طرح نگهداشت و افزایش تولید 27 مخزن

MECHANICAL CALCULATION BOOK FOR GLYCOL PARTICLE FILTER (F-100 A/B)

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\F-100\F

Date of Analysis : Dec 28,2024 1:51pm

PV Elite 2020, January 2020

ASME Code, Section VIII Division 1, 2019

Diameter Spec : 307.181 mm. OD		
Vessel Design Length, Tangent to Tangent	1405.58	mm.
Distance of Bottom Tangent above Grade	100.00	mm.
Specified Datum Line Distance	0.00	mm.
Internal Design Temperature	100	°C
Internal Design Pressure	8.000	bars
External Design Temperature	100	°C
External Design Pressure	1.034	bars
Maximum Allowable Working Pressure	16.977	bars
External Max. Allowable Working Pressure	1.856	bars
Hydrostatic Test Pressure	10.400	bars
Required Minimum Design Metal Temperature	5.0	°C
Warmest Computed Minimum Design Metal Temperature	-44.0	°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-106 B	...	...	K03006	No	No
Head	SA-234 WPB	...	...	K03006	No	No
Flange	SA-105	...	...	K03504	No	No
Nozzle	SA-105	...	...	K03504	No	No
Re-Pad	SA-516 70	...	...	K02700	No	No
Nozzle Flg	SA-105	...	...	K03504	No	No
Leg Baseplate	SA-283 C	...	...	K02401	No	No
Flg Bolting	SA-193 B7	...	<= 2 1/2	G41400	No	No
Leg Bolting	SA-325	...	...		No	No

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

Element Pressures and MAWP (bars & mm.):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
Ellipse	8.130	1.03	25.800	6.0000	Yes	No
Cylinder	8.118	1.03	17.000	6.0000	N/A	No
Body Flg	8.000	1.03	17.700	6.0000	N/A	No
Body Flg	8.000	1.03	17.700	6.0000	N/A	No

Liquid Level: 1326.20 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
Ellipse	50.0	50.0	9.5	9.5	7.5	7.5	1.00	1.00
Cylinder	1250.0	1200.0	9.5	8.3	7.5	7.8	1.00	1.00
Body Flg	1364.3	114.3	...	31.8	...	...	1.00	1.00
Body Flg	1405.6	31.7	...	31.8	...	...	1.00	1.00

Loads for Foundation/Support Design:

Factored Loads:

Total Wind Shear on top of all Legs	0.	kN
Total Earthquake Shear on top of all Legs	1.	kN
Total Wind Moment at top of all Legs	76.	N-m
Total Earthquake Moment at top of all Legs	822.	N-m
Max. Wind Shear on one Leg (top & bottom)	0.	kN
Max. Earthq. Shear on one Leg (top & bottom)	1.	kN
Max. Wind Moment at base of one Leg	106.	N-m
Max. Earthquake Moment at base of one Leg	665.	N-m
Max. Vertical Load (Wt. + Wind) on one Leg	2.	kN
Max. Vertical Load (Wt. + Eq.) on one Leg	6.	kN

Un-Factored Loads:

Total Wind Shear on top of all Legs	0.	kN
Total Earthquake Shear on top of all Legs	1.	kN
Total Wind Moment at top of all Legs	127.	N-m
Total Earthquake Moment at top of all Legs	1174.	N-m
Max. Wind Shear on one Leg (top & bottom)	0.	kN
Max. Earthq. Shear on one Leg (top & bottom)	1.	kN
Max. Wind Moment at base of one Leg	176.	N-m
Max. Earthquake Moment at base of one Leg	950.	N-m
Max. Vertical Load (Wt. + Wind) on one Leg	3.	kN
Max. Vertical Load (Wt. + Eq.) on one Leg	8.	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
LEGS	WRC-107/537	0.629	n/a	Passed
LEGS	WRC-107/537	0.076	n/a	Passed

Weights:

Fabricated - Bare W/O Removable Internals	258.2	kg.
Shop Test - Fabricated + Water (Full)	362.9	kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	271.0	kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	321.0	kg.
Empty - Fab. + Intls. + Details + Wghts.	321.0	kg.
Operating - Empty + Operating Liquid (No CA)	417.3	kg.
Field Test - Empty Weight + Water (Full)	309.4	kg.

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
N04 (1in)	25.8	OK	...	OK	7.50	OK	Passed
N02 (1in)	17	OK	...	OK	7.50	OK	Passed
N03 (1in)	17	OK	...	OK	7.50	OK	Passed
N01 (1in)	17	OK	...	OK	7.50	OK	Passed
N06 (1in)	17	OK	...	OK	7.50	OK	Passed
N05 (1in)	17.7	OK	...	OK	9.42	OK	Passed

Nozzle MAWP Summary:

```
Minimum MAWP Nozzles          :              17 Nozzle  : N06 (1in)
Minimum MAWP Shells/Flanges   :              17 Element :
Minimum MAPnc Shells/Flanges  :            19.6 Element :
-----------------------------------------------------
Computed Vessel M.A.W.P.      :              17 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.
10	N04 (1in)	0.000	0.000	74.800
20	N02 (1in)	150.000	0.000	74.800
20	N03 (1in)	350.000	180.000	74.800
20	N01 (1in)	1150.000	180.000	74.800
20	N06 (1in)	1150.000	0.000	74.800
40	N05 (1in)	0.000	0.000	102.300

The nozzle spacing is computed by the following:

= Sqrt($ll^2 + lc^2$) where

ll - Arc length along the inside vessel surface in the long. direction.

lc - Arc length along the inside vessel surface in the circ. direction

If any interferences/violations are found, they will be noted below.

No interference violations have been detected !

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

Comparing Nozzles on Element from Node: 40 to: 50

Note: No Nozzle pairs found on this element.

UG-39 Nozzle Diameter and Distance to Edge Checks:

Nozzle Description	Nozzle dia. mm.	Head Dia. /2 mm.	Distance from Edge mm.	Nozzle dia./4 mm.
N05 (1in)	37.4	179.89	215.9	9.35

No Multiple Nozzle spacing violations detected!

Bill of Materials:

QTY	DESCRIPTION	MATERIAL
1	ELLIPTICAL HEAD: 2.0 X 1, 9.5mm. THK X 304.8mm. ID X 50.0mm.	SA-234 WPB
1	CYLINDER: 9.5mm. THK X 307.2mm. ID X 1200.0mm.	SA-106 B
1	BODY FLANGE: 31.8mm. THK X 304.8mm. OD	SA-105
1	BODY FLANGE: 31.8mm. THK X 482.6mm. OD	SA-105
1	INSULATION: 104mm X 50mm THK	
1	INSULATION: 1200mm X 50mm THK	
3	LEGS, SHAPE: L60X60X8 999mm	...
3	BASEPLATES: 150mm X 150mm X 15mm	SA-283 C
3	BASEPLATE BOLTS: 20mm	SA-325
3	LEG RE-PADS: 100mm X 100mm X 8mm	SA-106 B
1	INSULATION: 101mm X 50mm THK	
1	INSULATION: 28mm X 50mm THK	
1	GASKET: 374mm. OD X 339mm. ID	...
12	BODY FLANGE BOLTS: 22mm. DIA	SA-193 B7
24	NUTS FOR BODY FLANGE BOLTS: 22mm. 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
N04 (1in)	1.000 in	Actual	LW	2.000	12.700	...	...	160.6	150
N02 (1in)	1.000 in	Actual	LW	2.000	12.700	...	...	160.4	150
N03 (1in)	1.000 in	Actual	LW	2.000	12.700	...	...	160.4	150
N01 (1in)	1.000 in	Actual	LW	2.000	12.700	...	...	160.4	150
N06 (1in)	1.000 in	Actual	LW	2.000	12.700	...	...	160.4	150
N05 (1in)	1.000 in	Actual	LW	2.000	12.700	150.00	8.00	231.8	150

General Notes for the above table:

The Cut Length is the Outside Projection + Inside Projection + Drop +
In Plane Shell Thickness. This value does not include weld gaps,

nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must
be increased. The Re-Pad WIDTH around the nozzle is calculated as follows:
Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller
and thinner section.

Nozzle Material and Weld Fillet Leg Size Details (mm.):

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
N04 (1in)	SA-105	8.334	10.000	...	...	...
N02 (1in)	SA-105	8.334	10.000	...	...	...
N03 (1in)	SA-105	8.334	10.000	...	...	...
N01 (1in)	SA-105	8.334	10.000	...	...	...
N06 (1in)	SA-105	8.334	10.000	...	...	...
N05 (1in)	SA-105	31.750	8.000	8.000	8.000	...

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
N04 (1in)	...	0.0	150.00	0.00	Node: 10
N02 (1in)	150.000	0.0	150.00	0.00	Node: 20
N03 (1in)	350.000	180.0	150.00	0.00	Node: 20
N01 (1in)	1150.000	180.0	150.00	0.00	Node: 20
N06 (1in)	1150.000	0.0	150.00	0.00	Node: 20
N05 (1in)	...	0.0	200.00	0.00	Node: 40

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
Nozzle Flg	[5]	A	-18	-48					
Nozzle Flg	[5]	A	-18	-48					
	[10]	B	-29	-48	-29	0.627	9.525	1.00	Yes
	[7]	B	-29	-48	-29	0.663	9.525	1.00	Yes
	[8]	B	-29	-48	-29	0.494	8.334	1.00	Yes
N04 (1in)	[1]	A	-8	-104	-29	0.269	9.525	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
N02 (1in)	[1]	A	-8	-44	-29	0.472	8.334	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
N03 (1in)	[1]	A	-8	-44	-29	0.471	8.334	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
N01 (1in)	[1]	A	-8	-45	-29	0.466	8.334	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
N06 (1in)	[1]	A	-8	-45	-29	0.466	8.334	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
N05 (1in)	[1]	A	-8	-104	-29	0.054	8.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-48					
Bolting	[21]		-48						
Warmest MDMT:			-8	-44					

Required Minimum Design Metal Temperature 5.0 °C
Warmest Computed Minimum Design Metal Temperature -44.0 °C

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

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

UCS-66(i) was not considered.

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

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

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

There were no geometry errors or warnings.

PV Elite Vessel Analysis Program: Input Data

Design Internal Pressure (for Hydrotest)	8	bars
Design Internal Temperature	100.0	°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	N	
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		2.500
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	Elliptical	
Description		
Distance "FROM" to "TO"	50	mm.
Element Outside Diameter	323.85	mm.
Element Thickness	9.525	mm.
Internal Corrosion Allowance	6	mm.

Nominal Thickness	9.525	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	8	bars
Design Temperature Internal Pressure	100	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-234 WPB	
Allowable Stress, Ambient	117.9	N./mm²
Allowable Stress, Operating	117.9	N./mm²
Allowable Stress, Hydrotest	217.2	N./mm²
Material Density	7750.4	kg/m³
P Number Thickness	30.988	mm.
Yield Stress, Operating	220.3	N./mm²
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K03006	
Product Form	Smls. & wld. fittings	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	
Element From Node	10	
Detail Type	Liquid	
Detail ID	Liquid: 10	
Dist. from "FROM" Node / Offset dist	-76.2	mm.
Height/Length of Liquid	126.2	mm.
Liquid Density	999.54	kg/m³
Element From Node	10	
Detail Type	Insulation	
Detail ID	Ins: 10	
Dist. from "FROM" Node / Offset dist	-54.769	mm.
Height/Length of Insulation	104.77	mm.
Thickness of Insulation	50	mm.
Density	125	kg/m³
Element From Node	10	
Detail Type	Nozzle	
Detail ID	N04 (1in)	
Dist. from "FROM" Node / Offset dist	0	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.03182	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

Element From Node	20	
Element To Node	30	

Element Type	Cylinder	
Description		
Distance "FROM" to "TO"	1200	mm.
Inside Diameter	307.18	mm.
Element Thickness	8.3344	mm.
Internal Corrosion Allowance	6	mm.
Nominal Thickness	9.525	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	8	bars
Design Temperature Internal Pressure	100	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-106 B	
Allowable Stress, Ambient	117.9	N./mm²
Allowable Stress, Operating	117.9	N./mm²
Allowable Stress, Hydrotest	217.2	N./mm²
Material Density	7750.4	kg/m³
P Number Thickness	29.007	mm.
Yield Stress, Operating	220.3	N./mm²
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K03006	
Product Form	Smls. pipe	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	
Element From Node	20	
Detail Type	Liquid	
Detail ID	Liquid: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1200	mm.
Liquid Density	999.54	kg/m³
Element From Node	20	
Detail Type	Insulation	
Detail ID	Ins: 10	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	1200	mm.
Thickness of Insulation	50	mm.
Density	125	kg/m³
Element From Node	20	
Detail Type	Nozzle	
Detail ID	N02 (1in)	
Dist. from "FROM" Node / Offset dist	100	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.03182	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N03 (1in)	
Dist. from "FROM" Node / Offset dist	300	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N01 (1in)	
Dist. from "FROM" Node / Offset dist	1100	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.03182	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N06 (1in)	
Dist. from "FROM" Node / Offset dist	1100	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.03182	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

Element From Node	20	
Detail Type	Leg	
Detail ID	LEGS	
Dist. from "FROM" Node / Offset dist	125	mm.
Diameter at Leg Centerline	377.48	mm.
Leg Orientation	3	
Number of Legs	3	
Section Identifier	L60X60X8	
Length of Legs	1000	mm.

Element From Node	20	
Detail Type	Weight	
Detail ID	FILTER	
Dist. from "FROM" Node / Offset dist	600	mm.
Miscellaneous Weight	0.4903	kN

Offset from Element Centerline	0	mm.

Element From Node	30	
Element To Node	40	
Element Type	Flange	
Description		
Distance "FROM" to "TO"	114.3	mm.
Flange Inside Diameter	304.8	mm.
Element Thickness	31.75	mm.
Internal Corrosion Allowance	6	mm.
Nominal Thickness	0	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	8	bars
Design Temperature Internal Pressure	100	°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	226.5	N./mm²
UCS-66 Chart Curve Designation	A	
External Pressure Chart Name	CS-2	
UNS Number	K03504	
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of Standard Flange	0	kN
Class of Standard Flange		
Grade of Standard Flange		
Weld is pre-Heated	No	
Element From Node	30	
Detail Type	Insulation	
Detail ID	Ins: 10	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	101.6	mm.
Thickness of Insulation	50	mm.
Density	125	kg/m³

Element From Node	40	
Element To Node	50	
Element Type	Flange	
Description		
Distance "FROM" to "TO"	31.75	mm.
Flange Inside Diameter	482.6	mm.
Element Thickness	31.75	mm.
Internal Corrosion Allowance	6	mm.
Nominal Thickness	0	mm.

External Corrosion Allowance	0	mm.
Design Internal Pressure	8	bars
Design Temperature Internal Pressure	100	°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	40	
Detail Type	Insulation	
Detail ID	Ins: 10	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	28.448	mm.
Thickness of Insulation	50	mm.
Density	125	kg/m^3

Element From Node	40	
Detail Type	Nozzle	
Detail ID	N05 (1in)	
Dist. from "FROM" Node / Offset dist	0	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.0471	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

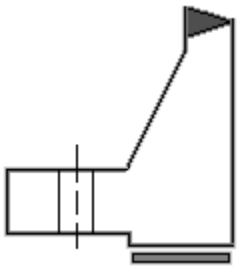
XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
10	20	...	50	...	50
20	30	...	1250	...	1200
30	40	...	1364.3	...	114.3
40	50	...	1405.58	...	31.75

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

Item: Node 30 to 40

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	8.00	bars
Design Temperature		100	°C
Internal Corrosion Allowance	ci	6.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		No	
Flange Inside Diameter	B	304.800	mm.
Flange Outside Diameter	A	482.600	mm.
Flange Thickness	t	31.7500	mm.
Thickness of Hub at Small End	go	8.3344	mm.
Thickness of Hub at Large End	g1	29.0354	mm.
Length of Hub	h	82.5500	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	431.800	mm.
Nominal Bolt Diameter	a	22.2250	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		12	
Flange Face Outside Diameter	Fod	381.000	mm.
Flange Face Inside Diameter	Fid	304.800	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	374.650	mm.
Gasket Inside Diameter	Gi	339.852	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.
Flange Class		150	
Flange Grade		GR 1.1	



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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)
= (8*(305/2+6))/(138*1-0.6*8)+Ca
= 6.9222 mm.

Hub Small End Hub MAWP:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (138 * 1 * 2.33)/(158 + 0.6 * 2.33)
= 20.143 bars

Corroded Flange ID,	Bcor = B+2*Fcor	316.800	mm.
Corroded Large Hub,	g1Cor = g1-ci	23.035	mm.
Corroded Small Hub,	g0Cor = go-ci	2.334	mm.
Code R Dimension,	R = ((C-Bcor)/2)-g1cor	34.465	mm.
Gasket Contact Width,	N = (Go - Gi) / 2	17.399	mm.
Basic Gasket Width,	bo = N / 2	8.699	mm.
Effective Gasket Width,	b = Cb sqrt(bo)	7.432	mm.
Gasket Reaction Diameter,	G = Go - 2 * b	359.785	mm.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
= 0.785 * G² * Peq
= 0.79 * 360² * 8
= 81.331 kN
Contact Load on Gasket Surfaces [Hp]:
= 2 * b * Pi * G * m * P
= 2 * 7.43 * 3.14 * 360 * 3 * 8
= 40.323 kN
Hydrostatic End Load at Flange ID [Hd]:
= Pi * Bcor² * P / 4
= 3.14 * 317² *8/4
= 63.058 kN
Pressure Force on Flange Face [Ht]:
= H - Hd
= 81.3 - 63.1
= 18.273 kN
Operating Bolt Load [Wm1]:
= max(H + Hp + H'p, 0)

