) / P	SP 1	0.03987	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / MC	SM 1	0.04607	(A,B,C,D)
M(x) * SQRT(Rm * T) / MC	SM 1	0.07071	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / ML	SM 1	0.04607	(A,B,C,D)
M(x) * SQRT(Rm * T) / ML	SM 1	0.07071	(A,B,C,D)
N(y) * T / P	SP 1	0.06367	(A,B,C,D)
M(y) / P	SP 1	0.01180	(A,B,C,D)
N(y) * T * SQRT(Rm * T) / MC	SM 1	0.06316	(A,B,C,D)
M(y) * SQRT(Rm * T) / MC	SM 1	0.02345	(A,B,C,D)
N(y) * T * SQRT(Rm * T) / ML	SM 1	0.06316	(A,B,C,D)
M(y) * SQRT(Rm * T) / ML	SM 1	0.02345	(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							
Rad. Memb.	P	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3
Rad. Bend.	P	-7.9	7.9	-7.9	7.9	-7.9	7.9	-7.9	7.9
Rad. Memb.	MC	0.0	0.0	0.0	0.0	5.7	5.7	-5.7	-5.7
Rad. Memb.	MC	0.0	0.0	0.0	0.0	52.6	-52.6	-52.6	52.6
Rad. Memb.	ML	5.7	5.7	-5.7	-5.7	0.0	0.0	0.0	0.0
Rad. Bend.	ML	52.6	-52.6	-52.6	52.6	0.0	0.0	0.0	0.0
Tot. Rad.	Str.	49.0	-40.2	-67.5	53.5	49.0	-40.2	-67.5	53.5
Tang. Memb.	P	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1
Tang. Bend.	P	-2.4	2.4	-2.4	2.4	-2.4	2.4	-2.4	2.4
Tang. Memb.	MC	0.0	0.0	0.0	0.0	7.8	7.8	-7.8	-7.8
Tang. Bend.	MC	0.0	0.0	0.0	0.0	17.4	-17.4	-17.4	17.4

```
Tang. Memb. ML |     7.8|      7.8|     -7.8|     -7.8|      0.0|      0.0|      0.0|      0.0|
Tang. Bend. ML |    17.4|    -17.4|    -17.4|     17.4|      0.0|      0.0|      0.0|      0.0|
               |                                                                              |
Tot. Tang. Str.|    20.8|     -9.4|    -29.7|      9.8|     20.8|     -9.4|    -29.7|      9.8|
-----------------------------------------------------------------------------------------------
      Shear VC |    -1.6|     -1.6|      1.6|      1.6|      0.0|      0.0|      0.0|      0.0|
      Shear VL |     0.0|      0.0|      0.0|      0.0|     -1.6|     -1.6|      1.6|      1.6|
      Shear MT |    -3.4|     -3.4|     -3.4|     -3.4|     -3.4|     -3.4|     -3.4|     -3.4|
               |                                                                              |
     Tot. Shear|    -5.0|     -5.0|     -1.7|     -1.7|     -5.0|     -5.0|     -1.7|     -1.7|
-----------------------------------------------------------------------------------------------
     Str. Int. |    49.9|     41.0|     67.6|     53.6|     49.9|     41.0|     67.6|     53.6|

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

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|
-----------------------------------------------------------------------------------------------
Rad.  Pm (SUS) |   115.5|    115.5|    115.5|    115.5|    115.5|    115.5|    115.5|    115.5|
Rad.  Pl (SUS) |     4.4|      4.4|     -7.0|     -7.0|      4.4|      4.4|     -7.0|     -7.0|
Rad.  Q  (SUS) |    44.6|    -44.6|    -60.5|     60.5|     44.6|    -44.6|    -60.5|     60.5|
-----------------------------------------------------------------------------------------------
Long. Pm (SUS) |   115.5|    115.5|    115.5|    115.5|    115.5|    115.5|    115.5|    115.5|
Long. Pl (SUS) |     5.7|      5.7|     -9.9|     -9.9|      5.7|      5.7|     -9.9|     -9.9|
Long. Q  (SUS) |    15.1|    -15.1|    -19.8|     19.8|     15.1|    -15.1|    -19.8|     19.8|
-----------------------------------------------------------------------------------------------
Shear Pm (SUS) |     0.0|      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
Shear Pl (SUS) |    -1.6|     -1.6|      1.6|      1.6|     -1.6|     -1.6|      1.6|      1.6|
Shear Q  (SUS) |    -3.4|     -3.4|     -3.4|     -3.4|     -3.4|     -3.4|     -3.4|     -3.4|
Pm (SUS)       |   115.5|    115.5|    115.5|    115.5|    115.5|    115.5|    115.5|    115.5|
-----------------------------------------------------------------------------------------------
Pm+Pl (SUS)    |   122.3|    122.3|    109.2|    109.2|    122.3|    122.3|    109.2|    109.2|
-----------------------------------------------------------------------------------------------
Pm+Pl+Q (Total)|   165.4|    106.9|     85.8|    169.1|    165.4|    106.9|     85.8|    169.1|
```

