Base Load Power Hub (BLPH)

MECHANICAL CALCULATION

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STABILITY CHECK OF THE EQUIPMENT
WITH CODE ASME VIII DIV.I ED 2023 + 2014/68/EU

ITEM IDENTIFICATION DATA

ITEM CODE	HYDROGEN VENT KO DRUM
WORK NUMBER	24-003
DRAWING N°	24003-VE-10

MATERIALS:

SHELL	SA-516 Gr.60N
HEAD	SA-516 Gr.60N
FLANGES NOZZLES	SA-350 LF2 Cl.1
PIPE NOZZLES	SA-333 Gr.6
STUD BOLTS	SA-320 Gr.L7
NUT	SA-194 Gr.4

DESIGN DATA

	Shell Side
DESIGN PRESSURE, bar(g)	3.5
HYDROSTATIC PRESSURE, bar(g)	5.0
DESIGN TEMPERATURE, °C	-29/+80
CORROSION THICKNESS, mm	1.0
JOINTS EFFICIENCY	0.85

-

Vessel Loading Requirements
ASME Section VIII, Div.1 (UG-22)

Shop Order No. 24003

ASME Section VIII Div. 1 **Edition 2023**

APPLIES YES	APPLIES NO	ITEM V-4301
■	☐	INTERNAL PRESSURE
☐	■	EXTERNAL PRESSURE
■	☐	WEIGHT OF THE EQUIPMENT
■	☐	WEIGHT OF NORMAL CONTENTS UNDER OPERATING CONDITIONS (STATIC HEAD)
■	☐	WEIGHT OF NORMAL CONTENTS UNDER TEST CONDITIONS (STATIC HEAD)
■	☐	SUPERIMPOSED STATIC REACTIONS FROM WEIGHT OF ATTACHED EQUIPMENT
☐	■	THE ATTACHMENTS OF INTERNALS (APP. D)
■	☐	THE ATTACHMENTS OF VESSEL SUPPORTS (SKIRT, LEGS, SADDLES ETC.) (APP. G)
■	☐	THE ATTACHMENTS OF LIFTING LUGS
☐	■	CYCLIC AND DYNAMIC REACTIONS DUE TO PRESSURE
☐	■	CYCLIC AND DYNAMIC REACTIONS DUE TO THERMAL VARIATIONS
☐	■	CYCLIC AND DYNAMIC REACTIONS DUE TO EQUIPMENT MOUNTED ON THE EXCH.
☐	■	CYCLIC AND DYNAMIC REACTIONS DUE TO MECHANICAL LOADINGS
■	☐	WIND REACTIONS
☐	■	SNOW REACTIONS
☐	■	SEISMIC REACTIONS
☐	■	IMPACT REACTIONS SUCH AS THOSE DUE TO FLUID SHOCK
☐	■	TEMPERATURE GRADIENTS
☐	■	DIFFERENTIAL THERMAL EXPANSION
☐	■	ABNORMAL PRESSURES, SUCH AS THOSE CAUSED BY DEFLAGRATION
■	☐	TEST PRESSURE AND COINCIDENT STATIC HEAD ACTING DURING THE TEST

verified and approved by E. Dall'Arche date 29-Feb.-2024

Table of Contents

Vessel Design Summary: 5
Nozzle Summary: 7
Nozzle Schedule: 8
Bill of Material: 9
MDMT Summary: 10
Input Echo: 12
Internal Pressure Calculations: 18
Element: BOTTOM HEAD 19
Element: MAIN SHELL 22
Element: TOP HEAD 24
Pressure Test Results: Shop Test 27
Element and Detail Weights: 29
Nozzle Flange MAWP: 32
Natural Frequency Calculation: 34
Wind Load Calculation: 35
Wind/Earthquake Shear, Bending: 39
Wind/Earthquake Deflection: 40
Longitudinal Stress Constants: 42
Longitudinal Allowable Stresses: 43
Longitudinal Stresses due to: 44
Stress due to Combined Loads: 46
Center of Gravity Calculation: 50
Lifting Lug Calcs: LIFTING LUG 52
Leg Check, (Operating Case): 60
Leg Check, (Filled w/Water): 63
Nozzle Calcs.: N3-LIQUID OUTLE 66
Nozzle Calcs.: N1- GAS INLET 69
Nozzle Calcs.: H1-INSPECTION P 80
Nozzle Calcs.: K1B-LT FOR ALAR 85
Nozzle Calcs.: H2-INSPECTION P 88
Nozzle Calcs.: N4-VENT 93
Nozzle Calcs.: K1A-LT FOR ALAR 96
Nozzle Calcs.: K3-PT 99
Nozzle Calcs.: N2-GAS OUTLET 102
Foundation/Support Summary: 112
PED Results: 113

Vessel Design Summary:

ASME Code, Section VIII Division 1, 2023

```
Diameter Spec : 600.000 mm. ID
Vessel Design Length, Tangent to Tangent          2350.00  mm.

Distance of Bottom Tangent above Grade               0.00  mm.
Specified Datum Line Distance                        0.00  mm.

Internal Design Temperature                            80  °C
Internal Design Pressure                            3.500  bar(g)

External Design Temperature                            80  °C

Maximum Allowable Working Pressure                     18  bar(g)
Shop Test Pressure                                  5.005  bar(g)

Required Minimum Design Metal Temperature           -29.0  °C
Warmest Computed Minimum Design Metal Temperature   -46.0  °C

Wind Design Code                                 EN-2010
Earthquake Design Code                        No Seismic
```