```
  = max( 81.3 + 40.3 + 0, 0 )
  = 121.654 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.9*7.43*3.141*360+0*0*0
  = 579.194 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 122/172, 579/172
  = 33.604 cm²
```

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 32.4  * 172/(68.9 * 3.14 * (375 + 340 ) )
  = 3.613 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa * ( Am + Ab ) / 2
  = 172 * ( 33.6 + 32.4 )/2
  = 569.15 kN
```
Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 122 - 81.3
  = 40.32 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
```
  = (C - G ) / 2
  = ( 432 - 360 )/2
  = 36.0075 mm.
```
Distance to Face Pressure Reaction [ht]:
```
  = ( R + g1 + hg ) / 2
  = ( 34.5 + 23 + 36 )/2
  = 46.7537 mm.
```
Distance to End Pressure Reaction [hd]:
```
  = R + ( g1 / 2 )
  = 34.5 + ( 23/2.0 )
  = 45.9823 mm.
```

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

```
Loading                 Force  |   Distance |  Bolt Corr |         Moment  |
-------------------------------------------------------------------------------
End Pressure,   Md         63. |    45.9823 |     1.2110 |           3513. |
Face Pressure,  Mt         18. |    46.7537 |     1.2110 |           1035. |
Gasket Load,    Mg         40. |    36.0075 |     1.2110 |           1759. |
Gasket Seating, Matm      569. |    36.0075 |     1.2110 |          24829. |

Total Moment for Operation,      Mop                              6307. N-m
Total Moment for Gasket seating, Matm                            24829. N-m
```

You chose not to perform Stress Calculations on this Standard Flange.
The pressure rating of the flange will be used to check code compliance.

```
Estimated Finished Weight of Flange at given Thk.        39.2 kg.
Estimated Unfinished Weight of Forging at given Thk      97.4 kg.
```

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)        -48 °C
```

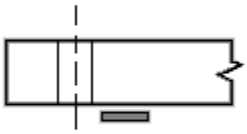
Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
Design Pressure/Ambient Rating = 8.00/19.60 = 0.408
```

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

Item: Node 40 to 50

Description of Flange Geometry (Type)		Blind	
Design Pressure	P	8.00	bars
Design Temperature		100	°C
Internal Corrosion Allowance	ci	6.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Outside Diameter	A	482.600	mm.
Flange Thickness	t	31.7500	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 the Load Reaction, Long Span	D	0.000	mm.
Diameter of the Load Reaction, Short Span	d	0.000	mm.
Perimeter along the Center of the Bolts	L	1356.540	mm.
Diameter of Bolt Circle	C	431.800	mm.
Nominal Bolt Diameter	a	22.2250	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		12	
Flange Face Outside Diameter	Fod	381.000	mm.
Flange Face Inside Diameter	Fid	285.750	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	374.650	mm.
Gasket Inside Diameter	Gi	339.852	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.
Flange Class		150	
Flange Grade		GR 1.1	



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Gasket Contact Width,	N = (Go - Gi) / 2	17.399	mm.
Basic Gasket Width,	bo = N / 2	8.699	mm.
Effective Gasket Width,	b = Cb sqrt(bo)	7.432	mm.
Gasket Reaction Diameter,	G = Go - 2 * b	359.785	mm.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
= 0.785 * G² * Peq
= 0.79 * 360² * 8
= 81.331 kN

Contact Load on Gasket Surfaces [Hp]:
= 2 * b * Pi * G * m * P
= 2 * 7.43 * 3.14 * 360 * 3 * 8
= 40.323 kN

Operating Bolt Load [Wm1]:
= max(H + Hp + H'p, 0)
= max(81.3 + 40.3 + 0, 0)
= 121.654 kN

Gasket Seating Bolt Load [Wm2]:
= y * b * Pi * G + yPart * bPart * lp
= 68.9*7.43*3.141*360+0*0*0
= 579.194 kN

Required Bolt Area [Am]:
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 122/172, 579/172
= 33.604 cm²

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
= Ab * Sa/(y * Pi * (Go + Gi))
= 32.4 * 172/(68.9 * 3.14 * (375 + 340))
= 3.613 mm.

Flange Design Bolt Load, Gasket Seating [W]:
= Sa * (Am + Ab) / 2
= 172 * (33.6 + 32.4)/2
= 569.15 kN

Gasket Load for the Operating Condition [HG]:
= Wm1

= 121.65 kN

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

= (C - G) / 2
= (432 - 360)/2
= 36.0075 mm.

You chose not to perform Stress Calculations on this Standard Flange.
The pressure rating of the flange will be used to check code compliance.

Estimated Finished Weight of Flange at given Thk. 45.0 kg.
Estimated Unfinished Weight of Forging at given Thk 45.0 kg.

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) -48 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 8.00/19.60 = 0.408

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd bars	Nominal Thickness mm.	Total Corr Allowance mm.	Element Diameter mm.	Allowable Stress(SE) N./mm²
10	20	8.13	9.525	6	323.85	117.9
20	30	8.1176	9.525	6	307.18	117.9
30	40	8	...	6	304.8	137.9
40	50	8	...	6	482.6	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.
10	20	8	25.8	73.2	9.525	7.5
20	30	8	17	62	8.33437	7.5
30	40	8	17.7	19.6	31.75	No Calc
40	50	8	17.7	19.6	31.75	No Calc
Minimum			17	19.6		

MAWP: 17 bars, limited by: Cylinder.

Elements Suitable for Design Internal Pressure.

Internal Pressure Calculation Results:

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Elliptical Head From 10 To 20 SA-234 WPB , UCS-66 Crv. B at 100 °C

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:

```
= (P*Do*Kcor)/(2*S*E+2*P*(Kcor-0.1)) per Appendix 1-4 (c)
= (8.13*324*0.95)/(2*118*1+2*8.13*(0.95-0.1))
= 1.0571 + 6.0000 = 7.0571 mm.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

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

Less Operating Hydrostatic Head Pressure of 0.130 bars

```
= (2*S*E*t)/(Kcor*Do-2*t*(Kcor-0.1)) per Appendix 1-4 (c)
= (2*118*1*3.52)/(0.95*324-2*3.52*(0.95-0.1))
= 27.5 - 0.13 = 27.4  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (2*S*E*t)/(K*Do-2*t*(K-0.1)) per Appendix 1-4 (c)
= (2*118*1*9.52)/(1*324-2*9.52*(1-0.1))
```

= 73.2 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*Do-2*t*(Kcor-0.1)))/(2*E*t)
= (8.13*(0.95*324-2*3.52*(0.95-0.1)))/(2*1*3.52)
= 34.871 N./mm²

Straight Flange Required Thickness:
= (P*Ro)/(S*E+0.4*P) + ca per Appendix 1-1 (a)(1)
= (8.13*162)/(118*1+0.4*8.13)+6
= 7.114 mm.

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.123 bars
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (118 * 1 * 3.52)/(162 - 0.4 * 3.52)
= 25.9 - 0.12 = 25.8 bars

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))²)/6
= (2 + (317/(2 * 82.2))²)/6
= 0.952226

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 9.52, tr = 2.21, c = 6 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.63, Temp. Reduction = 21 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 9.52, tr = 2.34, c = 6 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 B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C

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

Cylindrical Shell From 20 To 30 SA-106 B , UCS-66 Crv. B at 100 °C
Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (8.12*160)/(118*1-0.6*8.12)
= 1.1034 + 6.0000 = 7.1034 mm.

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.118 bars

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (118*1*2.33)/(160+0.6*2.33)
= 17.1 - 0.12 = 17  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (118*1*8.33)/(154+0.6*8.33)
= 62 bars
```

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

```
= (P*(R+0.6*t))/(E*t)
= (8.12*(160+0.6*2.33))/(1*2.33)
= 55.987 N./mm²
```

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 8.33, tr = 1.15, c = 6 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.49, Temp. Reduction = 33 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -48 °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          22.070  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S        10.400  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       25.477  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          18.675  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     11.440  bars
Pressure per App 27-4  = M.A.W.P.                        16.977  bars
```

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

```
= Test Factor * Design Pressure * Stress Ratio
= 1.3 * 8 * 1
= 10.400 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
10	20	45.2	217.2	0.208	10.54
20	30	72.6	217.2	0.334	10.53

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
N04 (1in)	Nozzle	137.90	137.90	1.000
N02 (1in)	Nozzle	137.90	137.90	1.000
N03 (1in)	Nozzle	137.90	137.90	1.000
N01 (1in)	Nozzle	137.90	137.90	1.000
N06 (1in)	Nozzle	137.90	137.90	1.000
N05 (1in)	Nozzle	137.90	137.90	1.000
N05 (1in)	Pad	137.90	137.90	1.000
Minimum				1.000

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

Description	Ambient	Operating	Ratio
	117.90	117.90	1.000
	117.90	117.90	1.000
	137.90	137.90	1.000
	137.90	137.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
N04 (1in)	3.58	223.40	0.016
N02 (1in)	3.57	223.40	0.016
N03 (1in)	3.56	223.40	0.016
N01 (1in)	3.54	223.40	0.016
N06 (1in)	3.54	223.40	0.016
N05 (1in)	3.53	223.40	0.016

Elements Suitable for Test Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm²
10	20	No Calc	323.85	3.525	0.0015118	96.9913
20	30	1275.4	323.85	2.33437	0.00019316	19.3115
30	40	No Calc	...	25.75	No Calc	No Calc
40	50	No Calc	...	25.75	No Calc	No Calc

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	9.525	7.5	1.034	11.7
20	30	8.33437	7.83462	1.034	1.86
30	40	31.75	No Calc	1.034	No Calc
40	50	31.75	No Calc	1.034	No Calc
Minimum					1.86

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	1275.4	2176.83	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

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

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

Results for Maximum Allowable Ext. Pressure				MAEP
Tca	Outer Dia	Do/t	Factor A	Factor B
3.525	323.85	91.87	0.0015118	96.99

```
MAEP = B/(K0*Do/t) = 97/(0.9 *91.9 ) = 11.7 bars

                                                |                                 |
Results for Required Thickness                  |                             Tca |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Do/t |  Factor A |                          Factor B |
  0.838 |     323.85 |      386.25 | 0.0003596 |                             35.95 |
-------------------------------------------------------------------------------------
MAEP = B/(K0*Do/t) = 36/(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: K03006

Required Thickness due to Internal Pressure [tr]:

```
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (1.73*317*0.95)/(2*118*1-0.2*1.73)
= 0.2210 + 6.0000 = 6.2210 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*118*1*3.52)/(0.95*317+0.2*3.52))/1.67
= 16.5 bars
```

Maximum Allowable External Pressure [MAEP]:

```
= min( MAEP, MAWP )
= min( 11.7, 16.5 )
= 11.730 bars
```

Thickness requirements per UG-33(a)(1) govern the required thickness of this head.

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

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

Results for Maximum Allowable Ext. Pressure — MAEP

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
2.334	323.85	1275.40	138.73	3.9382	0.0001932	19.31

MAEP = (4*B)/(3*(Do/t)) = (4*19.3)/(3*139) = 1.86 bars

Results for Required Thickness — Tca

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
1.835	323.85	1275.40	176.52	3.9382	0.0001369	13.69

MAEP = (4*B)/(3*(Do/t)) = (4*13.7)/(3*177) = 1.03 bars

Results for Maximum Stiffened Length — Slen

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
2.334	323.85	2176.83	138.73	6.7217	0.0001077	10.76

MAEP = (4*B)/(3*(Do/t)) = (4*10.8)/(3*139) = 1.03 bars

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	12.3745	7356.28	4.57956	8104.59	1.23746
20	30	88.142	88948.4	33.2375	96033.7	8.8142
30	40	39.2067	8527.53	34.0168	9011.23	3.92067
40	50	45.013	...	45.013	...	4.5013
Total		184	104832.26	116	113149.53	18

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Liqd	7.35179	...	-38.1	Liquid: 10
10	Insl	1.24608	...	-2.38437	Ins: 10
10	Nozl	3.56901	...	-201.206	N04 (1in)
20	Liqd	88.8942	...	600	Liquid: 20
20	Insl	8.80887	...	600	Ins: 10
20	Nozl	3.56901	166.291	100	N02 (1in)
20	Nozl	3.56916	166.291	300	N03 (1in)
20	Nozl	3.56901	166.291	1100	N01 (1in)
20	Nozl	3.56901	166.291	1100	N06 (1in)
20	Legs	31.8203	...	-375	LEGS
20	Wght	50	...	600	FILTER
30	Insl	1.36147	...	50.8	Ins: 10
40	Insl	1.4575	...	14.224	Ins: 10
40	Nozl	5.28403	...	131.75	N05 (1in)

Total Weight of Each Detail Type:

Liquid	96.2
Insulation	12.9
Nozzles	23.1
Legs	31.8
Weights	50.0
Sum of the Detail Weights	214.1 kg.

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	203.2	203.2	203.2	203.2	203.2	203.2
Nozzles	23.1	23.1	23.1	23.1	23.1	23.1
Legs	31.8	31.8	31.8	31.8	31.8	31.8
Insulation	...	...	12.9	12.9	12.9	12.9
Empty Weights	...	...	...	50.0	50.0	...

Ope Weights	...	...	...	...	...	50.0
Ope. Liquid	...	...	...	...	...	96.2
Test Liquid	...	104.8	...	...	...	...
Totals	258.2	362.9	271.0	321.0	321.0	417.3

Field Installation Options:

Miscellaneous Weight Percent: 10.0 %

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	258.2 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	362.9 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	271.0 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	321.0 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	321.0 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	417.3 kg.
Field Test Wt.	- Empty Weight + Water (Full)	309.4 kg.
Mass of the Upper 1/3 of the Vertical Vessel		137.2 kg.

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

Outside Surface Areas of Elements:

From	To	Surface Area cm²
10	20	1645.57
20	30	12298.6
30	40	2521.99
40	50	2310.59
Total		18776.781 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	18.4271	25.7789	17.9522	...	18.4271
20	Legs	17.7126	26.9724	16.2106	2.42592	17.7126
Legs	30	152.329	231.963	139.411	20.8629	152.329
30	40	44.4889	44.4889	47.7857	...	44.4889
40	50	56.2559	56.2559	56.2559	...	56.2559

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid kg.	Cumulative Oper. Wgt. kg.	Cumulative Hydro. Wgt. kg.
10	20	...	...	...
20	Legs	-18.4271	-25.7789	-17.9522
Legs	30	253.073	332.708	243.452
30	40	100.745	100.745	104.042
40	50	56.2559	56.2559	56.2559

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	...	...	...
20	Legs	2.42592	2.42592	2.42592
Legs	30	20.8629	20.8629	20.8629
30	40	...	...	...
40	50	...	...	...

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
N04 (1in)	17.70	19.60	100	150	GR 1.1	...	...	...	...
N02 (1in)	17.70	19.60	100	150	GR 1.1	...	...	...	...
N03 (1in)	17.70	19.60	100	150	GR 1.1	...	...	...	...
N01 (1in)	17.70	19.60	100	150	GR 1.1	...	...	...	...
N06 (1in)	17.70	19.60	100	150	GR 1.1	...	...	...	...
N05 (1in)	17.70	19.60	100	150	GR 1.1	...	...	...	...
Min Rating	17.700	19.600 bars [for Core Elements]					0.000	0.000	0.000

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

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

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 19.0594 Hz.

The Natural Frequency for the Vessel (Ope...) is 17.2516 Hz.

The Natural Frequency for the Vessel (Filled) is 19.2682 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*0.23*0.98)/(1+1.7*3.4*0.23)))
= min(0.85, 0.91 )
= 0.850
```

Natural Frequency of Vessel (Operating)		17.252 Hz
Natural Frequency of Vessel (Empty)		19.059 Hz
Natural Frequency of Vessel (Test)		19.268 Hz
Force Coefficient	[Cf]	0.539
Structure Height to Diameter ratio		3.332
Height to top of Structure		1405.575 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
= 104 + 100 = 204 mm.
= 0.67 ft. Imperial Units
```

Velocity Pressure coefficient evaluated at height z [Kz]:

```
Because z (0.67 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]:
$= max(16, 0.00256 * Kz * Kzt * Kd * V(mph)^2)$
$= max(16, 0.00256 * 0.85 * 1 * 0.95 * 74.6^2)$
$= 16$ psf [78.1] Kgs/m²

Force on the first element [F]:
$= qz * G * Cf * WindArea$
$= 16 * 0.85 * 0.54 * 0.86$
$= 6.28$ lbs. [0.028] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m²
Node 10 to 20	204.5	0.000	0.000	0.000	0.849	1.000	78.120
Node 20 to 30	826.2	0.000	0.000	0.000	0.849	1.000	78.120
Node 30 to 40	1483.4	0.000	0.000	0.000	0.849	1.000	78.120
Node 40 to 50	1565.9	0.000	0.000	0.000	0.849	1.000	78.120

Wind Vibration Calculations

This evaluation is based on work by Kanti Mahajan and Ed Zorilla

Nomenclature

Cf - Correction factor for natural frequency
D - Average internal diameter of vessel mm.
Df - Damping Factor < 0.75 Unstable, > 0.95 Stable
Dr - Average internal diameter of top half of vessel mm.
f - Natural frequency of vibration (Hertz)
f1 - Natural frequency of bare vessel based on a unit value of $(D/L^2)(10^4)$
L - Total height of structure mm.
Lc - Total length of conical section(s) of vessel mm.
tb - Uncorroded plate thickness at bottom of vessel mm.
V30 - Design Wind Speed provided by user Km/hr
Vc - Critical wind velocity Km/hr
Vw - Maximum wind speed at top of structure Km/hr
W - Total corroded weight of structure kN

```
Ws  - Cor. vessel weight excl. weight of parts which do not effect stiff. kN
 Z  - Maximum amplitude of vibration at top of vessel mm.
Dl  - Logarithmic decrement ( taken as 0.03 for Welded Structures )
Vp  - Vib. Chance, <= 0.31416E-08 (High); 0.31416E-08 < 0.39270E-08 (Probable)
P30 - wind pressure 30 feet above the base
```

Check other Conditions and Basic Assumptions:

```
#1 - Total Cone Length / Total Length < 0.5
     0/1406 = 0

#2 - ( D / L² ) * 10⁴ < 8.0 (English Units)
   - ( 1.38/4.61² ) * 10⁴ = 651 [Geometry Violation]
```

Compute the vibration possibility. If Vp > 0.39270E-08 no chance. [Vp]:

```
  = W / ( L * Dr²)
  = 3.36/( 1406 * 327² )
  = 0.22377E-07
```

Since Vp is > 0.39270E-08 no further vibration analysis is required !

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm²	Elevation mm.	Pressure Kgs/m²	Force kN
FILTER	0.00	750.00	78.12	0.00

The Natural Frequency for the Vessel (Ope...) is 17.2516 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	204.496	508.62	796.49	78.12	0.016768
20	30	826.2	508.62	6103.44	78.12	0.12849
30	40	1483.35	472.427	539.984	78.12	0.011368
40	50	1565.9	686.64	218.008	78.12	0.0045896

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		2.500
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.)

$= 0.020 * (7.29^{0.75})$

= 0.089 seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

= (1/Natural Frequency) = (1/17.3)

= 0.058

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

= Minimum Value of (1.4 * 0.089, 0.058) per 12.8.2

= 0.058

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

Compute the Base Shear per equation 15.4-5, [V]:

```
  = 0.3 * Sds * W * I
  = 0.3 * 1.02 * 3.78 * 1.25
  = 1.446 kN

 Final Base Shear,       V = 1.01 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 = $Wx*hx^k/(\text{ Sum of } Wi*hi^k)$ 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 17.2516 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	25	0.25279	0.0021247	0.0014081	...
20	Legs	175	0.26449	0.015562	0.0094746	...
Legs	30	712.5	2.27463	0.54489	0.33175	...
30	40	1307.15	0.43626	0.19173	0.17775	...
40	50	1389.7	0.55164	0.25775	0.23896	...

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.

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	206.229	...	...	...	...
20	Legs	62.5	0.016768	0.0021247	1.36261	0.17266
Legs	30	537.5	0.14783	0.99648	76.0519	821.944
30	40	1132.15	0.015958	0.44947	1.29137	46.9832
40	50	1214.7	0.0045896	0.25775	0.072889	4.09335

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.

Note:
Review the Vessel Design Summary for the cumulative shear force and bending moment on the support.

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	...	0.27648	0.27648	0.00041317
20	Legs	0.016768	0.2765	0.27659	0.00041488
Legs	30	0.14783	0.27908	0.28303	0.00042084
30	40	0.015958	0.28347	0.28391	0.00042084
40	50	0.0045896	0.28403	0.28416	0.00042084

Critical Wind Velocity for Tower Vibration:

From	To	1st Crit. Wind Speed Km/hr	2nd Crit. Wind Speed Km/hr
10	20	157.516	984.475
20	30	157.516	984.475
30	40	146.307	914.42
40	50	212.648	1329.05

Allowable deflection at the Tower Top (Ope)(6.000"/100ft. Criteria)
Allowable deflection : 7.028 Actual deflection : 0.284 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	94.0576	35.4732	718036	281016
20	30	82.6121	23.5789	635308	188168
30	40	82.6121	23.5789	635308	188168
40	50	82.6121	23.5789	635308	188168

Longitudinal Allowable Stresses:

From	To	Tensile N./mm²	Hydrotest Tensile N./mm²	Compressive N./mm²	Hydrotest Compressive N./mm²
10	20	117.9	217.2	-110.124	-132.148
20	Legs	117.9	217.2	-101.346	-121.615
Legs	30	117.9	217.2	-101.346	-121.615
30	40	137.9	223.4	-101.346	-121.615
40	50	137.9	223.4	-101.346	-121.615

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	17.8155	-2.40117	23.1602
20	30	27.1878	-3.61244	35.3441
30	40	...	...	...
40	50	...	...	...

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	...	...	...	...	...
20	Legs	0.076641	0.10722	0.074666	0.012888	0.012888
Legs	30	-1.05257	-1.01406	-1.05257	0.11084	0.11084
30	40	-0.41901	-0.41901	-0.41901	...	...
40	50	-0.23398	-0.23398	-0.23398	...	...

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	...	...	...	...	...
20	Legs	0.012888	0.0072391	0.00091729	0.0023889	...
Legs	30	0.11084	0.40404	4.36673	0.13333	...
30	40	...	0.0068607	0.24961	0.002264	...
40	50	...	0.00038724	0.021747	0.00012779	...

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	...	...	...	...
20	Legs	...	...	...	0.00060791
Legs	30	...	...	...	3.55532
30	40	...	...	...	0.23142
40	50	...	...	...	0.020162

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	Legs	...	...
Legs	30	...	...
30	40	...	...
40	50	...	...

Longitudinal Stresses due to User Forces and Moments:

From	To	Wind For/Mom Corroded N./mm²	Earthquake For/Mom Corroded N./mm²	Wind For/Mom No Corrosion N./mm²	Earthquake For/Mom No Corrosion N./mm²
10	20	...	...	...	...
20	Legs	...	...	...	...
Legs	30	...	...	...	...
30	40	...	...	...	...
40	50	...	...	...	...

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	0.00	117.90	0.00	110.12	0.0000	0.0000
20	0.10	117.90		101.35	0.0008	
20		117.90	-1.57	101.35		0.0155

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	0.00	117.90	0.00	110.12	0.0000	0.0000
20	0.09	117.90		101.35	0.0008	
20	2.61	117.90	-4.72	101.35	0.0222	0.0466

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	0.00	117.90	0.00	110.12	0.0000	0.0000
20	0.13	117.90		101.35	0.0011	
20		117.90	-1.53	101.35		0.0151

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	0.00	117.90	0.00	110.12	0.0000	0.0000
20	0.12	117.90		101.35	0.0010	
20	3.46	117.90	-5.49	101.35	0.0294	0.0542

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	0.00	217.20	0.00	132.15	0.0000	0.0000
20	0.09	217.20		121.61	0.0004	
20		217.20	-1.30	121.61		0.0107

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	0.00	217.20	0.00	132.15	0.0000	0.0000
20	0.09	217.20		121.61	0.0004	
20		217.20	-1.16	121.61		0.0096

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	17.82	117.90		110.12	0.1511	
20	27.32	117.90		101.35	0.2317	
20	26.69	117.90		101.35	0.2264	

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	17.82	117.90		110.12	0.1511	
20	27.31	117.90		101.35	0.2316	
20	30.65	117.90		101.35	0.2600	

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

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

Node	Stress	Stress	Stress	Stress	Ratio	Ratio
10		117.90	-2.40	110.12		0.0218
20		117.90	-3.53	101.35		0.0348
20		117.90	-5.14	101.35		0.0507

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		117.90	-2.40	110.12		0.0218
20		117.90	-3.52	101.35		0.0347
20		117.90	-9.10	101.35		0.0898

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	23.16	217.20		132.15	0.1066	
20	35.43	217.20		121.61	0.1631	
20	34.54	217.20		121.61	0.1590	

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	23.16	217.20		132.15	0.1066	
20	35.43	217.20		121.61	0.1631	
20	34.40	217.20		121.61	0.1584	

Analysis of Load Case 13 : IP+WE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	17.82	117.90		110.12	0.1511	
20	27.28	117.90		101.35	0.2314	
20	26.25	117.90		101.35	0.2226	

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	17.82	117.90		110.12	0.1511	
20	27.22	117.90		101.35	0.2309	
20	26.90	117.90		101.35	0.2281	

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	17.82	117.90		110.12	0.1511	
20	27.31	117.90		101.35	0.2316	
20	26.28	117.90		101.35	0.2229	

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	17.82	117.90		110.12	0.1511	
20	27.28	117.90		101.35	0.2314	
20	26.25	117.90		101.35	0.2226	

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	0.00	117.90	0.00	110.12	0.0000	0.0000
20	0.12	117.90		101.35	0.0010	
20		117.90	-1.12	101.35		0.0111

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	17.82	117.90		110.12	0.1511	
20	27.31	117.90		101.35	0.2316	
20	26.28	117.90		101.35	0.2229	

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		117.90	-2.40	110.12		0.0218
20		117.90	-3.52	101.35		0.0347
20		117.90	-4.74	101.35		0.0467

Absolute Maximum of the all of the Stress Ratio's 0.2600

Element From : 20 to : 30
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
Element # 1	17.8	...	...	...	17.8	+	Tens
Element # 1	17.8	...	...	...	...	-	Comp
Element # 2	27.2	0.1	...	...	27.3	+	Tens
Element # 2	27.2	0.1	-0.0	-0.0	...	-	Comp
Element # 2	27.2	-1.0	0.1	4.4	30.7	+	Tens
Element # 2	27.2	-1.0	-0.1	-4.4	...	-	Comp

Shop/Field Installation Options :

Insulation is installed in the Shop.

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

Center of Gravity of the Liquid	597.439 mm.
Center of Gravity of the Insulation	739.237 mm.
Center of Gravity of the Nozzles	744.974 mm.
Center of Gravity of the Legs	-325.000 mm.
Center of Gravity of the Added Weights (Operating)	650.000 mm.
Center of Gravity of the Added Weights (Empty)	650.000 mm.
Center of Gravity of Bare Shell New and Cold	925.490 mm.
Center of Gravity of Bare Shell Corroded	1100.397 mm.
Vessel CG in the Operating Condition	723.416 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	738.162 mm.
Vessel CG in the Test Condition	718.226 mm.

RESULTS FOR LEGS : Operating Case Description: LEGS

Legs attached to: node 20

Section Properties : Single Angle L60X60X8

European Structural Steel Data

Overall Leg Length		1000.000	mm.
Effective Leg Length	Leglen	925.000	mm.
Distance Leg Up Side of Vessel		125.000	mm.
Number of Legs	Nleg	3	
Cross Sectional Area for L60X60X8	Aleg	9.030	cm²
Section Inertia (strong axis)		29.200	cm**4
Section Inertia (weak axis)		29.200	cm**4
Section Modulus (strong axis)		6890.028	mm.³
Section Modulus (weak axis)		6890.028	mm.³
Radius of Gyration (strong axis)		18.000	mm.
Radius of Gyration (weak axis)		18.000	mm.

Leg Orientation - Diagonal

Overturning Moment at top of Legs		821.9	N-m
Total Weight Load at top of Legs	W	3.8	kN
Total Shear force at top of Legs		1.0	kN
Additional force in Leg due to Bracing	Fadd	0.0	kN
Occasional Load Factor	Occfac	1.333	
Effective Leg End Condition Factor	k	1.000	

Note: The Legs are Not Cross Braced
The Leg Shear Force includes Wind and Seismic Effects

Pad Width along Circumference	C11P	100.000	mm.
Pad Length along Vessel Axis	C22P	100.000	mm.
Pad Thickness	Tpad	8.000	mm.

Maximum Shear at top of one Leg [Vleg]:
= (max(Wind, Seismic) + applied forces)(Imax / Itot)
= (1.01)(47.1/71.7)
= 0.66 kN

Axial Compression, Leg furthest from the Neutral Axis [Sma]:
= W/Nleg + (Mleg/(Nlegm*Rn))/Aleg
= 3808/3 + (821617/(1 * 189))/903
= 6.23 N./mm²

Axial Compression, Leg closest to the Neutral Axis [Sva]:
= (W / Nleg) / Aleg
= (3.81/3)/9.03
= 1.41 N./mm²

Computing Principal Axis and Inertias for Angle.
Leg lengths and thickness: 60.000 60.000 8.0000