Vessel Stress Summation Comparison (N./mm²):

```
Type of        |    Max. S.I.     S.I. Allowable    |       Result      |
Stress Int.    |                                    |                   |
--------------------------------------------------------------------------
Pm (SUS)       |       115.49            137.90     |       Passed      |
Pm+Pl (SUS)    |       122.32            206.85     |       Passed      |
Pm+Pl+Q (TOTAL)|       169.07            413.70     |       Passed      |
```

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: N08 (2in) From: 150

```
Pressure for Reinforcement Calculations          P       62.000  bars
Temperature for Internal Pressure             Temp          148  °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       700.00  mm.
Aspect Ratio of Elliptical Head                 Ar         2.00
Head Finished (Minimum) Thickness                t      20.0000  mm.
Head Internal Corrosion Allowance                c       3.0000  mm.
Head External Corrosion Allowance               co       0.0000  mm.

Distance from Head Centerline                   L1     300.0000  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       137.90  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

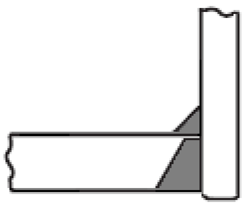
Corrosion Allowance                            can       3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1         1.00
Joint Efficiency of Nozzle Neck                 En         1.00

Outside Projection                              ho     200.0000  mm.
Weld leg size between Nozzle and Pad/Shell      Wo      12.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv        20.0000  mm.
Inside Projection                                h       0.0000  mm.
Weld leg size, Inside Element to Shell          Wi       0.0000  mm.

Flange Class                                          600
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 in the Meridional direction.

Reinforcement CALCULATION, Description: N08 (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 Elliptical Head, Tr [Int. Press]
```
  = (P*D*K)/(2*Sv*E-0.2*P) Appendix 1-4(c)
  = (62*706*0.99)/( 2*138*1-0.2*62)
  = 15.7651 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)
  = (62*28.4)/(138*1-0.6*62)
  = 1.3123 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    149.5337   mm.
 Parallel to Vessel Wall, opening length              d     74.7669   mm.
 Normal to Vessel Wall (Thickness Limit), no pad    Tlnp    34.0000   mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
```

```
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	11.787	0.716	NA
Area in Shell	A1	0.923	11.278	NA
Area in Nozzle Wall	A2	9.498	10.214	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.440	1.440	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.861	22.932	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  49.44  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (74.8*15.8*1+2*13.6*15.8*1*(1-1))
  = 11.787 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 )
  = 74.8 ( 1 * 17 - 1 * 15.8 ) - 2 * 13.6
    ( 1 * 17 - 1 * 15.8 ) * ( 1 - 1 )
  = 0.923 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 34 )( 13.6 - 1.31 )1/sin( 61.6 )
  = 9.498 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
  = 12² * 1 + ( 0 )² * 1
```