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-516 60	...	...	K02100	Yes	No
Head	SA-516 60	...	...	K02100	Yes	No
Nozzle	SA-350 LF2	1	...	K03011	No	Yes
Nozzle	SA-333 6	...	...	K03006	No	Yes
Re-Pad	SA-516 70	...	...	K02700	No	No
Re-Pad	SA-516 60	...	...	K02100	No	No
Nozzle Flg	SA-350 LF2	1	...	K03011	No	Yes
Leg Baseplate	SA-516 70	...	...	K02700	No	No
Leg Bolting	SA-307 B	...	...		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 (bar(g) & mm.):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Total Corrosion Allowance	Str. Flg. Gov.	In Creep Range
BOTTOM HEAD	3.588	0.00	23.000	1.0000	No	No
MAIN SHELL	3.568	0.00	29.000	1.0000	N/A	No
TOP HEAD	3.500	0.00	23.000	1.0000	No	No

```
Liquid Level: 900.00 mm.  Dens.: 0.001 kg./cm^3    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	10.0	8.0	2.5	...	0.85	0.85
Cylinder	2300.0	2250.0	10.0	10.0	2.5	...	0.85	0.85
Ellipse	2350.0	50.0	10.0	8.0	2.5	...	0.85	0.85

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Nozzle Calculation Summary (bar(g) & mm.):

Description	MAWP	Ext	MAPNC	UG-45	[tr]	Weld Path	Areas or Stresses
N3-LIQUID OUTLE	23	...	...	OK	4.42	OK	No Calc[*]
N1- GAS INLET	28	...	...	OK	5.73	OK	Passed
H1-INSPECTION P	22	...	...	...		OK	Passed
K1B-LT FOR ALAR	29	...	...	OK	4.42	OK	No Calc[*]
H2-INSPECTION P	22	...	...	...		OK	Passed
N4-VENT	29	...	...	OK	5.73	OK	No Calc[*]
K1A-LT FOR ALAR	29	...	...	OK	4.42	OK	No Calc[*]
K3-PT	29	...	...	OK	4.42	OK	No Calc[*]
N2-GAS OUTLET	23	...	...	OK	5.66	OK	Passed

Nozzle MAWP Summary:

Minimum MAWP Nozzles	:	22 Nozzle : H2-INSPECTION P
Minimum MAWP Shells/Flanges	:	18 bar(g)
Computed Vessel M.A.W.P.	:	18 bar(g)

[*] - This was a small opening and the areas were not computed or
the MAWP of this connection could not be computed because
the longitudinal bending stress was greater than the hoop stress.

Multiple output lines for the same nozzle indicates required Code calculations in both the longitudinal and circumferential planes of reinforcement where applicable.

Check the Spatial Relationship between the Nozzles:

From Node	Nozzle Description	Y Coordinate mm.	Layout Angle deg	Dia. Limit mm.
10	N3-LIQUID OUTLET	0.000	0.000	64.800
20	N1- GAS INLET	1260.000	90.000	505.650
20	H1-INSPECTION PO	280.000	180.000	302.145
20	K1B-LT FOR ALARM	350.000	315.000	68.800
20	H2-INSPECTION PO	2070.000	180.000	302.145
20	N4-VENT	2150.000	0.000	155.130
20	K1A-LT FOR ALARM	810.000	315.000	68.800
20	K3-PT	2150.000	60.000	68.800
30	N2-GAS OUTLET	0.000	0.000	505.650

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!

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Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk mm	Reinforcing Pad Diameter	Pad Thk mm	Cut Length mm	Flg Class
N3-LIQUID OUTLET	1.000 in	Actual	LWN	2.000	12.700	...	...	158.59	150
K1B-LT FOR ALARM	1.000 in	Actual	LWN	2.000	12.700	...	...	161.08	150
K1A-LT FOR ALARM	1.000 in	Actual	LWN	2.000	12.700	...	...	161.08	150
K3-PT	1.000 in	Actual	LWN	2.000	12.700	...	...	161.08	150
N4-VENT	3.000 in	XS	WNF	3.500	7.620	...	...	163.31	150
H1-INSPECTION PO	6.000 in	XS	WNF	6.625	10.973	...	...	172.04	150
H2-INSPECTION PO	6.000 in	XS	WNF	6.625	10.973	...	...	172.04	150
N1- GAS INLET	10.000 in	XS	WNF	10.750	12.700	373.05	10.00	192.87	150
N2-GAS OUTLET	10.000 in	XS	WNF	10.750	12.700	373.05	10.00	175.33	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
N3-LIQUID O	SA-350 LF2	8.000	10.000	...	...	...
K1B-LT FOR	SA-350 LF2	10.000	9.000	...	...	...
K1A-LT FOR	SA-350 LF2	10.000	9.000	...	...	...
K3-PT	SA-350 LF2	10.000	9.000	...	...	...
N4-VENT	SA-333 6	10.000	9.000	...	...	...
H1-INSPECTI	SA-333 6	10.000	9.000	...	...	...
H2-INSPECTI	SA-333 6	10.000	9.000	...	...	...
N1- GAS INL	SA-333 6	10.000	9.000	8.000	10.000	...
N2-GAS OUTL	SA-333 6	8.000	9.000	8.000	10.000	...

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

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
N3-LIQUID OUTLET	...	0.0	150.00	0.00	BOTTOM HEAD
K1B-LT FOR ALARM	350.000	315.0	150.00	0.00	MAIN SHELL
K1A-LT FOR ALARM	810.000	315.0	150.00	0.00	MAIN SHELL
K3-PT	2150.000	60.0	150.00	0.00	MAIN SHELL
N4-VENT	2150.000	0.0	150.00	0.00	MAIN SHELL
H1-INSPECTION PO	280.000	180.0	150.00	0.00	MAIN SHELL
H2-INSPECTION PO	2070.000	180.0	150.00	0.00	MAIN SHELL
N1- GAS INLET	1260.000	90.0	150.00	0.00	MAIN SHELL
N2-GAS OUTLET	...	0.0	150.00	0.00	TOP HEAD

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Bill of Materials:

QTY	DESCRIPTION	MATERIAL
2	ELLIPTICAL HEAD: 2.0 X 1, 10.0mm. THK X 600.0mm. ID X 50.0mm.	SA-516 60
1	CYLINDER: 10.0mm. THK X 600.0mm. ID X 2250.0mm.	SA-516 60
3	LEGS, SHAPE: L80X80X10 960.0mm	...
3	BASEPLATES: 160.0mm X 150.0mm X 20.0mm	SA-516 70
3	BASEPLATE BOLTS: 24.0mm	SA-307 B
3	LEG RE-PADS: 150.000mm X 150.000mm X 10.000mm	SA-516 60
2	LIFTING LUGS:	SA-516 70
2	LIFTING LUG PADS: 80.0mm X 190.0mm X 10.0mm THK	
2	CLASS 150 GR 1.1, 6.0" BLIND FLANGE(S)	SA-350 LF2
1	NAMEPLATE	...

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Minimum Design Metal Temperature Results Summary (°C):

Description	Notes	Curve	Basic MDMT	Reduced MDMT	UG-20(f) MDMT	Thickness ratio	Gov Thk mm.	E*	PWHT reqd
BOTTOM HEAD	[10]	D	-48	-48	-29	0.669	8.000	0.85	No
BOTTOM HEAD	[7]	D	-48	-48	-29	0.527	10.000	0.85	No
MAIN SHELL	[8]	D	-48	-48	-29	0.527	10.000	0.85	No
TOP HEAD	[10]	D	-48	-48	-29	0.666	8.000	0.85	No
TOP HEAD	[7]	D	-48	-48	-29	0.525	10.000	0.85	No
N3-LIQUID OUTL	[1]	D	-48	-48	-29	0.603	8.000	1.00	No
Nozzle Flg	[5]	!	-46	-46					
N1- GAS INLET	[1]	B	-46	-46		0.526	10.000	1.00	No
Nozzle Flg	[5]	!	-46	-49					
H1-INSPECTION	[1]	D	-46	-104		0.151	9.601	1.00	No
Nozzle Flg	[5]	!	-46	-49					
K1B-LT FOR ALA	[1]	D	-48	-48	-29	0.526	10.000	1.00	No
Nozzle Flg	[5]	!	-46	-46					
H2-INSPECTION	[1]	D	-46	-104		0.151	9.601	1.00	No
Nozzle Flg	[5]	!	-46	-49					
N4-VENT	[1]	D	-46	-104		0.121	6.668	1.00	No
Nozzle Flg	[5]	!	-46	-49					
K1A-LT FOR ALA	[1]	D	-48	-48	-29	0.526	10.000	1.00	No
Nozzle Flg	[5]	!	-46	-46					
K3-PT	[1]	D	-48	-48	-29	0.526	10.000	1.00	No
Nozzle Flg	[5]	!	-46	-46					
N2-GAS OUTLET	[1]	C	-46	-46		0.666	10.000	1.00	No
Nozzle Flg	[5]	!	-46	-49					
Nozl. Bolting	[22]		-48			1.000	63.500	1.00	No
Warmest MDMT:			-46	-46					

Required Minimum Design Metal Temperature -29.0 °C
Warmest Computed Minimum Design Metal Temperature -46.0 °C

Notes:
[!] - This was an impact tested material.
[1] - Governing Nozzle Weld.
[4] - ASME Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
[5] - ASME 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] - Body Flange Bolting Material
[22] - Nozzle Flange Bolting Material
[23] - Stiffening Ring to Shell Weld
[24] - Saddle to Shell Weld

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.

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Units used in this Analysis (bar(g)_UniCode):

Name	System Unit	Constant	User Unit
Length	Feet	304.8000	mm.
Force	Pounds	0.4536	kgf
Mass	Pounds	0.4536	kg.
Area	sq. inches	6.4516	cm^2
Moment	ft. lbs.	0.1383	Kg-m.
Stress	lbs./sq.in.	0.0069	N./mm^2
Temperature	Degrees F	0.5556	°C
Pressure	psig	0.0689	bar(g)
Elast. Modulus	lbs./sq.in.	6.8946	kPa.
Pipe Density	lbs./cu.in.	0.0277	kg./cm^3
Ins. Density	lbs./cu.ft.	0.1600E-04	kg./cm^3
Fluid Density	lbs./cu.ft.	0.1600E-04	kg./cm^3
Wind Speed	miles/hr	1.6093	km/hr
Tray Weight	lbs./sq.ft.	0.0005	kgs/cm^2
Inertia	in.^4	41.6231	cm^4
G Load	G's	1.0000	g's
Wind Load	lbs./sq.ft.	4.8825	kgs/m^2
Elevation	Feet	304.8000	mm.
Volume	in.^3	16.3900	cm³
Diameter	inches	25.4000	mm.
Thickness	inches	25.4000	mm.

PV Elite Vessel Analysis Program: Input Data

Design Internal Pressure (for Hydrotest)	3.4998	bar(g)
Design Internal Temperature	80.0	°C
Projection of Nozzle from Vessel Top	0	mm.
Projection of Nozzle from Vessel Bottom	0	mm.
Minimum Design Metal Temperature	-29.0	°C
Type of Construction	Welded	
Special Service	None	
Degree of Radiography	RT-3	
Use Higher Longitudinal Stresses (Flag)	Y	
Select t for Internal Pressure (Flag)	N	
Select t for External Pressure (Flag)	N	
Select t for Axial Stress (Flag)	N	
Select Location for Stiff. Rings (Flag)	N	
Consider Vortex Shedding	N	

Shop Pressure Test:

Type of Pressure Test	PED and UG-99(b)
Pressure Test Position	Vertical
Test Performed in Corroded Condition	No

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	
Load Case 20	BL+IP+OW	
Wind Design Code	EN 1991-1-4:2005+A1:2010	
Fundamental Wind Velocity [Vb,0]	162	km/hr
Direction Factor [Cdir]	1.0	
Seasonal Factor [CSeason]	1.0	
Force Coefficient [Cf]	0.69999999	
Terrain Category	0 - Sea or Costal Area	
Air Density	1.25	kg/m³
Orography Factor	1.0	
Check Vortex Shedding per Section 22.10	No	
Use Procedure 2 Annex C to compute CsCd	No	
User input CsCd, Operating Case	1.0	
User input CsCd, Empty Case	0.0	
User input CsCd, Test Case	0.0	
Damping Factor, deltaS, [Operating]	0.0400	
Damping Factor, deltaS, [Empty]	0.0120	
Damping Factor, deltaS, [Filled]	0.0400	
Seismic Design Code	No Seismic	
M.A.W.P. + Static Head to Element Bottom	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	
Perform Blast Load Analysis	No	
Material Database Year	Current w/Addenda or Code Year	

Configuration Directives:

g0 is taken as min(g0, attached shell thk)	Yes
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 Calculations	Yes

Complete Listing of Vessel Elements and Details:

Element#	1/3	
Element From Node	10	
Element To Node	20	
Element Type	Elliptical	
Description	BOTTOM HEAD	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	600	mm.

Element Thickness	8	mm.
Internal Corrosion Allowance	1	mm.
Nominal Thickness	10	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	3.4998	bar(g)
Design Temperature Internal Pressure	80	°C
Design External Pressure	0	bar(g)
Design Temperature External Pressure	80	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 60 [Normalized]	
Allowable Stress, Ambient	117.9	N./mm^2
Allowable Stress, Operating	117.9	N./mm^2
Allowable Stress, Hydrotest	198.58	N./mm^2
Material Density	0.00775	kg./cm^3
P Number Thickness	31.801	mm.
Yield Stress, Operating	204.67	N./mm^2
UCS-66 Chart Curve Designation	D	
External Pressure Chart Name	CS-2	
UNS Number	K02100	
Product Form	Plate	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	
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	-150	mm.
Height/Length of Liquid	200	mm.
Liquid Density	0.0009984	kg./cm^3
Element From Node	10	
Detail Type	Nozzle	
Detail ID	N3-LIQUID OUTLET	
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)	3.3388	kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2 [Impact Tested]	

Element#	2/3	
Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	MAIN SHELL	
Distance "FROM" to "TO"	2250	mm.
Inside Diameter	600	mm.
Element Thickness	10	mm.
Internal Corrosion Allowance	1	mm.
Nominal Thickness	10	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	3.4998	bar(g)
Design Temperature Internal Pressure	80	°C
Design External Pressure	0	bar(g)
Design Temperature External Pressure	80	°C
Effective Diameter Multiplier	1.2	

Material Name	SA-516 60 [Normalized]	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	
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	700	mm.
Liquid Density	0.0009984	kg./cm^3
Element From Node	20	
Detail Type	Nozzle	
Detail ID	N1- GAS INLET	
Dist. from "FROM" Node / Offset dist	1210	mm.
Nozzle Diameter	10	in.
Nozzle Schedule	XS	
Nozzle Class	150	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	58.941	kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6 [Impact Tested]	
Element From Node	20	
Detail Type	Nozzle	
Detail ID	H1-INSPECTION PO	
Dist. from "FROM" Node / Offset dist	230	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	XS	
Nozzle Class	150	
Layout Angle	180.0	
Blind Flange (Y/N)	Y	
Weight of Nozzle (Used if > 0)	49.648	kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6 [Impact Tested]	
Element From Node	20	
Detail Type	Nozzle	
Detail ID	K1B-LT FOR ALARM	
Dist. from "FROM" Node / Offset dist	300	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	315.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	3.3388	kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2 [Impact Tested]	
Element From Node	20	
Detail Type	Nozzle	
Detail ID	H2-INSPECTION PO	
Dist. from "FROM" Node / Offset dist	2020	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	XS	
Nozzle Class	150	
Layout Angle	180.0	
Blind Flange (Y/N)	Y	
Weight of Nozzle (Used if > 0)	49.648	kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6 [Impact Tested]	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N4-VENT	
Dist. from "FROM" Node / Offset dist	2100	mm.
Nozzle Diameter	3	in.
Nozzle Schedule	XS	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	9.6115	kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6 [Impact Tested]	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	K1A-LT FOR ALARM	
Dist. from "FROM" Node / Offset dist	760	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	315.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	3.3388	kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2 [Impact Tested]	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	K3-PT	
Dist. from "FROM" Node / Offset dist	2100	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	60.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	3.3388	kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2 [Impact Tested]	

Element From Node	20	
Detail Type	Leg	
Detail ID	LEGS	
Dist. from "FROM" Node / Offset dist	170	mm.
Diameter at Leg Centerline	685.07	mm.
Leg Orientation	3	
Number of Legs	3	
Section Identifier	L80X80X10	
Length of Legs	960	mm.

Element#	3/3	
Element From Node	30	
Element To Node	40	
Element Type	Elliptical	
Description	TOP HEAD	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	600	mm.
Element Thickness	8	mm.
Internal Corrosion Allowance	1	mm.
Nominal Thickness	10	mm.
External Corrosion Allowance	0	mm.

Design Internal Pressure	3.4998	bar(g)
Design Temperature Internal Pressure	80	°C
Design External Pressure	0	bar(g)
Design Temperature External Pressure	80	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 60 [Normalized]	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	
Element From Node	30	
Detail Type	Nozzle	
Detail ID	N2-GAS OUTLET	
Dist. from "FROM" Node / Offset dist	0	mm.
Nozzle Diameter	10	in.
Nozzle Schedule	XS	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	58.799	kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6 [Impact Tested]	

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Internal Pressure Results Summary:

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd bar(g)	Nominal Thickness mm.	Total Corr Allowance mm.	Element Diameter mm.	Allowable Stress(SE) N./mm^2	Element#
BOTTOM HEAD		3.588	10	1	600	100.22	1
MAIN SHELL		3.5684	10	1	600	100.22	2
TOP HEAD		3.4998	10	1	600	100.22	3

Element Required Thickness and MAWP :

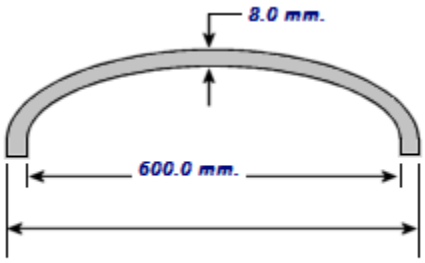
From	To	Design Pressure bar(g)	M.A.W.P. Corroded bar(g)	M.A.P. New & Cold bar(g)	Minimum Thickness mm.	Required Thickness mm.	Element#
BOTTOM HEAD		3.4998	23.2658	26.6525	8	2.5	1
MAIN SHELL		3.4998	29.3674	32.7494	10	2.5	2
TOP HEAD		3.4998	23.354	26.6525	8	2.5	3
Minimum			18	20			

Elements Suitable for Design Internal Pressure.

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Internal Pressure Calculation Results:

ASME Code, Section VIII Division 1, 2023



Internal Pressure Results for: BOTTOM HEAD

Elliptical Head Design Information:			
Design Pressure P	3.588 bar(g)	Int. Design Temperature	80 °C
Material	SA-516 60	Ext. Design Temperature	80 °C
Length	50.000 mm.	External Pressure Chart	CS-2
		UNS Number	K02100
Int. Corr. All. c	1.0000 mm.	Allowable Stress (ope) S	117.9 N./mm^2
Ext. Corr. All. ce	0.0000 mm.	Allowable Stress (amb) Sa	117.9 N./mm^2
Inside Diameter Di	600.000 mm.	Actual Stress	18.1 N./mm^2
Spec. Min. Thk t or e	8.0000 mm.	Spec. Nominal Thk.	10.000 mm.
Surface Area	5140.7 cm^2	SG of Contents	1.000
Element Volume	42419.1 cm³	Weight of Contents	42.4 kgf
Empty Weight	41.9 kgf	Operating Weight	84.3 kgf
		Comp. All. Ope. Stress	133.1 N./mm^2
		Aspect Ratio	2.00

Radiography Information:			
Spot Radiography per UW-11(b) Type 1		Seamless	
Circ. Joint Efficiency	85 %	Long. Joint Efficiency E	85 %

Tolerance for Formed Heads per UG-81(a):
Head inner surface maximum deviation outside the specified shape, 1.25% of D: 7.500 mm.
Head inner surface maximum deviation inside the specified shape, 0.625% of D: 3.750 mm.

Required Thickness due to Internal Pressure [tr]:
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (3.588*602.0*0.996)/(2*117.9*0.85-0.2*3.588)
= 1.0733 + 1.0000 = 2.0733 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 0.088 bar(g)
= (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
= (2*117.9*0.85*7.0)/(0.996*602.0+0.2*7.0)
= 23 - 0.1 = 23 bar(g)

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
= (2*117.9*0.85*8.0)/(1.0*600.0+0.2*8.0)
= 27 bar(g)

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*D+0.2*t))/(2*E*t)
= (3.588*(0.996*602.0+0.2*7.0))/(2*0.85*7.0)
= 18.114 N./mm^2

Straight Flange Required Thickness:
= (P*R)/(S*E-0.6*P) + c per UG-27 (c)(1)
= (3.588*301.0)/(117.9*0.85-0.6*3.588)+1.0
= 2.080 mm.

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.074 bar(g)
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (117.9 * 0.85 * 9.0)/(301.0 + 0.6 * 9.0)
= 29 - 0.1 = 29 bar(g)

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))^2)/6
= (2 + (602.0/(2 * 151.0))^2)/6
= 0.995592

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 7.009 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 8.0, tr = 5.509, c = 1.0 mm., E✱ = 0.85
Thickness Ratio = tr * E✱/(tg - c) = 0.669, Temp. Reduction = 18 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit	-48 °C

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 10.0, tr = 5.585, c = 1.0 mm., E✱ = 0.85
Thickness Ratio = tr * E✱/(tg - c) = 0.527, Temp. Reduction = 29 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit	-48 °C

MDMT Design Information:

MDMT Curve	D	Press. at MDMT	18.388 bar(g)
UCS-66(b) red.	No	Min. Des. Mtl. Temp.	-29 °C
Governing Thk.	10.000 mm.	Basic MDMT	-48 °C
Stress/Thk. Ratio	0.527	Temperature Difference	0 °C
UCS-66(c) red.	Yes	Computed Min. Temp.	-48 °C
		MDMT per UG-20(f)	-29 °C
		Joint Efficiency E*	85 %

Note: Temperature values displayed above are for the location with the highest basic MDMT

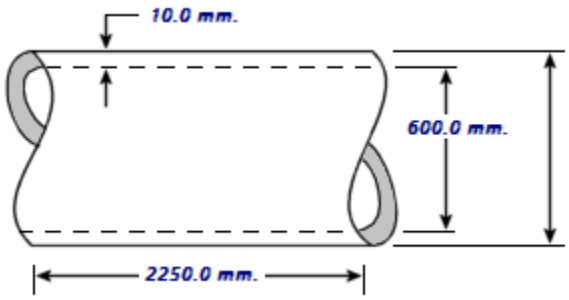
Tolerance for Formed Heads per UG-81(a):