```
Distance to geometric centroid:   17.700      17.700
Arm about YY:                     13.700      16.300
Arm about ZZ:                     12.300      13.700
Leg areas:                        4.8000      4.1600
Geometric inertia components YY:  9.2650      20.426
Geometric inertia components ZZ:  21.662      8.0297
Geometric inertias Iy & Iz:       29.691      29.691
Product of inertia:              0.17378E+06
Mohrs Radius:                     10.605
Average Inertia:                  29.691

QFACT =   1.0000        FBZ          =  0.16383
Principal Axis Inertias (Z&W)        =   12.313      47.069
Angle to Principal Axis              =   45.000
Distances to extreme fibers CW & CZ  =   42.426      17.395
FOB from Eq 5-5                      =   1.6846
Bending allowables Fby & Fbz         =  0.16383     0.16383

Shear Center Coordinates Wo & Zo:   18.583      0.0000
Values for Elastic Flexural-Torsional Buckling Stress:
E,    G,      J,   R0²:    29500.      11346.     0.46282E-01  1.5546
AREA, LENGTH, Kw,  Kz:     1.3996      36.417      1.0000      1.0000
H,    Few,    Fez, Fej:   0.65569      177.37      46.401      241.34
Fe computed from C4-1:     127.82

Initial (Kl/r)max, & (Kl/r)equiv     =   79.213      47.727
Final (Kl/r)max, & Cc                =   79.213      127.18
Fa based on Eq 4-1                   =  0.10699

                              Actual   Allowable
Weak Axis Bending    :         61.40      218.38   N./mm²
Strong Axis Bending  :         39.17      218.38   N./mm²
Axial Compression    :          6.23      142.62   N./mm²

UNITY CHECKS ARE: H1-1     0.000
                  H1-2     0.000
                  H1-3     0.504

AISC Unity Check :   0.504 Should be <= to 1
```

WRC 107 Stress Analysis for Leg to Shell Junction, Ope Condition

```
Rectangular Attachment Parameter          C11      84.853  mm.
Rectangular Attachment Parameter          C22      80.950  mm.
```

Input Echo, WRC107/537 Item 1, Description: LEGS

```
Diameter Basis for Vessel                Vbasis      ID
Cylindrical or Spherical Vessel          Cylsph      Cylindrical
Internal Corrosion Allowance               Cas      6.0000  mm.
Vessel Diameter                             Dv     307.181  mm.
Vessel Thickness                            Tv       8.334  mm.