```
  = 1.440 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 = 16.6, tr = 1.31, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.096, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              7 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -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)        -40 °C
```

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

```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

Weld Size Calculations, Description: N08 (2in)

```
Intermediate Calc. for nozzle/shell Welds    Tmin     13.6000  mm.
```

Results Per UW-16.1:

```
                          Required Thickness     Actual Thickness
Nozzle Weld             6.0000 = Min per Code 8.4840 = 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, (11.8 - 0.92 + 2 * 13.6 * 1 *
    (1 * 17 - 15.8 ) )138 )
  = 154.43 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 9.5 + 0 + 1.44 - 0 * 1 ) * 138
  = 150.82 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 9.5 + 0 + 1.44 + ( 4.62 ) ) * 138
  = 214.58 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 9.5 + 0 + 1.44 + 0 + ( 4.62 ) ) * 138
```

```
  = 214.58 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 111 * 12 * 0.49 * 138
  = 141. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 46.3 ) * ( 16.6 - 3 ) * 0.7 * 138
  = 191. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 111 * ( 20 - 3 ) * 0.74 * 138
  = 301. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 141 + 191 ) = 332 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 141 + 0 + 301 + 0 ) = 442 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 141 + 301 + 0 ) = 442 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 331 kN , must exceed W = 154 kN  or W1 = 150 kN
 Path 2-2 = 442 kN , must exceed W = 154 kN  or W2 = 214 kN
 Path 3-3 = 442 kN , must exceed W = 154 kN  or W3 = 214 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   62.2  bars

 Nozzle is O.K. for the External Pressure           1.03  bars
```

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: N08 (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 Elliptical Head, Tr [Int. Press]
```
  = (P*D*K)/(2*Sv*E-0.2*P) Appendix 1-4(c)
  = (62*706*0.99)/( 2*138*1-0.2*62)
  = 15.7651 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)
  = (62*28.4)/(138*1-0.6*62)
  = 1.3123 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    118.0000  mm.
 Parallel to Vessel Wall                         Rn+tn+t    59.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad    Tlnp    34.0000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.955	0.544	NA
Area in Shell	A1	0.756	9.232	NA
Area in Nozzle Wall	A2	8.356	8.985	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.440	1.440	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	10.551	19.657	NA

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*15.8*1+2*13.6*15.8*1*(1-1))
  = 8.955 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 )
  = 61.2 ( 1 * 17 - 1 * 15.8 ) - 2 * 13.6
    ( 1 * 17 - 1 * 15.8 ) * ( 1 - 1 )
  = 0.756 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34 )( 13.6 - 1.31 )1
  = 8.356 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 12² * 1 + ( 0 )² * 1
  = 1.440 cm²
```

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

```
Wall Thickness for Internal/External pressures       ta = 4.3123 mm.
Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure      trb1 = 18.7651 mm.
Wall Thickness                   tb1 = max(trb1, tr16b) = 18.7651 mm.
Wall Thickness, shell/head, external pressure      trb2 = 3.2618 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( 18.8, 4.5 ) ]
  = 7.8000 mm.
```

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

```
  = max( ta, tb )
  = max( 4.31, 7.8 )
  = 7.8000 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

<u>Weld Size Calculations, Description: N08 (2in)</u>

```
Intermediate Calc. for nozzle/shell Welds    Tmin      13.6000   mm.
```

Results Per UW-16.1:

```
                           Required Thickness     Actual Thickness
Nozzle Weld              6.0000 = Min per Code 8.4840 = 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, (8.95 - 0.76 + 2 * 13.6 * 1 *
    (1 * 17 - 15.8 ) )138 )
  = 117.68 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.36 + 0 + 1.44 - 0 * 1 ) * 138
  = 135.07 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.36 + 0 + 1.44 + ( 4.62 ) ) * 138
  = 198.83 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.36 + 0 + 1.44 + 0 + ( 4.62 ) ) * 138
  = 198.83 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 84 * 12 * 0.49 * 138
  = 107. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 35.2 ) * ( 16.6 - 3 ) * 0.7 * 138
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 84 * ( 20 - 3 ) * 0.74 * 138
  = 229. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 107 + 145 ) = 252 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 107 + 0 + 229 + 0 ) = 336 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 107 + 229 + 0 ) = 336 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 252 kN , must exceed W = 117 kN  or W1 = 135 kN
 Path 2-2 = 335 kN , must exceed W = 117 kN  or W2 = 198 kN
 Path 3-3 = 335 kN , must exceed W = 117 kN  or W3 = 198 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   66.8  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1.03  bars
```

The Drop for this Nozzle is : 24.0716 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 246.5620 mm.

Listed below are the known problem areas for the current design. If
one or more of the design flags are turned on, please re-run the analysis.
Some of these issues may be resolved when using updated input values.

*** Warning: The Concrete was Overstressed!*

Please review all reports carefully!

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(B&Y) Case

Skirt Data :

Skirt Outside Diameter at Base	SOD	736.0000	mm.
Skirt Thickness	STHK	25.0000	mm.
Skirt Internal Corrosion Allowance	SCA	0.0000	mm.
Skirt External Corrosion Allowance		0.0000	mm.
Skirt Material		SA-516 70	

Basering Input: Type of Geometry: Continuous Top Ring W/Gussets

Thickness of Basering	TBA	80.0000	mm.
Design Temperature of the Basering		85.00	°C
Basering Matl		SA-283 C	
Basering Operating All. Stress	BASOPE	108.25	N./mm²
Basering Yield Stress		191.06	N./mm²
Inside Diameter of Basering	DI	620.0000	mm.
Outside Diameter of Basering	DOU	1060.0000	mm.
Nominal Diameter of Bolts	BND	48.0000	mm.
Bolt Corrosion Allowance	BCA	0.0000	mm.
Bolt Material		SA-193 B7	
Bolt Material Class/Thickness Range		<= 2 1/2	
Bolt Operating Allowable Stress	SA	135.00	N./mm²
Number of Bolts	RN	12	
Diameter of Bolt Circle	DC	960.0000	mm.
Bolt Allowable Shear Stress		81.000	N./mm²
Ultimate Comp. Strength of Concrete	FPC	20.7	N./mm²
Allowable Comp. Strength of Concrete	FC	8.3	N./mm²
Modular ratio Steel/Concrete		9.833	
Thickness of Gusset Plates	TGA	12.0000	mm.
Width of Gussets at Top Plate	TWDT	200.0000	mm.
Width of Gussets at Base Plate	BWDT	162.0000	mm.
Gusset Plate Elastic Modulus	E	199042000.0	KPa.
Gusset Plate Yield Stress	SY	191.1	N./mm²
Height of Gussets	HG	265.0000	mm.
Distance between Gussets	RG	100.0000	mm.
Dist. from Bolt Center to Gusset (Rg/2)	CG	50.0000	mm.
Number of Gussets per bolt	NG	2	
Thickness of Top Plate or Ring	TTA	35.0000	mm.
Radial Width of the Top Plate	TOPWTH	200.0000	mm.
Anchor Bolt Hole Dia. in Top Plate	BHOLE	68.0000	mm.
External Corrosion Allowance	CA	1.6000	mm.
Dead Weight of Vessel	DW	143.0	kN
Operating Weight of Vessel	ROW	153.8	kN

```
Test Weight of Vessel                    TW            150.5   kN
Earthquake Moment on Basering          EQMOM        543250.0   N-m
Wind Moment on Basering                WIMOM         41469.9   N-m
Test Moment on Basering                   TM         20060.6   N-m
Percent Bolt Preload                     ppl           100.0

Use AISC A5.2 Increase in Fc and Bolt Stress              No
Use Allowable Weld Stress per AISC J2.5                   No