```
Head inner surface maximum deviation outside the specified shape,  1.25% of D: 7.500 mm.
Head inner surface maximum deviation inside the specified shape,  0.625% of D: 3.750 mm.
```

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Internal Pressure Calculation Results:

ASME Code, Section VIII Division 1, 2023



Internal Pressure Results for: MAIN SHELL

Cylindrical Shell Design Information:			
Design Pressure P	3.568 bar(g)	Int. Design Temperature	80 °C
Material	SA-516 60	Ext. Design Temperature	80 °C
Length	2250.000 mm.	External Pressure Chart	CS-2
		UNS Number	K02100
Int. Corr. All. c	1.0000 mm.	Allowable Stress (ope) S	117.9 N./mm^2
Ext. Corr. All. ce	0.0000 mm.	Allowable Stress (amb) Sa	117.9 N./mm^2
Inside Diameter Di	600.000 mm.	Actual Stress	14.3 N./mm^2
Spec. Min. Thk t or e	10.0000 mm.	Spec. Nominal Thk.	10.000 mm.
Surface Area	43825.2 cm^2	SG of Contents	1.000
Element Volume	636286.6 cm³	Weight of Contents	197.8 kgf
Empty Weight	334.2 kgf	Operating Weight	532.0 kgf
		Comp. All. Ope. Stress	138.1 N./mm^2

Radiography Information:			
Full Radiography per UW-11(a) Type 1		Full Radiography per UW-11(a) Type 1	
Circ. Joint Efficiency	85 %	Long. Joint Efficiency E	85 %

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (3.568*301.0)/(117.9*0.85-0.6*3.568)
= 1.0741 + 1.0000 = 2.0741 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 0.069 bar(g)
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (117.9*0.85*9.0)/(301.0+0.6*9.0)
= 29 - 0.1 = 29 bar(g)

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (117.9*0.85*10.0)/(300.0+0.6*10.0)
= 33 bar(g)

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