Design Temperature                          T1       100.0  °C
```

شماره پیمان:	MECHANICAL CALCULATION BOOK FOR GLYCOL PARTICLE FILTER (F-100 A/B)	شماره صفحه : 60 از 118

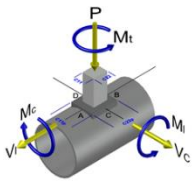
پروژه	بسته کاری	صادرکننده	تسهیلات	رشته	نوع مدرک	سریال	نسخه
BK	GCS	MF	120	ME	CN	0004	V00

053 – 073 – 9184

Attachment Type	Type	Rectangular	
Parameter C11	C11	84.85	mm.
Parameter C22	C22	80.95	mm.
Thickness of Reinforcing Pad	Tpad	8.000	mm.
Pad Parameter C11P	C11p	100.000	mm.
Pad Parameter C22P	C22p	100.000	mm.
Design Internal Pressure	Dp	8.000	bars
Include Pressure Thrust		No	
Vessel Centerline Direction Cosine	Vx	0.000	
Vessel Centerline Direction Cosine	Vy	1.000	
Vessel Centerline Direction Cosine	Vz	0.000	
Nozzle Centerline Direction Cosine	Nx	1.000	
Nozzle Centerline Direction Cosine	Ny	0.000	
Nozzle Centerline Direction Cosine	Nz	0.000	
Global Force (SUS)	Fx	0.0	kN
Global Force (SUS)	Fy	1.3	kN
Global Force (SUS)	Fz	0.0	kN
Global Moment (SUS)	Mx	0.0	N-m
Global Moment (SUS)	My	0.0	N-m
Global Moment (SUS)	Mz	34.1	N-m
Internal Pressure (SUS)	P	8.00	bars
Include Pressure Thrust		No	
Global Force (OCC)	Fx	0.7	kN
Global Force (OCC)	Fy	4.4	kN
Global Force (OCC)	Fz	0.0	kN
Global Moment (OCC)	Mx	0.0	N-m
Global Moment (OCC)	My	0.0	N-m
Global Moment (OCC)	Mz	424.2	N-m
Occasional Internal Pressure (OCC)	Pvar	0.00	bars

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".



WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	0.0	kN
Circumferential Shear	VC	0.0	kN
Longitudinal Shear	VL	1.3	kN
Circumferential Moment	MC	0.0	N-m
Longitudinal Moment	ML	-34.1	N-m
Torsional Moment	MT	0.0	N-m

Dimensionless Parameters used : Gamma = 15.94

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.251	4C	2.471	(A,B)
N(PHI) / (P/Rm)	0.251	3C	1.842	(C,D)
M(PHI) / (P)	0.255	2C1	0.045	(A,B)
M(PHI) / (P)	0.255	1C !	0.074	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.253	3A	0.657	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.286	1A	0.083	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.250	3B	1.768	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.259	1B	0.031	(A,B,C,D)
N(x) / (P/Rm)	0.254	3C	1.826	(A,B)
N(x) / (P/Rm)	0.254	4C	2.459	(C,D)
M(x) / (P)	0.252	1C1	0.077	(A,B)
M(x) / (P)	0.252	2C	0.045	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.253	4A	1.157	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.308	2A	0.039	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.250	4B	0.631	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.265	2B	0.050	(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	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend.	P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	1.4	-1.4	-1.4	1.4	0.0	0.0	0.0	0.0
Tot. Circ. Str.	2.2	-0.6	-2.2	0.6	0.0	0.0	0.0	0.0
Long. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	0.3	0.3	-0.3	-0.3	0.0	0.0	0.0	0.0
Long. Bend. ML	2.2	-2.2	-2.2	2.2	0.0	0.0	0.0	0.0
Tot. Long. Str.	2.5	-1.9	-2.5	1.9	0.0	0.0	0.0	0.0
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.8	-0.8	0.8	0.8
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-0.8	-0.8	0.8	0.8
Str. Int.	2.5	1.9	2.5	1.9	1.5	1.5	1.5	1.5

Dimensionless Parameters used : Gamma = 68.87

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.311	4C		6.034	(A,B)
N(PHI) / (P/Rm)	0.311	3C		2.361	(C,D)
M(PHI) / (P)	0.311	2C1		0.009	(A,B)
M(PHI) / (P)	0.311	1C	!	0.067	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.311	3A		1.801	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.311	1A		0.057	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.311	3B		3.647	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.311	1B		0.007	(A,B,C,D)
N(x) / (P/Rm)	0.311	3C		2.361	(A,B)
N(x) / (P/Rm)	0.311	4C		6.034	(C,D)
M(x) / (P)	0.311	1C1		0.025	(A,B)
M(x) / (P)	0.311	2C	!	0.035	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.311	4A		6.314	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.311	2A		0.022	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.311	4B		2.038	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.311	2B		0.010	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	6.6	6.6	-6.6	-6.6	0.0	0.0	0.0	0.0
Circ. Bend. ML	5.5	-5.5	-5.5	5.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	12.1	1.1	-12.1	-1.1	0.0	0.0	0.0	0.0
Long. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	3.7	3.7	-3.7	-3.7	0.0	0.0	0.0	0.0
Long. Bend. ML	7.8	-7.8	-7.8	7.8	0.0	0.0	0.0	0.0
Tot. Long. Str.	11.5	-4.1	-11.5	4.1	0.0	0.0	0.0	0.0
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-2.7	-2.7	2.7	2.7
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-2.7	-2.7	2.7	2.7
Str. Int.	12.1	5.2	12.1	5.2	5.4	5.4	5.4	5.4

WRC 107 Stress Calculation for OCCasional loads:

Radial Load	P	0.7	kN
Circumferential Shear	VC	0.0	kN
Longitudinal Shear	VL	4.4	kN
Circumferential Moment	MC	0.0	N-m
Longitudinal Moment	ML	-424.2	N-m
Torsional Moment	MT	0.0	N-m

Dimensionless Parameters used : Gamma = 15.94

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.0	-1.0	-1.0	-1.0	-0.7	-0.7	-0.7	-0.7
Circ. Bend. P	-1.7	1.7	-1.7	1.7	-2.7	2.7	-2.7	2.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	9.5	9.5	-9.5	-9.5	0.0	0.0	0.0	0.0

Circ. Bend. ML	17.2	-17.2	-17.2	17.2	0.0	0.0	0.0	0.0
Tot. Circ. Str.	24.1	-7.0	-29.4	8.4	-3.5	2.0	-3.5	2.0
Long. Memb. P	-0.7	-0.7	-0.7	-0.7	-1.0	-1.0	-1.0	-1.0
Long. Bend. P	-2.9	2.9	-2.9	2.9	-1.7	1.7	-1.7	1.7
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	3.5	3.5	-3.5	-3.5	0.0	0.0	0.0	0.0
Long. Bend. ML	27.1	-27.1	-27.1	27.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	27.0	-21.4	-34.2	25.7	-2.6	0.7	-2.6	0.7
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Str. Int.	27.0	21.4	34.2	25.7	5.7	5.4	5.7	5.4

Dimensionless Parameters used : Gamma = 68.87

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-10.7	-10.7	-10.7	-10.7	-4.2	-4.2	-4.2	-4.2
Circ. Bend. P	-6.9	6.9	-6.9	6.9	-49.3	49.3	-49.3	49.3
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	82.4	82.4	-82.4	-82.4	0.0	0.0	0.0	0.0
Circ. Bend. ML	68.5	-68.5	-68.5	68.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	133.3	10.1	-168.5	-17.7	-53.5	45.1	-53.5	45.1
Long. Memb. P	-4.2	-4.2	-4.2	-4.2	-10.7	-10.7	-10.7	-10.7
Long. Bend. P	-18.5	18.5	-18.5	18.5	-25.8	25.8	-25.8	25.8
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	46.1	46.1	-46.1	-46.1	0.0	0.0	0.0	0.0
Long. Bend. ML	96.8	-96.8	-96.8	96.8	0.0	0.0	0.0	0.0
Tot. Long. Str.	120.1	-36.4	-165.6	65.1	-36.4	15.1	-36.4	15.1
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-9.3	-9.3	9.3	9.3
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-9.3	-9.3	9.3	9.3
Str. Int.	133.3	46.5	168.5	82.8	57.6	47.8	57.6	47.8

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	12.0	12.8	12.0	12.8	12.0	12.8	12.0	12.8
Circ. Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pm(TOTAL)	12.0	12.8	12.0	12.8	12.0	12.8	12.0	12.8
Circ. Pl (SUS)	0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Circ. Pl (OCC)	8.6	8.6	-10.5	-10.5	-0.7	-0.7	-0.7	-0.7
Circ. Pl(TOTAL)	9.3	9.3	-11.3	-11.3	-0.7	-0.7	-0.7	-0.7
Circ. Q (SUS)	1.4	-1.4	-1.4	1.4	0.0	0.0	0.0	0.0
Circ. Q (OCC)	15.6	-15.6	-18.9	18.9	-2.7	2.7	-2.7	2.7
Circ. Q (TOTAL)	16.9	-16.9	-20.3	20.3	-2.7	2.7	-2.7	2.7
Long. Pm (SUS)	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Long. Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pm(TOTAL)	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Long. Pl (SUS)	0.3	0.3	-0.3	-0.3	0.0	0.0	0.0	0.0
Long. Pl (OCC)	2.8	2.8	-4.2	-4.2	-1.0	-1.0	-1.0	-1.0
Long. Pl(TOTAL)	3.1	3.1	-4.5	-4.5	-1.0	-1.0	-1.0	-1.0
Long. Q (SUS)	2.2	-2.2	-2.2	2.2	0.0	0.0	0.0	0.0
Long. Q (OCC)	24.2	-24.2	-29.9	29.9	-1.7	1.7	-1.7	1.7
Long. Q (TOTAL)	26.4	-26.4	-32.1	32.1	-1.7	1.7	-1.7	1.7
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pm(TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.0	0.0	0.0	0.0	-0.8	-0.8	0.8	0.8
Shear Pl (OCC)	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Shear Pl(TOTAL)	0.0	0.0	0.0	0.0	-3.4	-3.4	3.4	3.4
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	12.0	12.8	12.0	12.8	12.0	12.8	12.0	12.8
Pm (SUS+OCC)	12.0	12.8	12.0	12.8	12.0	12.8	12.0	12.8
Pm+Pl (SUS)	12.7	13.5	11.2	12.0	12.1	12.9	12.1	12.9
Pm+Pl (SUS+OCC)	21.3	22.1	1.5	1.5	12.7	13.4	12.7	13.4
Pm+Pl+Q (Total)	38.3	22.5	30.6	33.6	10.2	16.0	10.2	16.0

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	12.77	117.90	Passed
Pm (SUS+OCC)	12.77	141.48	Passed
Pm+Pl (SUS)	13.53	176.85	Passed
Pm+Pl (SUS+OCC)	22.11	212.22	Passed
Pm+Pl+Q (TOTAL)	38.26	353.70	Passed

The Pm+Pl+Q allowable above was based on the rules of ASME VIII-2 Part 4, 4.1.6.3 (a)&(b) or per ASME VIII-2, 5.5.6.1(1)&(2) Part 5 as applicable.

The Pm+Pl+Q allowable was based on a temperature range cycling from ambient to design temperature.

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm²)

Type of Stress	Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ.	Pm (SUS)	54.3	55.1	54.3	55.1	54.3	55.1	54.3	55.1
Circ.	Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ.	Pm(TOTAL)	54.3	55.1	54.3	55.1	54.3	55.1	54.3	55.1
Circ.	Pl (SUS)	6.6	6.6	-6.6	-6.6	0.0	0.0	0.0	0.0
Circ.	Pl (OCC)	71.7	71.7	-93.1	-93.1	-4.2	-4.2	-4.2	-4.2
Circ.	Pl(TOTAL)	78.4	78.4	-99.7	-99.7	-4.2	-4.2	-4.2	-4.2
Circ.	Q (SUS)	5.5	-5.5	-5.5	5.5	0.0	0.0	0.0	0.0
Circ.	Q (OCC)	61.6	-61.6	-75.4	75.4	-49.3	49.3	-49.3	49.3
Circ.	Q (TOTAL)	67.1	-67.1	-80.9	80.9	-49.3	49.3	-49.3	49.3
Long.	Pm (SUS)	27.1	27.1	27.1	27.1	27.1	27.1	27.1	27.1
Long.	Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long.	Pm(TOTAL)	27.1	27.1	27.1	27.1	27.1	27.1	27.1	27.1
Long.	Pl (SUS)	3.7	3.7	-3.7	-3.7	0.0	0.0	0.0	0.0
Long.	Pl (OCC)	41.9	41.9	-50.2	-50.2	-10.7	-10.7	-10.7	-10.7
Long.	Pl(TOTAL)	45.6	45.6	-53.9	-53.9	-10.7	-10.7	-10.7	-10.7
Long.	Q (SUS)	7.8	-7.8	-7.8	7.8	0.0	0.0	0.0	0.0
Long.	Q (OCC)	78.3	-78.3	-115.3	115.3	-25.8	25.8	-25.8	25.8
Long.	Q (TOTAL)	86.0	-86.0	-123.1	123.1	-25.8	25.8	-25.8	25.8
Shear	Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear	Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear	Pm(TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear	Pl (SUS)	0.0	0.0	0.0	0.0	-2.7	-2.7	2.7	2.7
Shear	Pl (OCC)	0.0	0.0	0.0	0.0	-9.3	-9.3	9.3	9.3
Shear	Pl(TOTAL)	0.0	0.0	0.0	0.0	-12.0	-12.0	12.0	12.0
Shear	Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear	Q (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Shear Q (TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	54.3	55.1	54.3	55.1	54.3	55.1	54.3	55.1
Pm (SUS+OCC)	54.3	55.1	54.3	55.1	54.3	55.1	54.3	55.1
Pm+Pl (SUS)	60.9	61.7	47.7	48.5	54.6	55.4	54.6	55.4
Pm+Pl (SUS+OCC)	132.7	133.5	45.4	44.6	54.0	54.7	54.0	54.7
Pm+Pl+Q (Total)	199.8	79.7	149.9	96.3	26.1	102.6	26.1	102.6

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	55.10	117.90	Passed
Pm (SUS+OCC)	55.10	141.48	Passed
Pm+Pl (SUS)	61.72	176.85	Passed
Pm+Pl (SUS+OCC)	133.46	212.22	Passed
Pm+Pl+Q (TOTAL)	199.76	353.70	Passed

The Pm+Pl+Q allowable above was based on the rules of ASME VIII-2 Part 4, 4.1.6.3 (a)&(b) or per ASME VIII-2, 5.5.6.1(1)&(2) Part 5 as applicable.

The Pm+Pl+Q allowable was based on a temperature range cycling from ambient to design temperature.

Bolting Size Requirement for Leg Baseplates :

Baseplate Material		SA-283 C	
Baseplate Allowable Stress	SBA	108.25	N./mm²
Baseplate Length	B	150.0000	mm.
Baseplate Width	D	150.0000	mm.
Baseplate Thickness	BTHK	15.0000	mm.
Leg Dimension Along Baseplate Length	d	59.9999	mm.
Leg Dimension Along Baseplate Width	b	59.9999	mm.
Bolt Circle Diameter	BCD	331.8000	mm.
Bolt Material		SA-325	
Bolt Allowable Tensile Stress	STBA	300.00	N./mm²
Bolt Allowable Shear Stress	SBShear	180.00	N./mm²
Anchor Bolt Nominal Diameter	BOD	20.0000	mm.
Number of Anchor Bolts in Tension per Leg	NB	1	
Total Number of Anchors Bolt per Leg	NBT	1	
Ultimate 28-day Concrete Strength	FCPRIME	20.685	N./mm²

Shear Stress in a Single Bolt [taub]:
= Shear Force / (2 * Bolt Area * Number of Bolts)
= 1.01/(2 * 2.17 * 1)
= 2.3 N./mm². Must be less than 180.0 N./mm².

Plate thickness required (1/2"; 13mm) per D. Moss

Since there is only 1 bolt, the standard computation for this

geometry is not possible. A reasonable bolt size should be selected. Per Megyesy, use a 1 inch (25.4 mm) bolt.

Computing the required bolt area based on a standard method not including the baseplate's interaction with the foundation.

Calculation of Load per Bolt, Wind Empty [W,wind]:

```
= (( 4 * Moment/BCD ) - Weight )/Num Bolts
= (( 4 * 76.1/332 ) - 3.15 )/3
= -0.744 kN
```

Calculation of Load per Bolt, Seismic Operating [W,seismic]:

```
= (( 4 * Moment/BCD ) - Weight )/Num Bolts
= (( 4 * 822/332 ) - 4.09 )/3
= 1.938 kN
```

Calculation of Maximum Load per Bolt [Wmax]:

```
= max( W,wind, W,seismic )
= max( -0.74, 1.94 )
= 1.938 kN
```

Area Available in a Single Bolt, corroded [Ab]:

```
= 2.171 cm²
```

Required Area of a single Bolt, Simplified Method:

```
= Wmax / Bolt Allowable Stress
= 1.94/280708
= 0.065 cm²
```

Note: The Seismic Operating case governs.

RESULTS FOR LEGS : HydroTest Case Description: LEGS

Legs attached to: node 20

Section Properties : Single Angle L60X60X8

European Structural Steel Data

Overall Leg Length		1000.000	mm.
Effective Leg Length	Leglen	925.000	mm.
Distance Leg Up Side of Vessel		125.000	mm.
Number of Legs	Nleg	3	
Cross Sectional Area for L60X60X8	Aleg	9.030	cm^2
Section Inertia (strong axis)		29.200	cm**4
Section Inertia (weak axis)		29.200	cm**4
Section Modulus (strong axis)		6890.028	$mm.^3$
Section Modulus (weak axis)		6890.028	$mm.^3$
Radius of Gyration (strong axis)		18.000	mm.
Radius of Gyration (weak axis)		18.000	mm.

Leg Orientation - Diagonal

Overturning Moment at top of Legs		25.1	N-m
Total Weight Load at top of Legs	W	3.3	kN
Total Shear force at top of Legs		0.1	kN
Additional force in Leg due to Bracing	Fadd	0.0	kN
Occasional Load Factor	Occfac	1.333	
Effective Leg End Condition Factor	k	1.000	

Note: The Legs are Not Cross Braced
The Leg Shear Force includes Wind and Seismic Effects

Pad Width along Circumference	C11P	100.000	mm.
Pad Length along Vessel Axis	C22P	100.000	mm.
Pad Thickness	Tpad	8.000	mm.

Maximum Shear at top of one Leg [Vleg]:
= (max(Wind, Seismic) + applied forces)(Imax / Itot)
= (0.053)(47.1/71.7)
= 0.03 kN

Axial Compression, Leg furthest from the Neutral Axis [Sma]:
= W/Nleg + (Mleg/(Nlegm*Rn))/Aleg
= 3275/3 + (25087/(1 * 189))/903
= 1.36 $N./mm^2$

Axial Compression, Leg closest to the Neutral Axis [Sva]:
= (W / Nleg) / Aleg
= (3.28/3)/9.03
= 1.21 $N./mm^2$

Computing Principal Axis and Inertias for Angle.
Leg lengths and thickness: 60.000 60.000 8.0000

```
Distance to geometric centroid:   17.700      17.700
Arm about YY:                     13.700      16.300
Arm about ZZ:                     12.300      13.700
Leg areas:                        4.8000      4.1600
Geometric inertia components YY:  9.2650      20.426
Geometric inertia components ZZ:  21.662      8.0297
Geometric inertias Iy & Iz:       29.691      29.691
Product of inertia:              0.17378E+06
Mohrs Radius:                     10.605
Average Inertia:                  29.691

QFACT =   1.0000        FBZ          =  0.16383
Principal Axis Inertias (Z&W)        =   12.313      47.069
Angle to Principal Axis              =   45.000
Distances to extreme fibers CW & CZ  =   42.426      17.395
FOB from Eq 5-5                      =   1.6846
Bending allowables Fby & Fbz         =  0.16383     0.16383

Shear Center Coordinates Wo & Zo:   18.583      0.0000
Values for Elastic Flexural-Torsional Buckling Stress:
E,    G,      J,   R0²:    29500.      11346.     0.46282E-01  1.5546
AREA, LENGTH, Kw,  Kz:     1.3996      36.417      1.0000      1.0000
H,    Few,    Fez, Fej:   0.65569      177.37      46.401      241.34
Fe computed from C4-1:     127.82

Initial (Kl/r)max, & (Kl/r)equiv     =   79.213      47.727
Final (Kl/r)max, & Cc                =   79.213      127.18
Fa based on Eq 4-1                   =  0.10699

                              Actual   Allowable
Weak Axis Bending    :          3.23      218.38   N./mm²
Strong Axis Bending  :          2.06      218.38   N./mm²
Axial Compression    :          1.36      142.62   N./mm²

UNITY CHECKS ARE: H1-1     0.000
                  H1-2     0.000
                  H1-3     0.034

AISC Unity Check :   0.034 Should be <= to 1
```

WRC 107 Stress Analysis for Leg to Shell Junction, Test Condition

```
Rectangular Attachment Parameter          C11      84.853  mm.
Rectangular Attachment Parameter          C22      80.950  mm.
```

Input Echo, WRC107/537 Item 1, Description: LEGS

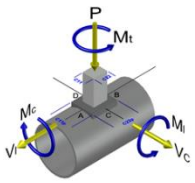
```
Diameter Basis for Vessel                Vbasis      ID
Cylindrical or Spherical Vessel          Cylsph      Cylindrical
Internal Corrosion Allowance               Cas       0.0000  mm.
Vessel Diameter                             Dv     307.181  mm.
Vessel Thickness                            Tv       8.334  mm.