Factor for Increase of Allowables      Fact          1.0000
```

Results for Brownell and Young Basering Analysis : Analyze Option

Note: This analysis is based on Neutral Axis shift method for Steel on Concrete (or a material with significantly different Young's modulus).

Calculation of Bolt Loads for Multiple Load Conditions:

Operating Bolt Load, Earthquake Operating Case:

```
= (( 4 * M/DC ) - W ) / RN      per Jawad & Farr, Eq. 12.3
= (( 4 * 543250/960 ) - 154 )/12
= 175.7 kN
```

Operating Bolt Load, Windload Empty Case:

```
= (( 4 * M/DC ) - W ) / RN      per Jawad & Farr, Eq. 12.3
= (( 4 * 41470/960 ) - 143 )/12
= 2.5 kN
```

Operating Bolt Load, Windload Vortex Shedding Case:

```
= (( 4 * M/DC ) - W ) / RN      per Jawad & Farr, Eq. 12.3
= (( 4 * 0/960 ) - 154 )/12
= -12.8 kN
```

Operating Bolt Load, Test Moment Case:

```
= (( 4 * M/DC ) - W ) / RN      per Jawad & Farr, Eq. 12.3
= (( 4 * 20061/960 ) - 151 )/12
= -5.6 kN
```

Governing Bolt Load Condition, Earthquake + Operating Condition:

```
Area Available in one Bolt            Abss :        13.4296   cm²
Area Available in all the Bolts   Abss * RN :      161.1551   cm²
```

Trial#	k	knew	Cc	Ct	z	j	Ft	Fc
2	0.167	0.251	1.110	2.734	0.466	0.773	639.2	792.9
4	0.293	0.272	1.489	2.458	0.439	0.781	637.9	791.7
6	0.282	0.287	1.460	2.481	0.442	0.780	637.9	791.6
8	0.290	0.289	1.482	2.464	0.440	0.781	637.9	791.7
10	0.289	0.289	1.480	2.465	0.440	0.781	637.9	791.7
12	0.289	0.289	1.480	2.466	0.440	0.781	637.9	791.7

The Actual Stress in a Single Bolt [Sbolt]:

```
= 2 * Ft / ( T1 * Dc * Ct )
```

```
  = 2 * 638/( 5.34 * 960 * 2.47 )
  = 101  N./mm², Should be less than 135
```

Thickness of the Band of Bolting Steel [T1]

```
  = RN * Bolt Area / ( 3.14159 * Dc )
  = 12 * 13.4/( 3.14159 * 960 )
  = 5.34 mm.
```

Check the Bearing Stress in the Concrete [fc(max)]

```
  = fc'[( 2kd + t3 ) / ( 2kd )]
  = 4.17[(2*0.29*960+220)/(2*0.29*960)]
  = 5.83 N./mm², Should be less than 8.27
```

Values for table 10.3, l = 162, b = 126, l/b = 1.28915513

Maximum Moment per unit width [Mmax]:

```
  = Max( Mx, My ) = Max( 10.3, 18.6 ) = 18.6 kN
```

Reqd Thickness of Basering, Brownell & Young Method [T]:

```
  = ( 6 * Mmax / fallow )½ + Ca
  = ( 6 * 18.6/126 )½ + 1.6
  = 31.4 mm.
```

Nomenclature:

```
  a   = ( Dc-Ds )/2         Skirt Distance to Bolt Circle
  P   = Sbolt* Abss = Wmax  Maximum Load on one Bolt
  l                         Radial Top Plate Width
  lavg                      Average Gusset Plate Width
  g1  = Gamma 1             Constant Term f( b/l )
  g2  = Gamma 2             Constant Term f( b/l )
  g   = Flat distance / 2   Nut 1/2 Dimension (from Tema)
  Fb                        Allowable Bending Stress
```

Values for table 10.6, l = 200, b = 100, b/l = 0.500
As b/l (0.5) is less than 1, inverting b/l = 2 0.

Moment Term, based on geometry [Mo]:

```
  = P/(4pi) [ 1.3(ln((2lsin(pi*a/l)/(pi*g))) + 1 ] - [ (0.7-g2)P/(4pi) ]
  = 135/(4*3.14) [1.3( ln((2*200 *SIN(3.14* 112/200 ))/
    (3.14 * 40 )) ) + 1] - [(0.7 - 0.022 )* 135/(4 * 3.14)]
  = 19.4436 kN
```

Required Thickness of Continuous Top Ring [Tc]:

```
  = ( 6 * Abs(Mo) / Fb )½  + Ca
  = ( 6 * Abs( 19.4 )/162 )½ + 1.6
  = 28.4053 mm.
```

Required Gusset Plate Thickness [tg]:

```
  = P / ( Stress Term * lavg ) + Ca
  = 135/( 124 * 181 ) + 1.6
  = 11.1 (not less than 9.52 + 1.6 ) mm.
```

Bolt spacing [m]:
```
  = pi * Bolt Circle Diameter / number of Bolts
  = 3.14 * 960/12 = 251 mm.
```

Req. Skirt Thk. to withstand Local Bending, (Brownell and Young) [t]:
  = $1.76 * (P*a/(m * (h + tba) * 1.5 * Sktope))^{2/3} * r^{1/3} + Ca$
  = $1.76*(135*112/(251*345*207))^{2/3}*368^{1/3}+Ca$
  = 11.3 + 0 = 11.3 mm.

Shear Stress in a Single Bolt [taub]:
  = Shear Force / (2 * Bolt Area * Number of Bolts)
  = 60.5/(2 * 13.4 * 12)
  = 1.9 N./mm². Must be less than 81.0 N./mm².

Summary of Basering Thickness Calculations

Required Basering Thickness (tension)	31.3761	mm.
Actual Basering Thickness as entered by user	80.0000	mm.
Required Thickness of Chair Cap	28.4053	mm.
Actual Top Ring Thickness as entered by user	35.0000	mm.
Required Gusset thickness, + CA	11.1250	mm.
Actual Gusset Thickness as entered by user	12.0000	mm.
Required Thickness of Skirt for Local Stress	11.2814	mm.
Given Thickness of Skirt	25.0000	mm.
Required Gusset Height to meet local stress	35.4888	mm.

Weld Size Calculations per Steel Plate Engineering Data - Vol. 2

Compute the Weld load at the Skirt/Base Junction [W]
```
  = SkirtStress * ( SkirtThickness - CA )
  = 59.7 * ( 25 - 0 )
  = 1.49 kN/mm.
```

Results for Computed Minimum Basering Weld Size [BWeld]
```
  = W / [( 0.4 * Yield ) * 2 * 0.707]
  = 1.49/[( 0.4 * 191 ) * 2 * 0.707]
  = 13.8 mm.
```

Results for Computed Minimum Gusset and Top Plate to Skirt Weld Size

Vertical Plate Load [Wv]
```
  = Bolt Load / ( Cmwth + 2 * ( Hg + Tta ) )
  = 135/( 170 + 2 * ( 265 + 35 ) )
  = 0.18 kN/mm.
```

Horizontal Plate Load [Wh]
  = Bolt Load * e / (Cmwth * (Hg+Tta) + 0.6667 * $(Hg+Tta)^2$)
  = 135 * 112/(170 * (300) + 0.6667 * $(300)^2$)
  = 0.14 kN/mm.

Resultant Weld Load [Wr]

```
  = ( Wv² + Wh²)½
  = ( 0.18² + 0.14²)½
  = 0.22 kN/mm.
```

Results for Computed Min Gusset and Top Plate to Skirt Weld Size [GsWeld]

```
  = Wr / [( 0.4 * Yield ) * 2 * 0.707]
  = 0.22/[( 0.4 * 191 ) * 2 * 0.707]
  = 2.06 mm.
```

Results for Computed Minimum Gusset to Top Plate Weld Size

Weld Load [Wv]