```
= (P*(R+0.6*t))/(E*t)
= (3.568*(301.0+0.6*9.0))/(0.85*9.0)
= 14.293 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.639 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 10.0, tr = 5.579, c = 1.0 mm., E✱ = 0.85
Thickness Ratio = tr * E✱/(tg - c) = 0.527, Temp. Reduction = 29 °C

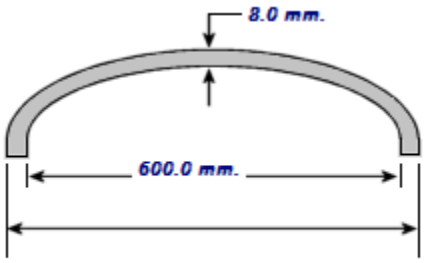
```
Min Metal Temp. w/o impact per UCS-66, Curve D            -48 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit       -48 °C
```

MDMT Design Information:			
MDMT Curve	D	Press. at MDMT	18.369 bar(g)
UCS-66(b) red.	No	Min. Des. Mtl. Temp.	-29 °C
Governing Thk.	10.000 mm.	Basic MDMT	-48 °C
Stress/Thk. Ratio	0.527	Temperature Difference	0 °C
UCS-66(c) red.	Yes	Computed Min. Temp.	-48 °C
		MDMT per UG-20(f)	-29 °C
		Joint Efficiency E*	85 %

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Internal Pressure Calculation Results:

ASME Code, Section VIII Division 1, 2023



Internal Pressure Results for: TOP HEAD

Elliptical Head Design Information:			
Design Pressure P	3.500 bar(g)	Int. Design Temperature	80 °C
Material	SA-516 60	Ext. Design Temperature	80 °C
Length	50.000 mm.	External Pressure Chart	CS-2
		UNS Number	K02100
Int. Corr. All. c	1.0000 mm.	Allowable Stress (ope) S	117.9 N./mm^2
Ext. Corr. All. ce	0.0000 mm.	Allowable Stress (amb) Sa	117.9 N./mm^2
Inside Diameter Di	600.000 mm.	Actual Stress	17.7 N./mm^2
Spec. Min. Thk t or e	8.0000 mm.	Spec. Nominal Thk.	10.000 mm.
Surface Area	5140.7 cm^2	SG of Contents	0.000
Element Volume	42419.1 cm³	Weight of Contents	0.0 kgf
Empty Weight	41.9 kgf	Operating Weight	41.9 kgf
		Comp. All. Ope. Stress	133.1 N./mm^2
		Aspect Ratio	2.00

Radiography Information:			
Spot Radiography per UW-11(b) Type 1		Seamless	
Circ. Joint Efficiency	85 %	Long. Joint Efficiency E	85 %

Tolerance for Formed Heads per UG-81(a):

Head inner surface maximum deviation outside the specified shape, 1.25% of D: 7.500 mm.
Head inner surface maximum deviation inside the specified shape, 0.625% of D: 3.750 mm.

Required Thickness due to Internal Pressure [tr]:

= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (3.5*602.0*0.996)/(2*117.9*0.85-0.2*3.5)
= 1.0469 + 1.0000 = 2.0469 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]:

= (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
= (2*117.9*0.85*7.0)/(0.996*602.0+0.2*7.0)
= 23 bar(g)

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
= (2*117.9*0.85*8.0)/(1.0*600.0+0.2*8.0)
= 27 bar(g)

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*D+0.2*t))/(2*E*t)
= (3.5*(0.996*602.0+0.2*7.0))/(2*0.85*7.0)
= 17.669 N./mm^2

Straight Flange Required Thickness:
= (P*R)/(S*E-0.6*P) + c per UG-27 (c)(1)
= (3.5*301.0)/(117.9*0.85-0.6*3.5)+1.0
= 2.053 mm.

Straight Flange Maximum Allowable Working Pressure:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (117.9 * 0.85 * 9.0)/(301.0 + 0.6 * 9.0)
= 29 bar(g)

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))^2)/6
= (2 + (602.0/(2 * 151.0))^2)/6
= 0.995592

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 7.009 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 8.0, tr = 5.482, c = 1.0 mm., E✱ = 0.85
Thickness Ratio = tr * E✱/(tg - c) = 0.666, Temp. Reduction = 19 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit	-48 °C

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 10.0, tr = 5.557, c = 1.0 mm., E✱ = 0.85
Thickness Ratio = tr * E✱/(tg - c) = 0.525, Temp. Reduction = 29 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit	-48 °C

MDMT Design Information:

MDMT Curve	D	Press. at MDMT	18.300 bar(g)
UCS-66(b) red.	No	Min. Des. Mtl. Temp.	-29 °C
Governing Thk.	10.000 mm.	Basic MDMT	-48 °C
Stress/Thk. Ratio	0.525	Temperature Difference	0 °C
UCS-66(c) red.	Yes	Computed Min. Temp.	-48 °C
		MDMT per UG-20(f)	-29 °C
		Joint Efficiency E*	85 %

Note: Temperature values displayed above are for the location with the highest basic MDMT

Tolerance for Formed Heads per UG-81(a):

```
Head inner surface maximum deviation outside the specified shape,  1.25% of D: 7.500 mm.
Head inner surface maximum deviation inside the specified shape,  0.625% of D: 3.750 mm.
```