Design Temperature                          T1       100.0  °C
```

Attachment Type	Type	Rectangular	
Parameter C11	C11	84.85	mm.
Parameter C22	C22	80.95	mm.
Thickness of Reinforcing Pad	Tpad	8.000	mm.
Pad Parameter C11P	C11p	100.000	mm.
Pad Parameter C22P	C22p	100.000	mm.
Design Internal Pressure	Dp	8.000	bars
Include Pressure Thrust		No	
Vessel Centerline Direction Cosine	Vx	0.000	
Vessel Centerline Direction Cosine	Vy	1.000	
Vessel Centerline Direction Cosine	Vz	0.000	
Nozzle Centerline Direction Cosine	Nx	1.000	
Nozzle Centerline Direction Cosine	Ny	0.000	
Nozzle Centerline Direction Cosine	Nz	0.000	
Global Force (SUS)	Fx	0.0	kN
Global Force (SUS)	Fy	1.1	kN
Global Force (SUS)	Fz	0.0	kN
Global Moment (SUS)	Mx	0.0	N-m
Global Moment (SUS)	My	0.0	N-m
Global Moment (SUS)	Mz	29.3	N-m
Internal Pressure (SUS)	P	8.00	bars
Include Pressure Thrust		No	
Global Force (OCC)	Fx	0.0	kN
Global Force (OCC)	Fy	0.1	kN
Global Force (OCC)	Fz	0.0	kN
Global Moment (OCC)	Mx	0.0	N-m
Global Moment (OCC)	My	0.0	N-m
Global Moment (OCC)	Mz	19.7	N-m
Occasional Internal Pressure (OCC)	Pvar	2.52	bars

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".



WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	0.0	kN
Circumferential Shear	VC	0.0	kN
Longitudinal Shear	VL	1.1	kN
Circumferential Moment	MC	0.0	N-m
Longitudinal Moment	ML	-29.3	N-m
Torsional Moment	MT	0.0	N-m

Dimensionless Parameters used : Gamma = 9.90

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.256	4C		1.611	(A,B)
N(PHI) / (P/Rm)	0.256	3C		1.314	(C,D)
M(PHI) / (P)	0.259	2C1		0.062	(A,B)
M(PHI) / (P)	0.259	1C		0.087	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.258	3A	!	0.345	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.292	1A		0.090	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.254	3B	!	1.196	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.264	1B		0.037	(A,B,C,D)
N(x) / (P/Rm)	0.259	3C		1.304	(A,B)
N(x) / (P/Rm)	0.259	4C		1.606	(C,D)
M(x) / (P)	0.257	1C1		0.091	(A,B)
M(x) / (P)	0.257	2C		0.063	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.258	4A	!	0.615	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.314	2A		0.047	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.254	4B	!	0.348	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.270	2B		0.061	(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	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	0.3	0.3	-0.3	-0.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	0.6	-0.6	-0.6	0.6	0.0	0.0	0.0	0.0
Tot. Circ. Str.	0.9	-0.3	-0.9	0.3	0.0	0.0	0.0	0.0
Long. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	0.1	0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
Long. Bend. ML	0.9	-0.9	-0.9	0.9	0.0	0.0	0.0	0.0
Tot. Long. Str.	1.0	-0.8	-1.0	0.8	0.0	0.0	0.0	0.0
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.4	-0.4	0.4	0.4
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-0.4	-0.4	0.4	0.4
Str. Int.	1.0	0.8	1.0	0.8	0.8	0.8	0.8	0.8

Dimensionless Parameters used : Gamma = 18.93

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.317	4C		2.505	(A,B)
N(PHI) / (P/Rm)	0.317	3C		1.577	(C,D)
M(PHI) / (P)	0.317	2C1		0.029	(A,B)
M(PHI) / (P)	0.317	1C	!	0.059	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.317	3A		0.812	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.317	1A		0.079	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.317	3B		1.829	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.317	1B		0.023	(A,B,C,D)
N(x) / (P/Rm)	0.317	3C		1.577	(A,B)
N(x) / (P/Rm)	0.317	4C		2.505	(C,D)
M(x) / (P)	0.317	1C1		0.054	(A,B)
M(x) / (P)	0.317	2C	!	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.317	4A		1.642	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.317	2A		0.036	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.317	4B		0.776	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.317	2B		0.038	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	1.1	-1.1	-1.1	1.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.	2.0	-0.3	-2.0	0.3	0.0	0.0	0.0	0.0
Long. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	0.3	0.3	-0.3	-0.3	0.0	0.0	0.0	0.0
Long. Bend. ML	1.9	-1.9	-1.9	1.9	0.0	0.0	0.0	0.0
Tot. Long. Str.	2.3	-1.6	-2.3	1.6	0.0	0.0	0.0	0.0
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Str. Int.	2.3	1.6	2.3	1.6	1.3	1.3	1.3	1.3

WRC 107 Stress Calculation for OCCasional loads:

Radial Load	P	0.0	kN
Circumferential Shear	VC	0.0	kN
Longitudinal Shear	VL	0.1	kN
Circumferential Moment	MC	0.0	N-m
Longitudinal Moment	ML	-19.7	N-m
Torsional Moment	MT	0.0	N-m

Dimensionless Parameters used : Gamma = 9.90

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
Circ. Bend. P	-0.0	0.0	-0.0	0.0	-0.1	0.1	-0.1	0.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	0.2	0.2	-0.2	-0.2	0.0	0.0	0.0	0.0

Circ. Bend. ML	0.4	-0.4	-0.4	0.4	0.0	0.0	0.0	0.0
Tot. Circ. Str.	0.5	-0.2	-0.7	0.2	-0.1	0.1	-0.1	0.1
Long. Memb. P	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
Long. Bend. P	-0.1	0.1	-0.1	0.1	-0.0	0.0	-0.0	0.0
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	0.1	0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
Long. Bend. ML	0.6	-0.6	-0.6	0.6	0.0	0.0	0.0	0.0
Tot. Long. Str.	0.6	-0.5	-0.8	0.6	-0.1	0.0	-0.1	0.0
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.1	-0.1	0.1	0.1
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-0.1	-0.1	0.1	0.1
Str. Int.	0.6	0.5	0.8	0.6	0.1	0.1	0.1	0.1

Dimensionless Parameters used : Gamma = 18.93
Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-0.1	-0.1	-0.1	-0.1	-0.0	-0.0	-0.0	-0.0
Circ. Bend. P	-0.1	0.1	-0.1	0.1	-0.2	0.2	-0.2	0.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	0.5	0.5	-0.5	-0.5	0.0	0.0	0.0	0.0
Circ. Bend. ML	0.8	-0.8	-0.8	0.8	0.0	0.0	0.0	0.0
Tot. Circ. Str.	1.2	-0.2	-1.5	0.2	-0.2	0.1	-0.2	0.1
Long. Memb. P	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1
Long. Bend. P	-0.2	0.2	-0.2	0.2	-0.1	0.1	-0.1	0.1
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	0.2	0.2	-0.2	-0.2	0.0	0.0	0.0	0.0
Long. Bend. ML	1.3	-1.3	-1.3	1.3	0.0	0.0	0.0	0.0
Tot. Long. Str.	1.3	-0.9	-1.7	1.2	-0.2	0.0	-0.2	0.0
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.1	-0.1	0.1	0.1
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-0.1	-0.1	0.1	0.1
Str. Int.	1.3	0.9	1.7	1.2	0.3	0.2	0.3	0.2

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	7.1	7.9	7.1	7.9	7.1	7.9	7.1	7.9
Circ. Pm (OCC)	2.2	2.5	2.2	2.5	2.2	2.5	2.2	2.5
Circ. Pm(TOTAL)	9.4	10.4	9.4	10.4	9.4	10.4	9.4	10.4
Circ. Pl (SUS)	0.3	0.3	-0.3	-0.3	0.0	0.0	0.0	0.0
Circ. Pl (OCC)	0.2	0.2	-0.2	-0.2	-0.0	-0.0	-0.0	-0.0
Circ. Pl(TOTAL)	0.5	0.5	-0.5	-0.5	-0.0	-0.0	-0.0	-0.0
Circ. Q (SUS)	0.6	-0.6	-0.6	0.6	0.0	0.0	0.0	0.0
Circ. Q (OCC)	0.3	-0.3	-0.4	0.4	-0.1	0.1	-0.1	0.1
Circ. Q (TOTAL)	0.9	-0.9	-1.0	1.0	-0.1	0.1	-0.1	0.1
Long. Pm (SUS)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Long. Pm (OCC)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Long. Pm(TOTAL)	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
Long. Pl (SUS)	0.1	0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
Long. Pl (OCC)	0.0	0.0	-0.1	-0.1	-0.0	-0.0	-0.0	-0.0
Long. Pl(TOTAL)	0.1	0.1	-0.2	-0.2	-0.0	-0.0	-0.0	-0.0
Long. Q (SUS)	0.9	-0.9	-0.9	0.9	0.0	0.0	0.0	0.0
Long. Q (OCC)	0.5	-0.5	-0.7	0.7	-0.0	0.0	-0.0	0.0
Long. Q (TOTAL)	1.5	-1.5	-1.6	1.6	-0.0	0.0	-0.0	0.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pm(TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.0	0.0	0.0	0.0	-0.4	-0.4	0.4	0.4
Shear Pl (OCC)	0.0	0.0	0.0	0.0	-0.1	-0.1	0.1	0.1
Shear Pl(TOTAL)	0.0	0.0	0.0	0.0	-0.5	-0.5	0.5	0.5
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	7.1	7.9	7.1	7.9	7.1	7.9	7.1	7.9
Pm (SUS+OCC)	9.4	10.4	9.4	10.4	9.4	10.4	9.4	10.4
Pm+Pl (SUS)	7.4	8.2	6.9	7.7	7.2	8.0	7.2	8.0
Pm+Pl (SUS+OCC)	9.9	10.9	8.9	9.9	9.4	10.5	9.4	10.5
Pm+Pl+Q (Total)	10.8	10.0	7.9	11.0	9.4	10.5	9.4	10.5

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	7.94	217.20	Passed
Pm (SUS+OCC)	10.44	260.64	Passed
Pm+Pl (SUS)	8.23	325.80	Passed
Pm+Pl (SUS+OCC)	10.90	390.96	Passed
Pm+Pl+Q (TOTAL)	10.95	651.60	Passed

The Pm+Pl+Q allowable above was based on the rules of ASME VIII-2 Part 4, 4.1.6.3 (a)&(b) or per ASME VIII-2, 5.5.6.1(1)&(2) Part 5 as applicable.

The Pm+Pl+Q allowable was based on a temperature range cycling from ambient to design temperature.

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	14.4	15.2	14.4	15.2	14.4	15.2	14.4	15.2
Circ. Pm (OCC)	4.5	4.8	4.5	4.8	4.5	4.8	4.5	4.8
Circ. Pm(TOTAL)	18.9	19.9	18.9	19.9	18.9	19.9	18.9	19.9
Circ. Pl (SUS)	0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Circ. Pl (OCC)	0.5	0.5	-0.6	-0.6	-0.0	-0.0	-0.0	-0.0
Circ. Pl(TOTAL)	1.3	1.3	-1.4	-1.4	-0.0	-0.0	-0.0	-0.0
Circ. Q (SUS)	1.1	-1.1	-1.1	1.1	0.0	0.0	0.0	0.0
Circ. Q (OCC)	0.7	-0.7	-0.9	0.9	-0.2	0.2	-0.2	0.2
Circ. Q (TOTAL)	1.8	-1.8	-2.0	2.0	-0.2	0.2	-0.2	0.2
Long. Pm (SUS)	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
Long. Pm (OCC)	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Long. Pm(TOTAL)	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
Long. Pl (SUS)	0.3	0.3	-0.3	-0.3	0.0	0.0	0.0	0.0
Long. Pl (OCC)	0.2	0.2	-0.3	-0.3	-0.1	-0.1	-0.1	-0.1
Long. Pl(TOTAL)	0.5	0.5	-0.6	-0.6	-0.1	-0.1	-0.1	-0.1
Long. Q (SUS)	1.9	-1.9	-1.9	1.9	0.0	0.0	0.0	0.0
Long. Q (OCC)	1.1	-1.1	-1.4	1.4	-0.1	0.1	-0.1	0.1
Long. Q (TOTAL)	3.0	-3.0	-3.4	3.4	-0.1	0.1	-0.1	0.1
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pm(TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear Pl (OCC)	0.0	0.0	0.0	0.0	-0.1	-0.1	0.1	0.1
Shear Pl(TOTAL)	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Shear Q (TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	14.4	15.2	14.4	15.2	14.4	15.2	14.4	15.2
Pm (SUS+OCC)	18.9	19.9	18.9	19.9	18.9	19.9	18.9	19.9
Pm+Pl (SUS)	15.2	16.0	13.5	14.3	14.4	15.2	14.4	15.2
Pm+Pl (SUS+OCC)	20.2	21.2	17.4	18.5	18.9	19.9	18.9	19.9
Pm+Pl+Q (Total)	22.0	19.4	15.5	20.5	18.7	20.1	18.7	20.1

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	15.15	217.20	Passed
Pm (SUS+OCC)	19.93	260.64	Passed
Pm+Pl (SUS)	15.97	325.80	Passed
Pm+Pl (SUS+OCC)	21.22	390.96	Passed
Pm+Pl+Q (TOTAL)	21.99	651.60	Passed

The Pm+Pl+Q allowable above was based on the rules of ASME VIII-2 Part 4, 4.1.6.3 (a)&(b) or per ASME VIII-2, 5.5.6.1(1)&(2) Part 5 as applicable.

The Pm+Pl+Q allowable was based on a temperature range cycling from ambient to design temperature.

Bolting Size Requirement for Leg Baseplates :

Baseplate Material		SA-283 C	
Baseplate Allowable Stress	SBA	108.25	N./mm²
Baseplate Length	B	150.0000	mm.
Baseplate Width	D	150.0000	mm.
Baseplate Thickness	BTHK	15.0000	mm.
Leg Dimension Along Baseplate Length	d	59.9999	mm.
Leg Dimension Along Baseplate Width	b	59.9999	mm.
Bolt Circle Diameter	BCD	331.8000	mm.
Bolt Material		SA-325	
Bolt Allowable Tensile Stress	STBA	300.00	N./mm²
Bolt Allowable Shear Stress	SBShear	180.00	N./mm²
Anchor Bolt Nominal Diameter	BOD	20.0000	mm.
Number of Anchor Bolts in Tension per Leg	NB	1	
Total Number of Anchors Bolt per Leg	NBT	1	
Ultimate 28-day Concrete Strength	FCPRIME	20.685	N./mm²

Shear Stress in a Single Bolt [taub]:
= Shear Force / (2 * Bolt Area * Number of Bolts)
= 1.01/(2 * 2.17 * 1)
= 2.3 N./mm². Must be less than 180.0 N./mm².

Plate thickness required (1/2"; 13mm) per D. Moss

Since there is only 1 bolt, the standard computation for this geometry is not possible. A reasonable bolt size should be selected. Per Megyesy, use a 1 inch (25.4 mm) bolt.

Input, Nozzle Desc: N04 (1in) **From: 10**

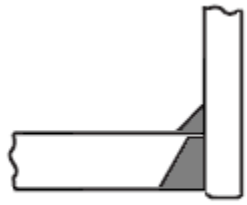
Pressure for Reinforcement Calculations	P	8.130	bars
Temperature for Internal Pressure	Temp	100	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-234 WPB	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm²
Shell Allowable Stress At Ambient	Sva	117.90	N./mm²
Inside Diameter of Elliptical Head	D	304.80	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	9.5250	mm.
Head Internal Corrosion Allowance	c	6.0000	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-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		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: 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                0.500  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)
= (8.13*0.87*317)/(2 *118*1-0.2*8.13)
= 0.9496 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)
= (8.13*18.7)/(138*1-0.6*8.13)
= 0.1106 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2564 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl    74.8000  mm.
Parallel to Vessel Wall, opening length            d    37.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    8.8125  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 138/118 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 138/118 )
```