```
  = Bolt Load / ( 2 * TopWth )
  = 135/( 2 * 200 )
  = 0.34 kN/mm.
```

Weld Load [Wh]

```
  = Bolt Load * e / ( 2 * Hgt * TopWth )
  = 135 * 112/( 2 * 300 * 200 )
  = 0.13 kN/mm.
```

Resultant Weld Load [Wr]

```
  = ( Wv² + Wh²)½
  = ( 0.34² + 0.13²)½
  = 0.36 kN/mm.
```

Results for Computed Min Gusset to Top Plate Weld Size [GtpWeld]

```
  = Wr / [( 0.4 * Yield ) * 2 * 0.707]
  = 0.36/[( 0.4 * 191 ) * 2 * 0.707]
  = 3.35 mm.
```

Note: The calculated weld sizes need not exceed the component thickness framing into the weld. At the same time, the weld must meet a minimum size specification which is 3/16 in. (4.76 mm) or 1/4 in. (6.35 mm), depending on the component thickness.

Summary of Required Weld Sizes:

```
 Required Basering to Skirt Double Fillet Weld Size      13.8030  mm.
 Required Gusset to Skirt Double Fillet Weld Size         4.7625  mm.
 Required Top Plate to Skirt Weld Size                    6.3500  mm.
 Required Gusset to Top Plate Double Fillet Weld Size     3.3453  mm.
```

Hydrotest Case

Hydrostatic Test Pressure Results:

Pressure per UG99b	= 1.30 * M.A.W.P. * Sa/S	80.840	bars
Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	80.600	bars
Pressure per UG99c	= 1.30 * M.A.P. - Head(Hyd)	81.531	bars
Pressure per UG100	= 1.10 * M.A.W.P. * Sa/S	68.403	bars
Pressure per PED	= max(1.43*DP, 1.25*DP*ratio)	88.660	bars
Pressure per App 27-4	= M.A.W.P.	62.185	bars
User Defined Hydrostatic Test Pressure at High Point		81.740	bars

Horizontal Test performed per: User Hydro Pressure

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
Bottom Head	145.2	235.8	0.616	81.81
30 40	149.3	235.8	0.633	81.81
60 70	149.3	235.8	0.633	81.81
90 100	174.8	235.8	0.741	81.81
100 110	174.8	235.8	0.741	81.81
110 120	174.8	235.8	0.741	81.81
140 150	174.8	235.8	0.741	81.81
Top Head	168.8	235.8	0.716	81.81

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
N07 (1in)	Nozzle	117.90	117.90	1.000
K07A (3in)	Nozzle	137.90	137.90	1.000
K09A (2in)	Nozzle	117.90	117.90	1.000
N01 (6in)	Nozzle	137.90	137.90	1.000
N09 (1in)	Nozzle	137.90	137.90	1.000
K07B (3in)	Nozzle	137.90	137.90	1.000
K08A (2in)	Nozzle	137.90	137.90	1.000
K08B (2in)	Nozzle	137.90	137.90	1.000
K09B (2in)	Nozzle	137.90	137.90	1.000
N10A (8in)	Nozzle	137.90	137.90	1.000
N05 (2in)	Nozzle	137.90	137.90	1.000
N04 (1in)	Nozzle	137.90	137.90	1.000