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Hydrostatic Test Pressure Results:

```
UG99(b)          = 1.30 * M.A.W.P. * Sa/S              23.790 bar(g)
UG99b(b)(35)     = 1.30 * Design Pres * Sa/S             4.550 bar(g)
UG99(c)          = 1.30 * M.A.P. - Head(Hyd)           25.480 bar(g)
UG100            = 1.10 * M.A.W.P. * Sa/S              20.130 bar(g)
PED              = max(1.43*DP, 1.25*DP*ratio)          5.005 bar(g)
PED&UG99(b)(35)  = max(1.43*DP, 1.3*DP*ratio)           5.005 bar(g)
App 27-4         = M.A.W.P.                            18.300 bar(g)
```

Pressure per the PED and UG-99(b)(35):
= max(1.43 * Design Pressure, 1.3 * Design Pressure * Stress ratio)
= max(1.43 * 3.5, 1.3 * 3.5 * 1.0)
= max(5.005, 4.55)
= 5.005 bar(g)

Vertical Test performed per: PED & UG-99(b)(35)

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./mm^2 & bar(g)):

From To	Stress	Allowable	Ratio	Pressure
BOTTOM HEAD	23.3	198.6	0.117	5.26
MAIN SHELL	18.9	198.6	0.095	5.24
TOP HEAD	22.2	198.6	0.112	5.02

Stress ratios for Nozzle and Pad Materials (N./mm^2):

Description	Pad/Nozzle	Ambient	Operating	Ratio
N3-LIQUID OUTLET	Nozzle	137.90	137.90	1.000
N1- GAS INLET	Nozzle	117.90	117.90	1.000
N1- GAS INLET	Pad	137.90	137.90	1.000
H1-INSPECTION PO	Nozzle	117.90	117.90	1.000
K1B-LT FOR ALARM	Nozzle	137.90	137.90	1.000
H2-INSPECTION PO	Nozzle	117.90	117.90	1.000
N4-VENT	Nozzle	117.90	117.90	1.000
K1A-LT FOR ALARM	Nozzle	137.90	137.90	1.000
K3-PT	Nozzle	137.90	137.90	1.000
N2-GAS OUTLET	Nozzle	117.90	117.90	1.000
N2-GAS OUTLET	Pad	117.90	117.90	1.000
Minimum				1.000

Stress ratios for Pressurized Vessel Elements (N./mm^2):

Description	Ambient	Operating	Ratio
BOTTOM HEAD	117.90	117.90	1.000
MAIN SHELL	117.90	117.90	1.000
TOP HEAD	117.90	117.90	1.000
Minimum			1.000

Hoop Stress in Nozzle Wall during Pressure Test (N./mm^2):

Description	Ambient	Operating	Ratio
N3-LIQUID OUTLET	0.84	223.40	0.004
N1- GAS INLET	6.09	217.19	0.028
H1-INSPECTION PO	4.37	217.19	0.020
K1B-LT FOR ALARM	0.83	223.40	0.004
H2-INSPECTION PO	4.22	217.19	0.019
N4-VENT	3.16	217.19	0.015
K1A-LT FOR ALARM	0.83	223.40	0.004
K3-PT	0.81	223.40	0.004
N2-GAS OUTLET	5.97	217.19	0.027

Elements Suitable for Test Pressure.

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Element and Detail Weights:

From	To	Element Metal Wgt. kg.	Element ID Volume cm³	Corroded Metal Wgt. kg.	Corroded ID Volume cm³	Extra due Misc % kg.
10	20	41.941	42419.1	37.7469	42797.3	4.1941
20	30	334.172	636287	301.247	640536	33.4172
30	40	41.941	42419.1	37.7469	42797.3	4.1941
Total		418	721124.75	376	726130.12	41

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Z Offset Dtl. Cent. mm.	Description
10	Liqd	42.3932	...	-75	...	Liquid: 10
10	Nozl	3.67268	...	-271.006	...	N3-LIQUID OUTLET
20	Liqd	197.835	...	350	...	Liquid: 20
20	Nozl	64.8352	-375.006	1210	...	N1- GAS INLET
20	Nozl	54.6131	...	230	375.006	H1-INSPECTION PO
20	Nozl	3.67268	265.169	300	-265.169	K1B-LT FOR ALARM
20	Nozl	54.6131	...	2020	375.006	H2-INSPECTION PO
20	Nozl	10.5727	...	2100	-375.006	N4-VENT
20	Nozl	3.67268	265.169	760	-265.169	K1A-LT FOR ALARM
20	Nozl	3.67268	-324.765	2100	-187.503	K3-PT
20	Legs	49.4842	...	-310	...	LEGS
30	Nozl	64.6793	...	271.006	...	N2-GAS OUTLET

Total Weight of Each Detail Type:

Liquid	240.2
Nozzles	264.0
Legs	49.5
Sum of the Detail Weights	553.7 kg.

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	459.9	459.9	459.9	459.9	459.9	459.9
Nozzles	264.0	264.0	264.0	264.0	264.0	264.0
Legs	49.5	49.5	49.5	49.5	49.5	49.5
Ope. Liquid	...	...	...	...	...	240.2
Test Liquid	...	720.7	...	...	...	...
Totals	773.3	1494.0	773.3	773.3	773.3	1013.6

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                 773.3 kg.
Shop Test Wt.   - Fabricated Weight + Water ( Full )                     1494.0 kg.
Shipping Wt.    - Fab. Weight + removable Intls.+ Shipping App.           773.3 kg.
Erected  Wt.    - Fab. Wt + or - loose items (trays,platforms etc.)       773.3 kg.
Ope. Wt. no Liq - Fab. Weight + Internals. + Details + Weights            773.3 kg.
Operating Wt.   - Empty Weight + Operating Liq. Uncorroded               1013.6 kg.
Field Test Wt.  - Empty Weight + Water (Full)                            1494.0 kg.
```

Weights used in Vortex Shedding Calculations:

```
Mass of the Upper 1/3 of the Vertical Vessel (operating)                  283.1 kg.
Mass of the Upper 1/3 of the Vertical Vessel (filled w/water)             430.7 kg.
Mass of the Upper 1/3 of the Vertical Vessel (empty)                      299.5 kg.
```

Surface Areas of Elements:

From	To	Outside Surface Area cm^2	Inside Surface Area cm^2
10	20	5140.73	4844.82
20	30	43825.2	42411.5
30	40	5140.73	4844.82
Total		54106.7	52101.2 cm^2
Total		58.2	56.1 ft²

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. Kg-m.	Oper. Wgt. No Liquid kg.
10	20	49.8078	92.201	92.201	...	49.8078
20	Legs	42.556	57.5035	90.6016	34.36	42.556
Legs	30	520.685	703.572	1108.54	...	520.685
30	40	110.814	110.814	153.208	...	110.814

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid kg.	Cumulative Oper. Wgt. kg.	Cumulative Hydro. Wgt. kg.
10	20	...	...	...
20	Legs	-49.8078	-92.201	-92.201
Legs	30	631.499	814.387	1261.75
30	40	110.814	110.814	153.208

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. Kg-m.	Cumulative Oper. Mom. Kg-m.	Cumulative Hydro. Mom. Kg-m.
10	20	...	...	...
20	Legs	34.36	34.36	34.36
Legs	30	...	...	...
30	40	...	...	...

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Nozzle Flange MAWP Results: (bar(g) & °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
N3-LIQUID OUTL	18.30	19.60	80	150	GR 1.1	...	...	...	...
N1- GAS INLET	18.30	19.60	80	150	GR 1.1	19.790	18.300	18.300	7.66
H1-INSPECTION	18.30	19.60	80	150	GR 1.1	...	...	...	...
K1B-LT FOR ALA	18.30	19.60	80	150	GR 1.1	...	...	...	...
H2-INSPECTION	18.30	19.60	80	150	GR 1.1	...	...	...	...
N4-VENT	18.30	19.60	80	150	GR 1.1	...	...	...	...
K1A-LT FOR ALA	18.30	19.60	80	150	GR 1.1	...	...	...	...
K3-PT	18.30	19.60	80	150	GR 1.1	...	...	...	...
N2-GAS OUTLET	18.30	19.60	80	150	GR 1.1	19.790	18.300	18.300	7.66
Min Rating	18.300	19.600, [for Core Elements]				...	...	...	...

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

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

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

Nozzle Description	Gasket Dimension G mm.	Fm Value	Resolved Moment ME Kg-m.	Axial Force FE kgf	MAWP PD bar(g)	Maximum Pressure Pmax bar(g)	Pass Fail
N1- GAS INLET	302.387	1.20	1003	1224	18.300	18.300	Pass
N2-GAS OUTLET	302.387	1.20	1003	1224	18.300	18.300	Pass

Evaluating Flange on Nozzle [N1- GAS INLET]:
```
= 16*ME + 4*FE*G <= pi*G^3[((PR - PD) + FM * PR)]
= 16(1003)+4*abs(1224)302.387 < pi*302.387^3[(18.300-18.300)+1.200*18.300]
= 0.17531+05 <= 0.19453+05  Check Passes
```

Maximum Pressure for Flange on Nozzle N1- GAS INLET [Pmax]:
```
= min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
= min( 18.300, 1.200 * 18.300 + 18.300 - 17530.7/(pi * 302.387^3)
= min( 18.300, 20.470 )
= 18.300 bar(g)
```

Evaluating Flange on Nozzle [N2-GAS OUTLET]:
```
= 16*ME + 4*FE*G <= pi*G^3[((PR - PD) + FM * PR)]
= 16(1003)+4*abs(1224)302.387 < pi*302.387^3[(18.300-18.300)+1.200*18.300]
= 0.17531+05 <= 0.19453+05  Check Passes
```

Maximum Pressure for Flange on Nozzle N2-GAS OUTLET [Pmax]:
```
= min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
= min( 18.300, 1.200 * 18.300 + 18.300 - 17530.7/(pi * 302.387^3)
= min( 18.300, 20.470 )
= 18.300 bar(g)
```

Pressure Ratings are per ASME B16.5 2017 Metric Edition

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Natural Frequency [fn]:
```
  = 1 / ( 2 * pi * sqrt( wyy /( 386 * |( wy )| )))
  = 1/( 2 * pi * sqrt( 64.344/( 386 * |( 414.835 )| ))) Imperial units
  = 7.940 Hz.
```

where:
```
 wy = SumOf( weight * deflection )
 wyy = SumOf( weight * deflection^2 )
```

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 21.3243 Hz.

Natural Frequency [fn]:
```
  = 1 / ( 2 * pi * sqrt( wyy /( 386 * |( wy )| )))
  = 1/( 2 * pi * sqrt( 144.418/( 386 * |( 699.431 )| ))) Imperial units
  = 6.881 Hz.
```

where:
```
 wy = SumOf( weight * deflection )
 wyy = SumOf( weight * deflection^2 )
```

The Natural Frequency for the Vessel (Ope...) is 19.0713 Hz.

Natural Frequency [fn]:
```
  = 1 / ( 2 * pi * sqrt( wyy /( 386 * |( wy )| )))
  = 1/( 2 * pi * sqrt( 512.448/( 386 * |( 1657.306 )| ))) Imperial units
  = 5.623 Hz.
```

where:
```
 wy = SumOf( weight * deflection )
 wyy = SumOf( weight * deflection^2 )
```

The Natural Frequency for the Vessel (Filled) is 15.5408 Hz.

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Wind Load Calculation Results:

Wind Load results per EN 1991-1-4:2005+A1:2010

Input Data:

Wind Design Code	EN 1991-1-4:2005+A1:2010	
Fundamental Wind Velocity [Vb,0]	162	km/hr
Direction Factor [Cdir]	1.0	
Seasonal Factor [CSeason]	1.0	
Force Coefficient [Cf]	0.69999999	
Terrain Category	0 - Sea or Costal Area	
Air Density	1.25	kg/m³
Orography Factor	1.0	
Check Vortex Shedding per Section 22.10	No	
Use Procedure 2 Annex C to compute CsCd	No	
User input CsCd, Operating Case	1.0	
User input CsCd, Empty Case	0.0	
User input CsCd, Test Case	0.0	
Damping Factor, deltaS, [Operating]	0.0400	
Damping Factor, deltaS, [Empty]	0.0120	
Damping Factor, deltaS, [Filled]	0.0400	

The vessel must be skirt supported at the base to include the effects of vortex shedding per EN 13445 Section 22.10.

Analysis Results:

Note: The Wind Load Results below are in Metric Units.

Category 2 Basic Wind Velocity [Vb]:
= Cdir * CSeason * Vb,0
= 1.0 * 1.0 * 45.001
= 45.001 m/s

Terrain Factor dependant on Roughness Length [kr]:
$= 0.19(Zo / Z0,ii)^{0.07}$
$= 0.19(0.003/0.05)^{0.07}$
= 0.156

Sample Calculation for the first Element:

Determine the Roughness factor as a function of Elevation [Cr(z)]:
= kr * ln(z / zo)
= 0.156 * ln(1.0/0.003)
= 0.906

Mean Velocity at Height z [Vm(z)]:
= cr(z) * Co(z) * Vb
= 0.906 * 1.0 * 45.001
= 40.791 m/s

Turbulence Intensity at Height z [Iv(z)]:
= 1 / (Co(z) * ln(z / zo))
= 1/(1.0 * ln(1.0/0.003))
= 0.172

Peak Velocity Pressure at Height z [qp(z)]:

$= [\ 1 + 7 * Iv(z)\ ] * 1/2 * rho * Vm(z)^2$

$= [\ 1 + 7 * 0.172\ ] * 1/2 * 1.25 * 40.791^2$

$= 2293.027\ N/m^2$

Note: The turbulence factor ki(z) is taken to be 1.

EN 1991, Calculation of the Gust Response Factor CsCd:

Natural Frequency	n operating	19.07133	hz
Natural Frequency	n empty	21.32426	hz
Natural Frequency	n filled	15.54081	hz
Average Outer Diameter	b	0.61983	meters
Maximum Height	h	2.50800	meters
Zmin	zmin	1.00000	meters
z0	z0	0.00300	meters
Air Density	rho	1.25000	kg/m³
alpha	alpha	0.37954	
L(z) at height 0.6 * h, B.1	L(0.6h)	46.89674	
Structural Damping	deltaS	0.02000	
Surface Roughness	k	0.02000	mm
Effective Slenderness Table 7.16, 15	h/b	4.04627	
Effective Slenderness Table 7.16, 50	0.7 * h/b	2.83239	
Effective Slenderness, final	lambda	4.04627	
Solidity ratio	phi	1.00000	
End Effect Factor Fig. 7.36	psi lambda	0.73978	
Factor, see Figure 7.28 Note 2	v; v(ze)	64.73548	
Reynold's Number, eqn. 7.19	Re	2674998	
Force Coefficient, see 7.28	Cf,0	1.05390	

Parameters for the Empty Case:

Non dimensional frequency from B.2	fl(zs)	22.42646	
One sided variance spectrum from B.2	Sl(zs)	0.01769	
Parameter from B.7	etah	5.51701	
Parameter from B.8	etab	1.36348	
Aerodynamic admittance value	Rh	0.16483	
Aerodynamic admittance value	Rb	1.36348	
Mass per Unit Length	mue	308.99487	kg/m
Aerodynamic Damping	deltaA	0.00204	
Final Value (deltaA + deltaS)	delta	0.02204	
Resonance Response Factor	R²	0.31475	
Background Factor Factor	B²	0.85950	
Up Crossing Frequency	nu	11.04017	Hz
Peak Factor	kp	4.33790	
Size Factor, see 6.2	cs	0.96167	
Dynamic Factor, see 6.3	cd	1.22737	
Final Value, see 6.3.1	CsCd	1.18033	

Parameters for the Test Case:

Non dimensional frequency from B.2	fl(zs)	16.34407	
One sided variance spectrum from B.2	Sl(zs)	0.02179	
Parameter from B.7	etah	4.02071	
Parameter from B.8	etab	0.99368	
Aerodynamic admittance value	Rh	0.21779	
Aerodynamic admittance value	Rb	0.99368	
Mass per Unit Length	mue	596.94812	kg/m
Aerodynamic Damping	deltaA	0.00145	
Final Value (deltaA + deltaS)	delta	0.02145	
Resonance Response Factor	R²	0.62162	
Background Factor Factor	B²	0.85950	
Up Crossing Frequency	nu	10.06796	Hz

```
Peak Factor                                                    kp      4.31662
Size Factor, see 6.2                                           cs      0.96167
Dynamic Factor, see 6.3                                        cd      1.31369
Final Value, see 6.3.1                                       CsCd      1.26334
```

Force on the First Element at Height z, Operating [Fw(z)]:
```
  = qp(z) * CsCd * Aref * Cf
  = 47.891 * 1.0 * 1.385 * 0.7
  = 206.562 Newtons
```

Wind Vibration Calculations

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

Nomenclature

```
 Cf  - Correction factor for natural frequency
  D  - Average outer insulated diameter of vessel, mm.
 Df  - Damping Factor < 0.75 Unstable,  > 0.95 Stable
 Dr  - Average outer insulated 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/L²)(10⁴)
  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, kgf
 Ws  - Cor. vessel weight excl. weight of parts which do not effect stiff. kgf
  Z  - Maximum amplitude of vibration at top of vessel, mm.
 Dl  - Logarithmic decrement ( taken as 0.03 for Welded Structures )
 Vp  - Vib. Chance, <= 0.320E-06 (High); 0.320E-06 < 0.400E-06 (Probable)
 P30 - wind pressure 30 feet above the base
```

Check other Conditions and Basic Assumptions:
```
 :: Total Cone Length / Total Length < 0.5
 :: 0.0/2350.0 = 0.0