= 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	0.355	0.280	NA
Area in Shell	A1	0.963	0.757	NA
Area in Nozzle Wall	A2	1.161	1.136	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.986	0.986	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.110	2.879	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(37.4*1.5*1+2*6.7*1.5*1(1-1))
= 0.280 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)
= 37.4 (1 * 3.52 - 1 * 1.5) - 2 * 6.7
(1 * 3.52 - 1 * 1.5) * (1 - 1)
= 0.757 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 8.81)(6.7 - 0.26)1
= 1.136 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= (Wo² - Area Lost)*fr2 + ((Wi-can/0.707)² - Area Lost)*fr2
= (10² - 0.014) * 1 + (0² -0) * 1
= 0.986 cm²

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

Wall Thickness for Internal/External pressures ta = 6.2564 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 7.0409 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 7.5000 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 7.5000 mm.

```
Wall Thickness per table UG-45                    tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.42, max( 7.5, 7.5 ) ]
  = 7.5000 mm.
```

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

```
  = max( ta, tb )
  = max( 6.26, 7.5 )
  = 7.5000 mm.
```

Available Nozzle Neck Thickness = 12.7000 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 = 9.52, tr = 0.95, c = 6 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.27, Temp. Reduction = 78 °C

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -48 °C
```

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

```
Design Pressure/Ambient Rating = 8.13/19.60 = 0.415
```

Weld Size Calculations, Description: N04 (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      3.5250  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.4675 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (0.28 - 0.76 + 2 * 6.7 * 1 *
    (1 * 3.52 - 1.5 ) )118 )
  = max( 0, -2.42) kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.14 + 0 + 0.99 - 0 * 1 ) * 118
  = 25.01 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.14 + 0 + 0.99 + ( 0.47 ) ) * 118
  = 30.58 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.14 + 0 + 0.99 + 0 + ( 0.47 ) ) * 118
  = 30.58 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 ) * 50.8 * 10 * 0.49 * 118
  = 46. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 22 ) * ( 12.7 - 6 ) * 0.7 * 138
  = 45. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 50.8 * ( 8.33 - 6 ) * 0.74 * 138
  = 19. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 46.1 + 44.8 ) = 90.9 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 46.1 + 0 + 19 + 0 ) = 65.1 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 46.1 + 19 + 0 ) = 65.1 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 90 kN , must exceed W = 0 kN  or W1 = 25 kN
 Path 2-2 = 65 kN , must exceed W = 0 kN  or W2 = 30 kN
 Path 3-3 = 65 kN , must exceed W = 0 kN  or W3 = 30 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   25.9  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 : 1.1465 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 160.6715 mm.

Input, Nozzle Desc: N02 (1in) **From: 20**

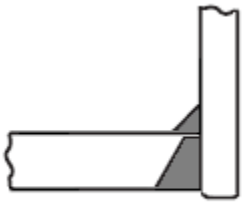
Pressure for Reinforcement Calculations	P	8.108	bars
Temperature for Internal Pressure	Temp	100	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm²
Shell Allowable Stress At Ambient	Sva	117.90	N./mm²
Inside Diameter of Cylindrical Shell	D	307.18	mm.
Design Length of Section	L	1275.4000	mm.
Shell Finished (Minimum) Thickness	t	8.3344	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		150.00	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		0.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: N02 (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                0.500  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)
= (8.11*160)/(118*1-0.6*8.11)
= 1.1021 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)
= (8.11*18.7)/(138*1-0.6*8.11)
= 0.1103 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2564 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl    74.8000  mm.
Parallel to Vessel Wall, opening length            d    37.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    5.8359  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 138/118 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 138/118 )
```

= 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	0.412	0.343	NA
Area in Shell	A1	0.461	0.187	NA
Area in Nozzle Wall	A2	0.769	0.752	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.827	0.827	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	2.057	1.766	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(37.4*1.83*1+2*6.7*1.83*1(1-1))
= 0.343 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)
= 37.4 (1 * 2.33 - 1 * 1.83) - 2 * 6.7
(1 * 2.33 - 1 * 1.83) * (1 - 1)
= 0.187 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 5.84)(6.7 - 0.26)1
= 0.752 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= (Wo² - Area Lost)*fr2 + ((Wi-can/0.707)² - Area Lost)*fr2
= (10² - 0.17) * 1 + (0² -0) * 1
= 0.827 cm²

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

Wall Thickness for Internal/External pressures ta = 6.2564 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 7.1021 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 7.5000 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 7.5000 mm.

```
Wall Thickness per table UG-45                    tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.42, max( 7.5, 7.5 ) ]
  = 7.5000 mm.
```

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

```
  = max( ta, tb )
  = max( 6.26, 7.5 )
  = 7.5000 mm.
```

Available Nozzle Neck Thickness = 12.7000 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 = 8.33, tr = 1.1, c = 6 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.47, Temp. Reduction = 36 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -44 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -44 °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 = 8.11/19.60 = 0.414
```

Weld Size Calculations, Description: N02 (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      3.5250  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.4675 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (0.34 - 0.19 + 2 * 6.7 * 1 *
    (1 * 2.33 - 1.83 ) )118 )
  = 2.63 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.75 + 0 + 0.83 - 0 * 1 ) * 118
  = 18.61 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.75 + 0 + 0.83 + ( 0.31 ) ) * 118
  = 22.30 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 0.75 + 0 + 0.83 + 0 + ( 0.31 ) ) * 118
  = 22.30 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 ) * 50.8 * 10 * 0.49 * 118
  = 46. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 22 ) * ( 12.7 - 6 ) * 0.7 * 138
  = 45. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 50.8 * ( 8.33 - 6 ) * 0.74 * 138
  = 19. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 46.1 + 44.8 ) = 90.9 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 46.1 + 0 + 19 + 0 ) = 65.1 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 46.1 + 19 + 0 ) = 65.1 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 90 kN , must exceed W = 2 kN  or W1 = 18 kN
 Path 2-2 = 65 kN , must exceed W = 2 kN  or W2 = 22 kN
 Path 3-3 = 65 kN , must exceed W = 2 kN  or W3 = 22 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    17.1  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 : 2.1148 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 160.4492 mm.

Input, Nozzle Desc: N03 (1in) **From: 20**

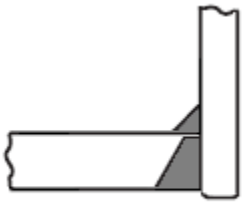
Pressure for Reinforcement Calculations	P	8.088	bars
Temperature for Internal Pressure	Temp	100	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm²
Shell Allowable Stress At Ambient	Sva	117.90	N./mm²
Inside Diameter of Cylindrical Shell	D	307.18	mm.
Design Length of Section	L	1275.4000	mm.
Shell Finished (Minimum) Thickness	t	8.3344	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		350.00	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		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: N03 (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                0.500  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)
= (8.09*160)/(118*1-0.6*8.09)
= 1.0994 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)
= (8.09*18.7)/(138*1-0.6*8.09)
= 0.1101 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2564 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl    74.8000  mm.
Parallel to Vessel Wall, opening length            d    37.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    5.8359  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 138/118 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 138/118 )
```

= 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	0.411	0.343	NA
Area in Shell	A1	0.462	0.187	NA
Area in Nozzle Wall	A2	0.769	0.752	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.827	0.827	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	2.058	1.766	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(37.4*1.83*1+2*6.7*1.83*1(1-1))
= 0.343 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)
= 37.4 (1 * 2.33 - 1 * 1.83) - 2 * 6.7
(1 * 2.33 - 1 * 1.83) * (1 - 1)
= 0.187 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 5.84)(6.7 - 0.26)1
= 0.752 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= (Wo² - Area Lost)*fr2 + ((Wi-can/0.707)² - Area Lost)*fr2
= (10² - 0.17) * 1 + (0² -0) * 1
= 0.827 cm²

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

Wall Thickness for Internal/External pressures ta = 6.2564 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 7.0994 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 7.5000 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 7.5000 mm.

```
Wall Thickness per table UG-45                    tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.42, max( 7.5, 7.5 ) ]
  = 7.5000 mm.
```

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

```
  = max( ta, tb )
  = max( 6.26, 7.5 )
  = 7.5000 mm.
```

Available Nozzle Neck Thickness = 12.7000 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 = 8.33, tr = 1.1, c = 6 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.47, Temp. Reduction = 37 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -44 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -44 °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 = 8.09/19.60 = 0.413
```

Weld Size Calculations, Description: N03 (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      3.5250  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.4675 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (0.34 - 0.19 + 2 * 6.7 * 1 *
    (1 * 2.33 - 1.83 ) )118 )
  = 2.63 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.75 + 0 + 0.83 - 0 * 1 ) * 118
  = 18.61 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.75 + 0 + 0.83 + ( 0.31 ) ) * 118
  = 22.30 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 0.75 + 0 + 0.83 + 0 + ( 0.31 ) ) * 118
  = 22.30 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 ) * 50.8 * 10 * 0.49 * 118
  = 46. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 22 ) * ( 12.7 - 6 ) * 0.7 * 138
  = 45. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 50.8 * ( 8.33 - 6 ) * 0.74 * 138
  = 19. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 46.1 + 44.8 ) = 90.9 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 46.1 + 0 + 19 + 0 ) = 65.1 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 46.1 + 19 + 0 ) = 65.1 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 90 kN , must exceed W = 2 kN  or W1 = 18 kN
 Path 2-2 = 65 kN , must exceed W = 2 kN  or W2 = 22 kN
 Path 3-3 = 65 kN , must exceed W = 2 kN  or W3 = 22 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 17.1 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 : 2.1148 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 160.4492 mm.

Input, Nozzle Desc: N01 (1in) **From: 20**

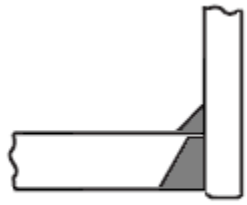
Pressure for Reinforcement Calculations	P	8.010	bars
Temperature for Internal Pressure	Temp	100	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm²
Shell Allowable Stress At Ambient	Sva	117.90	N./mm²
Inside Diameter of Cylindrical Shell	D	307.18	mm.
Design Length of Section	L	1275.4000	mm.
Shell Finished (Minimum) Thickness	t	8.3344	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1150.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	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		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: N01 (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                0.500  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)
= (8.01*160)/(118*1-0.6*8.01)
= 1.0887 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)
= (8.01*18.7)/(138*1-0.6*8.01)
= 0.1090 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2564 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl    74.8000  mm.
Parallel to Vessel Wall, opening length            d    37.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    5.8359  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 138/118 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 138/118 )
```

= 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	0.407	0.343	NA
Area in Shell	A1	0.466	0.187	NA
Area in Nozzle Wall	A2	0.769	0.752	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.827	0.827	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	2.062	1.766	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(37.4*1.83*1+2*6.7*1.83*1(1-1))
= 0.343 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)
= 37.4 (1 * 2.33 - 1 * 1.83) - 2 * 6.7
(1 * 2.33 - 1 * 1.83) * (1 - 1)
= 0.187 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 5.84)(6.7 - 0.26)1
= 0.752 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= (Wo² - Area Lost)*fr2 + ((Wi-can/0.707)² - Area Lost)*fr2
= (10² - 0.17) * 1 + (0² -0) * 1
= 0.827 cm²

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

Wall Thickness for Internal/External pressures ta = 6.2564 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 7.0887 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 7.5000 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 7.5000 mm.

```
Wall Thickness per table UG-45                    tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.42, max( 7.5, 7.5 ) ]
  = 7.5000 mm.
```

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

```
  = max( ta, tb )
  = max( 6.26, 7.5 )
  = 7.5000 mm.
```

Available Nozzle Neck Thickness = 12.7000 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 = 8.33, tr = 1.09, c = 6 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.47, Temp. Reduction = 37 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -45 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -45 °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 = 8.01/19.60 = 0.409
```

Weld Size Calculations, Description: N01 (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      3.5250  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.4675 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (0.34 - 0.19 + 2 * 6.7 * 1 *
    (1 * 2.33 - 1.83 ) )118 )
  = 2.63 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.75 + 0 + 0.83 - 0 * 1 ) * 118
  = 18.61 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.75 + 0 + 0.83 + ( 0.31 ) ) * 118
  = 22.30 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 0.75 + 0 + 0.83 + 0 + ( 0.31 ) ) * 118
  = 22.30 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 ) * 50.8 * 10 * 0.49 * 118
  = 46. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 22 ) * ( 12.7 - 6 ) * 0.7 * 138
  = 45. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 50.8 * ( 8.33 - 6 ) * 0.74 * 138
  = 19. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 46.1 + 44.8 ) = 90.9 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 46.1 + 0 + 19 + 0 ) = 65.1 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 46.1 + 19 + 0 ) = 65.1 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 90 kN , must exceed W = 2 kN  or W1 = 18 kN
 Path 2-2 = 65 kN , must exceed W = 2 kN  or W2 = 22 kN
 Path 3-3 = 65 kN , must exceed W = 2 kN  or W3 = 22 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 17 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 : 2.1148 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 160.4492 mm.

Input, Nozzle Desc: N06 (1in) **From: 20**

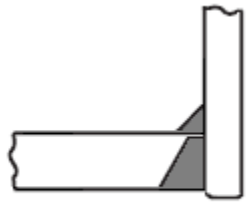
Pressure for Reinforcement Calculations	P	8.010	bars
Temperature for Internal Pressure	Temp	100	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm²
Shell Allowable Stress At Ambient	Sva	117.90	N./mm²
Inside Diameter of Cylindrical Shell	D	307.18	mm.
Design Length of Section	L	1275.4000	mm.
Shell Finished (Minimum) Thickness	t	8.3344	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1150.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	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		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: N06 (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                0.500  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)
= (8.01*160)/(118*1-0.6*8.01)
= 1.0887 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)
= (8.01*18.7)/(138*1-0.6*8.01)
= 0.1090 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2564 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl    74.8000  mm.
Parallel to Vessel Wall, opening length            d    37.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    5.8359  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 138/118 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 138/118 )
```