```
N10B (8in)              |      Nozzle |     137.90 |        137.90 |    1.000 |
K2B (2in)               |      Nozzle |     137.90 |        137.90 |    1.000 |
K2A (2in)               |      Nozzle |     137.90 |        137.90 |    1.000 |
K3B (2in)               |      Nozzle |     137.90 |        137.90 |    1.000 |
K3A (2in)               |      Nozzle |     137.90 |        137.90 |    1.000 |
K4B (2in)               |      Nozzle |     137.90 |        137.90 |    1.000 |
K4A (2in)               |      Nozzle |     137.90 |        137.90 |    1.000 |
K10A (2in)              |      Nozzle |     137.90 |        137.90 |    1.000 |
K05 (2in)               |      Nozzle |     137.90 |        137.90 |    1.000 |
K10B (2in)              |      Nozzle |     137.90 |        137.90 |    1.000 |
K1 (2in)                |      Nozzle |     137.90 |        137.90 |    1.000 |
N06 (2in)               |      Nozzle |     137.90 |        137.90 |    1.000 |
K6A (2in)               |      Nozzle |     137.90 |        137.90 |    1.000 |
K6B (2in)               |      Nozzle |     137.90 |        137.90 |    1.000 |
N03 (2in)               |      Nozzle |     137.90 |        137.90 |    1.000 |
N10C (8in)              |      Nozzle |     137.90 |        137.90 |    1.000 |
N02 (6in)               |      Nozzle |     137.90 |        137.90 |    1.000 |
N08 (2in)               |      Nozzle |     137.90 |        137.90 |    1.000 |
-------------------------------------------------------------------------
Minimum                                                               1.000
```

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

```
Description                          |   Ambient |     Operating |    Ratio |
-------------------------------------------------------------------------
Bottom Head                          |    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 |        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 |        137.90 |    1.000 |
                                     |    137.90 |        137.90 |    1.000 |
                                     |    137.90 |        137.90 |    1.000 |
Top Head                             |    137.90 |        137.90 |    1.000 |
-------------------------------------------------------------------------
Minimum                                                               1.000
```

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

```
Description                          |   Ambient |     Operating |    Ratio |
-------------------------------------------------------------------------
N07 (1in)                            |     18.93 |        217.19 |    0.087 |
K07A (3in)                           |     72.48 |        223.40 |    0.324 |
K09A (2in)                           |     22.19 |        217.19 |    0.102 |
N01 (6in)                            |    107.35 |        223.40 |    0.481 |
N09 (1in)                            |     12.21 |        223.40 |    0.055 |
K07B (3in)                           |     20.19 |        223.40 |    0.090 |
K08A (2in)                           |     17.31 |        223.40 |    0.077 |
```

```
K08B (2in)                        |    17.31 |      223.40 |   0.077 |
K09B (2in)                        |    17.31 |      223.40 |   0.077 |
N10A (8in)                        |   121.96 |      223.40 |   0.546 |
N05 (2in)                         |    17.31 |      223.40 |   0.077 |
N04 (1in)                         |    12.17 |      223.40 |   0.054 |
N10B (8in)                        |    77.37 |      223.40 |   0.346 |
K2B (2in)                         |    17.43 |      223.40 |   0.078 |
K2A (2in)                         |    17.43 |      223.40 |   0.078 |
K3B (2in)                         |    17.43 |      223.40 |   0.078 |
K3A (2in)                         |    17.43 |      223.40 |   0.078 |
K4B (2in)                         |    20.19 |      223.40 |   0.090 |
K4A (2in)                         |    20.19 |      223.40 |   0.090 |
K10A (2in)                        |    21.99 |      223.40 |   0.098 |
K05 (2in)                         |    21.99 |      223.40 |   0.098 |
K10B (2in)                        |    21.99 |      223.40 |   0.098 |
K1 (2in)                          |    21.99 |      223.40 |   0.098 |
N06 (2in)                         |    21.99 |      223.40 |   0.098 |
K6A (2in)                         |    21.99 |      223.40 |   0.098 |
K6B (2in)                         |    21.99 |      223.40 |   0.098 |
N03 (2in)                         |    16.28 |      223.40 |   0.073 |
N10C (8in)                        |   107.19 |      223.40 |   0.480 |
N02 (6in)                         |   101.01 |      223.40 |   0.452 |
N08 (2in)                         |    21.99 |      223.40 |   0.098 |
-----------------------------------------------------------------------
```

Elements Suitable for Test Pressure.