 :: [ D / L² ] * 10⁴ < 8 (English Units, ft.)
 :: [ 2.03/7.71² ] * 10⁴ = 342.099 [Geometry Violation]
```

Compute the vibration possibility. If Vp > 0.400E-06 no chance. [Vp]:
```
  = W / ( L * Dr²)
  = 968/( 2350.0 * 619.83² )
  = 0.10723E-05
```

Since Vp is > 0.400E-06 no further vibration analysis is required !

The Natural Frequency for the Vessel (Ope...) is 19.0713 Hz.

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm^2	Wind Pressure kgs/m^2	Element Wind Load kgf
10	20	117.382	739.2	1286.89	233.828	21.0632
20	30	1325	744	16740	250.539	293.572
30	40	2540.62	739.2	1286.89	291.109	26.2231

The Natural Frequency for the Vessel (Empty.) is 21.3243 Hz.

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm^2	Wind Pressure kgs/m^2	Element Wind Load kgf
10	20	117.382	739.2	1286.89	233.828	24.8616
20	30	1325	744	16740	250.539	346.512
30	40	2540.62	739.2	1286.89	291.109	30.9519

The Natural Frequency for the Vessel (Filled) is 15.5408 Hz.

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm^2	Wind Pressure kgs/m^2	Element Wind Load kgf
10	20	117.382	739.2	1286.89	233.828	26.6101
20	30	1325	744	16740	250.539	370.883
30	40	2540.62	739.2	1286.89	291.109	33.1288

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The following table is for the Filled Case.

Cumulative Wind Shear and Bending Moment

From	To	Distance to Support mm.	Cumulative Wind Shear kgf	Wind Bending Kg-m.
10	20	260.618	...	...
20	Legs	85	26.6101	2.41141
Legs	30	1040	402.6	419.176
30	40	2170.62	33.1288	3.00213

The following table is for the Empty Case.

Wind/Earthquake Shear, Bending:

From	To	Distance to Support mm.	Cumulative Wind Shear kgf	Earthquake Shear kgf	Wind Bending Kg-m.	Earthquake Bending Kg-m.
10	20	260.618	...	...	...	...
20	Legs	85	24.8616	...	2.25295	...
Legs	30	1040	376.145	...	391.632	...
30	40	2170.62	30.9519	...	2.80486	...

The following table is for the Operating Case.

Wind/Earthquake Shear, Bending:

From	To	Distance to Support mm.	Cumulative Wind Shear kgf	Earthquake Shear kgf	Wind Bending Kg-m.	Earthquake Bending Kg-m.
10	20	260.618	...	...	...	...
20	Legs	85	21.0632	...	1.90875	...
Legs	30	1040	318.677	...	331.799	...
30	40	2170.62	26.2231	...	2.37633	...

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: 1.000; Earthquake: 1.000.

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

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Wind Deflection Calculations:

The following table is for Wind Deflection; Filled(test) Case.

Note: Test Case Deflections were computed using un-corr. section properties.

Wind Load Deflection:

From	To	Cumulative Shear kgf	Centroid Deflection mm.	Elem. End Deflection mm.	Elem. Ang. Rotation
10	20	...	0.5451	0.5451	0.00085084
20	Legs	6.65253	0.54513	0.54519	0.00085186
Legs	30	100.65	0.54871	0.55444	0.00085656
30	40	8.28219	0.55458	0.55472	0.00085656

Allowable deflection at the Tower Top (Hyd)(6.000"/100ft. Criteria)
Allowable deflection : 11.750 Actual deflection : 0.555 mm.

The following table is for Wind Deflection; Empty Case.

Wind Load Deflection:

From	To	Cumulative Shear kgf	Centroid Deflection mm.	Elem. End Deflection mm.	Elem. Ang. Rotation
10	20	...	2.03711	2.03711	0.0031793
20	Legs	24.8616	2.0372	2.03747	0.0031836
Legs	30	376.145	2.05201	2.07567	0.0032029
30	40	30.9519	2.07626	2.07685	0.0032029

Allowable deflection at the Tower Top (Emp)(6.000"/100ft. Criteria)
Allowable deflection : 11.750 Actual deflection : 2.077 mm.

The following table is for Wind Deflection; Operating Case.

Wind Load Deflection:

From	To	Cumulative Shear kgf	Centroid Deflection mm.	Elem. End Deflection mm.	Elem. Ang. Rotation
10	20	...	1.72588	1.72588	0.0026935
20	Legs	21.0632	1.72596	1.72619	0.0026972
Legs	30	318.677	1.73866	1.75894	0.0027138
30	40	26.2231	1.75945	1.75996	0.0027138

Critical Wind Velocity for Tower Vibration:

From	To	1st Crit. Wind Speed km/hr	2nd Crit. Wind Speed km/hr
10	20	253.072	1581.7
20	30	254.715	1591.97
30	40	253.072	1581.7

Allowable deflection at the Tower Top (Ope)(6.000"/100ft. Criteria)
Allowable deflection : 11.750 Actual deflection : 1.760 mm.

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Longitudinal Stress Constants:

From	To	Metal Area New cm^2	Metal Area Corroded cm^2	Section Modulus New mm.³	Section Modulus Corroded mm.³
10	20	152.807	133.926	2292900	2016116
20	30	191.637	172.756	2876101	2601103
30	40	152.807	133.926	2292900	2016116

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Longitudinal Allowable Stresses:

From	To	Tensile N./mm^2	Hydrotest Tensile N./mm^2	Compressive N./mm^2	Hydrotest Compressive N./mm^2
10	20	120.263	202.547	-133.109	-135.92
20	Legs	120.263	202.547	-138.07	-139.941
Legs	30	120.263	202.547	-138.07	-139.941
30	40	120.263	202.547	-133.109	-135.92

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Longitudinal Stress Report

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

Longitudinal Pressure Stresses due to:

From	To	Longitudinal Stress Internal Pressure N./mm^2	Longitudinal Stress External Pressure N./mm^2	Longitudinal Stress Hydrotest Pressure N./mm^2
10	20	7.455	...	9.28427
20	30	5.78278	...	7.4074
30	40	7.455	...	9.28427

Longitudinal Stresses due to Weight Loads for these Conditions:

From	To	Wght. Str. Empty N./mm^2	Wght. Str. Operating N./mm^2	Wght. Str. Hydrotest N./mm^2	Wght. Str. Emp. Mom. N./mm^2	Wght. Str. Opr. Mom. N./mm^2
10	20	...	...	...	...	...
20	Legs	0.028274	0.05234	0.047183	0.12954	0.12954
Legs	30	-0.35848	-0.35	-0.32316	...	...
30	40	-0.081145	-0.081145	-0.071118	...	...

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

From	To	Wght. Str. Hyd. Mom. N./mm^2	Bend. Str. Oper. Wind N./mm^2	Bend. Str. Oper. Equ. N./mm^2	Bend. Str. Hyd. Wind N./mm^2	Bend. Str. Hyd. Equ. N./mm^2
10	20	...	...	...	...	...
20	Legs	0.11716	0.0071963	...	0.0020555	...
Legs	30	...	1.25094	...	0.35732	...
30	40	...	0.011559	...	0.00321	...

Longitudinal Stresses due to these Conditions:

From	To	Vortex Shedding Operating Case N./mm^2	Vortex Shedding Empty Case N./mm^2	Vortex Shedding Test Case N./mm^2	Earthquake Empty Case N./mm^2
10	20	...	...	...	...
20	Legs	...	...	...	...
Legs	30	...	...	...	...
30	40	...	...	...	...

Longitudinal Stresses due to Applied Axial Forces:

From	To	Longitudinal Stress Y Forces Wind N./mm^2	Longitudinal Stress Y Forces Seismic N./mm^2
10	20	...	...
20	Legs	...	...
Legs	30	...	...
30	40	...	...

Longitudinal Stresses due to User Forces and Moments:

From	To	Wind For/Mom Corroded N./mm^2	Earthquake For/Mom Corroded N./mm^2	Wind For/Mom No Corrosion N./mm^2	Earthquake For/Mom No Corrosion N./mm^2
10	20	...	...	...	...
20	Legs	...	...	...	...
Legs	30	...	...	...	...
30	40	...	...	...	...

Bending Stresses due to Blast Load:

From	To	Bending Stress N./mm^2
10	20	...
20	Legs	...
Legs	30	...
30	40	...

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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
BL = Bending Stress due to Blast Loads, Corroded
```

General Notes:

Case types HI and HE are in the Un-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	120.26	0.00	133.11	0.0000	0.0000
20	0.17	120.26	-0.11	138.07	0.0014	0.0008
20	0.89	120.26	-1.61	138.07	0.0074	0.0117
30		120.26	-0.09	133.11		0.0007