= 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	0.407	0.343	NA
Area in Shell	A1	0.466	0.187	NA
Area in Nozzle Wall	A2	0.769	0.752	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.827	0.827	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	2.062	1.766	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(37.4*1.83*1+2*6.7*1.83*1(1-1))
= 0.343 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)
= 37.4 (1 * 2.33 - 1 * 1.83) - 2 * 6.7
(1 * 2.33 - 1 * 1.83) * (1 - 1)
= 0.187 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 5.84)(6.7 - 0.26)1
= 0.752 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= (Wo² - Area Lost)*fr2 + ((Wi-can/0.707)² - Area Lost)*fr2
= (10² - 0.17) * 1 + (0² -0) * 1
= 0.827 cm²

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

Wall Thickness for Internal/External pressures ta = 6.2564 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 7.0887 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 7.5000 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 7.5000 mm.

```
Wall Thickness per table UG-45                    tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.42, max( 7.5, 7.5 ) ]
  = 7.5000 mm.
```

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

```
  = max( ta, tb )
  = max( 6.26, 7.5 )
  = 7.5000 mm.
```

Available Nozzle Neck Thickness = 12.7000 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 = 8.33, tr = 1.09, c = 6 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.47, Temp. Reduction = 37 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -45 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -45 °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 = 8.01/19.60 = 0.409
```

Weld Size Calculations, Description: N06 (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      3.5250  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.4675 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (0.34 - 0.19 + 2 * 6.7 * 1 *
    (1 * 2.33 - 1.83 ) )118 )
  = 2.63 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.75 + 0 + 0.83 - 0 * 1 ) * 118
  = 18.61 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.75 + 0 + 0.83 + ( 0.31 ) ) * 118
  = 22.30 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 0.75 + 0 + 0.83 + 0 + ( 0.31 ) ) * 118
  = 22.30 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 ) * 50.8 * 10 * 0.49 * 118
  = 46. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 22 ) * ( 12.7 - 6 ) * 0.7 * 138
  = 45. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 50.8 * ( 8.33 - 6 ) * 0.74 * 138
  = 19. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 46.1 + 44.8 ) = 90.9 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 46.1 + 0 + 19 + 0 ) = 65.1 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 46.1 + 19 + 0 ) = 65.1 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 90 kN , must exceed W = 2 kN  or W1 = 18 kN
 Path 2-2 = 65 kN , must exceed W = 2 kN  or W2 = 22 kN
 Path 3-3 = 65 kN , must exceed W = 2 kN  or W3 = 22 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   17  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 : 2.1148 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 160.4492 mm.

Input, Nozzle Desc: N05 (1in) **From: 40**

Pressure for Reinforcement Calculations	P	8.000	bars
Temperature for Internal Pressure	Temp	100	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-105	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Outside Diameter of Bolted Blind Flange	D	482.60	mm.
Head Finished (Minimum) Thickness	t	31.7500	mm.
Head Internal Corrosion Allowance	c	6.0000	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

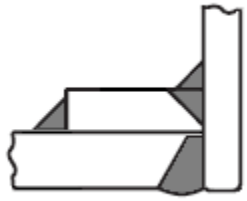
Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		0.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	31.7500	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm²
Diameter of Pad along vessel surface	Dp	150.0000	mm.
Thickness of Pad	te	8.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.

```
Groove weld depth between Pad and Nozzle    Wgpn      8.0000  mm.
Reinforcing Pad Width                                49.6000  mm.

Flange Class                                         150
Flange Grade                                         GR 1.1
```

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: N05 (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                  0.500  in.
```

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

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (8*18.7)/(138*1-0.6*8)
  = 0.1089 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2877 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl   102.3000  mm.
Parallel to Vessel Wall                         Rn+tn+t    51.1500  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     24.7500  mm.
```

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

Weld Strength Reduction Factor [fr1]:

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

```
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

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

Weld Strength Reduction Factor [fr4]:

```
  = min( 1, Sp/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	4.815	NA	NA
Area in Shell	A1	0.000	NA	NA
Area in Nozzle Wall	A2	3.263	NA	NA
Area in Inward Nozzle	A3	0.000	NA	NA
Area in Welds	A41+A42+A43	0.640	NA	NA
Area in Element	A5	4.120	NA	NA
TOTAL AREA AVAILABLE	Atot	8.023	NA	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	62.2080	8.0000	mm.
Based on given Pad Diameter:	150.0000	1.7721	mm.
Based on Shell or Nozzle Thickness:	57.9861	12.7000	mm.

Area Required [A]:

```
  = 0.5 * d * t + t * tn(1-fr1) per UG-39(a)(1)
  = 0.5*37.4*25.8+25.8*6.7(1-1)
  = 4.815 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 )
  = 64.9 ( 1 * 25.8 - 1 * 25.8 ) - 2 * 6.7
    ( 1 * 25.8 - 1 * 25.8 ) * ( 1 - 1 )
  = 0.000 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
= ( 2 * Tlwp ) * ( tn - trn ) * fr2
= ( 2 * 24.8 ) * ( 6.7 - 0.11 ) * 1
= 3.263 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 8² * 1 + (0 )² * 1 + 0² * 1
= 0.640 cm²
```

Area Available in Element [A5]:

```
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= ( 102 - 50.8 ) * 8 * 1
= 4.120 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 6.2877 mm.
Wall Thickness per UG16(b),                      tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 31.7500 mm.
Wall Thickness                tb1 = max(trb1, tr16b) = 31.7500 mm.
Wall Thickness                tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                  tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 9.42, max( 31.8, 7.5 ) ]
= 9.4200 mm.
```

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

```
= max( ta, tb )
= max( 6.29, 9.42 )
= 9.4200 mm.
```

Available Nozzle Neck Thickness = 12.7000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 8, c = 6 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.054, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 8, c = 6 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.054, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
```

```
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

Shell to Pad Weld Junction at Pad OD, min(Curve:B, Curve:A)

Govrn. thk, tg = 8, c = 6 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.054, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -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: A

Govrn. thk, tg = 12.7, tr = 0.11, c = 6 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.016, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -1 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -48 °C
```

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

```
Design Pressure/Ambient Rating = 8.00/19.60 = 0.408
```

Weld Size Calculations, Description: N05 (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.7000  mm.
Intermediate Calc. for pad/shell Welds   TminPad      8.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.6900 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	4.0000 = 0.5*TminPad	5.6560 = 0.7 * Wp mm.

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (4.82 - 0 + 2 * 6.7 * 1 *
    (1 * 25.8 - 25.8 ) )138 )
  = 66.40 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.26 + 4.12 + 0.64 - 0 * 1 ) * 138
  = 110.62 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.26 + 0 + 0.64 + ( 3.45 ) ) * 138
  = 101.39 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.26 + 0 + 0.64 + 4.12 + ( 3.45 ) ) * 138
  = 158.20 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 ) * 50.8 * 8 * 0.49 * 138
  = 43. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.14/2.0 ) * 150 * 8 * 0.49 * 138
  = 127. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 22 ) * ( 12.7 - 6 ) * 0.7 * 138
  = 45. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.14/2 ) * 50.8 * 8 * 0.74 * 138
  = 65. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 50.8 * ( 31.8 - 6 ) * 0.74 * 138
  = 210. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 127 + 44.8 ) = 172 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 43.1 + 65.1 + 210 + 0 ) = 318 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 127 + 210 + 0 ) = 337 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 172 kN , must exceed W = 66 kN  or W1 = 110 kN
 Path 2-2 = 317 kN , must exceed W = 66 kN  or W2 = 101 kN
 Path 3-3 = 337 kN , must exceed W = 66 kN  or W3 = 158 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   17.7  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 Cut Length for this Nozzle is, Drop + Ho + H + T : 231.8008 mm.

G Loading Seismic Setting Bolt Calc. F-100

Seismic Calculation

Seismic Design Method: **G Loading**

Vessel Diameter	D =	304.7	(mm)
Vessel Height (T.L.-T.L.)	H =	1250	(mm)
Shell Thickness	Thk.=	4	(mm)
High Liquid Level	HLL =	1250	(mm)
Content Specific Gravity	G =	1.02	
Material Density	ρ =	7750	(Kg/m^2)
Elastic modulus	E =	1.98E+11	(N/mm^2)
No of Lugs	N_L =	3	
No of Bolts per Lug	N_B =	1	
Importance Factor	I =	1.5	
	Sds =	1.02	
	A_P =	1	
	R =	2.5	
	z/h =	1	
Global Scalar for Seismic Load	Gss =	0.7	
Empty Weight	W_E =	265	(kg)
Operating Weight	W_O =	426	(kg)
Test Weight	W_T =	371	(kg)

G Loading Parameters:

Longitudinal Acceleration = 0.4 * Ap * Sds * (1+ 2 * (z/h)) / (R/I)

	Gx =	0.7344	
Lateral Acceleration	Gz =	0	
Vertical Acceleration = 0.2*Sds	Gy =	0.204	
Distance from CG to bottom of base plate	d =	1650	(mm)
Seismic Shear Force = Gx * W	S_L =	313	(kg)
Seismic Vertical Force = Gy * W	S_V =	87	(kg)

Final Seismic Loads

Seismic Shear Force = Gss * S_L	=	219	(kg)
Seismic Vertical Force = Gss * S_V	=	87	(kg)
Seismic Moment = Gss * S_L * d	=	361	(kg.m)

Final Loads Acc. To PV

Shear Force	=	204	(kg)
Moment	=	148	(kg.m)

SETTING BOLT CALCULATION

Setting Bolt Material			SA-193 B7			
Allowable Tensile Stress	$\sigma_{u=}$	3059.1	kg/cm^2	=	300	Mpa
Allowable Shear Stress		1835.5	kg/cm^2		180	Mpa
Using Parameters:						
F= seismic force		0.22	ton		219	kg
n= Number of bolt		3			3	
d=bolt's diameter		2.2	cm		22	mm
V= shearing force at one bolt	$V=\frac{F(ton)*1000}{n}$	73.0	Kg			
A=According to Table 5-DM of TEMA		2.17	cm^2		217	mm^2
τ=shear stress at one bolt (kg / cm^2)	$\tau=\frac{V(Kg)}{A(cm^2)}$	33.64	Kg/cm^2		3.30	Mpa
Shear stresse in bolts(τ=3.30 Mpa) is less than maximum allowable shear stress.(τy=180 Mpa)						
M_{LUG} (OPERATING)		36134.683	kg-cm	=	361	kg-m
R_{LUG} (Distance from bolt to center line of vessel)		16.6	cm		166	mm
D_{LUG} (Distance from bolt to outer surfacer of vessel)		0.4	cm		4	mm
N_{LUG} (NUMBER OF LUG)		3			3	
W_{OP} (OPERAITING)		426	kgf		426	Kg
σ allow= bolt allowable stress		3059.1	kg/cm^2	=	300	Mpa
Fb= axial force on bolts	$F_b=\left[\frac{M_{LUG\,(OPERATING)}}{\left(R_{LUG}*\frac{N_{LUG}}{2}\right)}-\frac{W_{(OPERATING)}}{N_{LUG}}\right]$	1309.2	kg			
σ_b= Tension stress on one bolt		301.7	kg/cm^2		29.6	Mpa
σ_{eq}= equivalent stress	$\sigma_{eq}=\sqrt{\sigma_b^2+3\tau^2}$	307.2	kg/cm^2		30.1	Mpa

Tension stress in bolts (σb=29.58 Mpa) is less than maximum allowable stress. (σallow=300.00 Mpa)

Equivalent stress in bolts (σeq=30.13 Mpa) is less than maximum allowable stress. (σallow=300.00 Mpa)

TABLE D-5M
METRIC BOLTING DATA - RECOMMENDED MINIMUM
(All Dimensions in Millimeters Unless Noted)

Bolt Size d_B	Threads		Nut Dimensions		Bolt Spacing B	Radial Distance R_h	Radial Distance R_f	Edge Distance E	Bolt Size d_B
	Pitch	Root Area (mm^2)	Across Flats	Across Corners					
M12	1.75	72.398	21.00	24.25	31.75	20.64	15.88	15.88	M12
M16	2.00	138.324	27.00	31.18	44.45	28.58	20.64	20.64	M16
M20	2.50	217.051	34.00	39.26	52.39	31.75	23.81	23.81	M20
M22	2.50	272.419	36.00	41.57	53.98	33.34	25.40	25.40	M22
M24	3.00	312.748	41.00	47.34	58.74	36.51	28.58	28.58	M24
M27	3.00	413.852	46.00	53.12	63.50	38.10	29.00	29.00	M27
M30	3.50	502.965	50.00	57.74	73.03	46.04	33.34	33.34	M30
M36	4.00	738.015	60.00	69.28	84.14	53.97	39.69	39.69	M36
M42	4.50	1018.218	70.00	80.83	100.00	61.91		49.21	M42
M48	5.00	1342.959	80.00	92.38	112.71	68.26		55.56	M48
M56	5.50	1862.725	90.00	103.92	127.00	76.20		63.50	M56
M64	6.00	2467.150	100.00	115.47	139.70	84.14		66.68	M64
M72	6.00	3221.775	110.00	127.02	155.58	88.90		69.85	M72
M80	6.00	4076.831	120.00	138.56	166.69	93.66		74.61	M80
M90	6.00	5287.085	135.00	155.88	188.91	107.95		84.14	M90
M100	6.00	6651.528	150.00	173.21	207.96	119.06		93.66	M100