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	120.26	0.00	133.11	0.0000	0.0000
20	0.16	120.26	-0.10	138.07	0.0013	0.0007
20		120.26	-0.36	138.07		0.0026
30		120.26	-0.08	133.11		0.0006

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	120.26	0.00	133.11	0.0000	0.0000
20	0.19	120.26	-0.08	138.07	0.0016	0.0006
20	0.90	120.26	-1.60	138.07	0.0075	0.0116
30		120.26	-0.09	133.11		0.0007

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	120.26	0.00	133.11	0.0000	0.0000
20	0.18	120.26	-0.08	138.07	0.0015	0.0006
20		120.26	-0.35	138.07		0.0025
30		120.26	-0.08	133.11		0.0006

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	202.55	0.00	135.92	0.0000	0.0000
20	0.17	202.55	-0.07	139.94	0.0008	0.0005
20	0.03	202.55	-0.68	139.94	0.0002	0.0049
30		202.55	-0.07	135.92		0.0005

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	202.55	0.00	135.92	0.0000	0.0000
20	0.16	202.55	-0.07	139.94	0.0008	0.0005
20		202.55	-0.32	139.94		0.0023
30		202.55	-0.07	135.92		0.0005

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	7.46	120.26		133.11	0.0620	
20	5.97	120.26		138.07	0.0497	
20	6.68	120.26		138.07	0.0556	
30	7.39	120.26		133.11	0.0614	

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	7.46	120.26		133.11	0.0620	
20	5.96	120.26		138.07	0.0496	
20	5.43	120.26		138.07	0.0452	
30	7.37	120.26		133.11	0.0613	

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	120.26	0.00	133.11	0.0000	0.0000
20	0.19	120.26	-0.08	138.07	0.0016	0.0006
20	0.90	120.26	-1.60	138.07	0.0075	0.0116
30		120.26	-0.09	133.11		0.0007

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	0.00	120.26	0.00	133.11	0.0000	0.0000
20	0.18	120.26	-0.08	138.07	0.0015	0.0006
20		120.26	-0.35	138.07		0.0025
30		120.26	-0.08	133.11		0.0006

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	9.28	202.55		135.92	0.0458	
20	7.57	202.55		139.94	0.0374	
20	7.44	202.55		139.94	0.0367	
30	9.22	202.55		135.92	0.0455	

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	9.28	202.55		135.92	0.0458	
20	7.57	202.55		139.94	0.0374	
20	7.08	202.55		139.94	0.0350	
30	9.21	202.55		135.92	0.0455	

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	7.46	120.26		133.11	0.0620	
20	5.95	120.26		138.07	0.0495	
20	6.76	120.26		138.07	0.0562	
30	7.39	120.26		133.11	0.0614	

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	7.46	120.26		133.11	0.0620	
20	5.84	120.26		138.07	0.0485	
20	6.90	120.26		138.07	0.0573	
30	7.40	120.26		133.11	0.0615	

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	7.46	120.26		133.11	0.0620	
20	5.96	120.26		138.07	0.0496	
20	5.43	120.26		138.07	0.0452	
30	7.37	120.26		133.11	0.0613	

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	7.46	120.26		133.11	0.0620	
20	5.94	120.26		138.07	0.0494	
20	5.42	120.26		138.07	0.0451	
30	7.37	120.26		133.11	0.0613	

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	120.26	0.00	133.11	0.0000	0.0000
20	0.18	120.26	-0.08	138.07	0.0015	0.0006
20		120.26	-0.35	138.07		0.0025
30		120.26	-0.08	133.11		0.0006

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	7.46	120.26		133.11	0.0620	
20	5.96	120.26		138.07	0.0496	
20	5.43	120.26		138.07	0.0452	
30	7.37	120.26		133.11	0.0613	

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	0.00	120.26	0.00	133.11	0.0000	0.0000
20	0.18	120.26	-0.08	138.07	0.0015	0.0006
20		120.26	-0.35	138.07		0.0025
30		120.26	-0.08	133.11		0.0006

Analysis of Load Case 20 : BL+IP+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	7.46	120.26		133.11	0.0620	
20	5.96	120.26		138.07	0.0496	
20	5.43	120.26		138.07	0.0452	
30	7.37	120.26		133.11	0.0613	

Absolute Maximum of the all of the Stress Ratio's 0.0620

Governing Element: BOTTOM HEAD
Governing Load Case 7 : IP+OW+WI+FW+BW

Element Description	Long Pressure Stress	Weight + Axial Load Stress	Eccentric Moment Stress	Wind or Earthquake Stress	Combined Stress	Which Side
BOTTOM HEAD	7.5	...	...	...	7.5	+ Tens
BOTTOM HEAD	7.5	...	...	...	...	- Comp
MAIN SHELL	5.8	0.1	0.1	...	6.0	+ Tens
MAIN SHELL	5.8	0.1	-0.1	-0.0	...	- Comp
MAIN SHELL	5.8	-0.3	...	1.3	6.7	+ Tens
MAIN SHELL	5.8	-0.3	...	-1.3	...	- Comp
TOP HEAD	7.5	-0.1	...	...	7.4	+ Tens
TOP HEAD	7.5	-0.1	...	-0.0	...	- Comp

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Shop/Field Installation Options :

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

```
Center of Gravity of the Liquid                          316.176 mm.
Center of Gravity of the Nozzles                        1553.826 mm.
Center of Gravity of the Legs                           -260.000 mm.

Center of Gravity of Bare Shell New and Cold            1175.000 mm.
Center of Gravity of Bare Shell Corroded                1175.000 mm.

Vessel CG in the Operating Condition                     991.852 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition      1212.502 mm.
Vessel CG in the Test Condition                         1194.412 mm.
```

Rigging Analysis Results:

- Lifting weight based on the user selected calculated empty weight

```
Total Effective Length of Vessel for this analysis       2350.00 mm.
Total vessel weight (No Liquid)                Twt        773.35 kgf
Impact weight multiplication factor            Imp          2.00
Design lifting weight,  DWT = Imp * Twt                  1546.69 kgf
Elevation of the Tailing Lug (bottom)                       0.00 mm.
Elevation of the Lifting Lug (top   )                    2065.00 mm.
Design Reaction force at the tailing lug                  638.53 kgf
Design Reaction force at the lifting lug                  908.17 kgf

CG distance during field lifting operation               1212.50 mm.
CG distance from tailing lug                             1212.50 mm.
CG distance from the nearer lifting lug/trunnion          852.50 mm.

Compressive Allowable Increase Factor                       1.00
```

Critical Values: (N./mm^2, mm.)

	Max Stress	Elevation	Allowables	
Bending	0.66	1850.00	116.62	(UG-23)
Shear	0.35	1850.00	82.53	(0.7*S)

The compressive bending allowable stress is the minimum of the tensile allowable and the compressive allowable times the specified compressive allowable increase factor.

Forces and Moments at selected elevations (not all analysis points shown):

Distance mm.	Bending Moment Kg-m.	Bending Stress N./mm^2	Shear Force kgf	Shear Stress N./mm^2
0.00	0.0	0.0	498.4	0.3
500.00	26.9	0.1	551.3	0.3
1400.00	119.5	0.4	633.6	0.3
2300.00	89.2	0.4	122.4	0.1

Unity Check (Actual Stress / Allowable Stress):

Maximum Unity Check is 0.0057 at elevation 1850.0002 mm. - Must be <=1

Note: The rigging analysis is performed using a uniformly distributed load.

--- Plot data successfully generated ...----

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Lifting Lug Calculations:

Input Values:

Lifting Lug Material		SA-516 70	
Lifting Lug Yield Stress	Yield	262.01	N./mm^2
Total Height of Lifting Lug	w	140.0000	mm.
Thickness of Lifting Lug	t	12.0000	mm.
Diameter of Hole in Lifting Lug	dh	32.0000	mm.
Radius of Semi-Circular Arc of Lifting Lug	r	40.0000	mm.
Height of Lug from bottom to Center of Hole	h	100.0000	mm.
Offset from Vessel OD to Center of Hole	off	68.0000	mm.
Lug Fillet Weld Size	tw	8.0000	mm.
Length of weld along side of Lifting Lug	wl	140.0000	mm.
Length of Weld along Bottom of Lifting Lug	wb	12.0000	mm.
Thickness of Collar (if any)	tc	0.0000	mm.
Diameter of Collar (if any)	dc	0.0000	mm.
Impact Factor	Impfac	2.00	
Sling Angle from Horizontal		90.0	deg
Number of Lugs in Group		2	
Reinforcing Pad Circumferential Width	wpb	80.00	mm.
Reinforcing Pad Longitudinal Length	wpl	190.00	mm.
Reinforcing Pad Thickness	thkp	10.00	mm.
Reinforcing Pad Fillet Weld Size	tfp	8.00	mm.

Lifting Lug Orientation to Vessel: Perpendicular
Lift Orientation : From Horizontal to Vertical

Lifting Lug and Weld Stresses at various Angles: N./mm^2

	Weld Stresses			Lug Stresses		Maximum
Angle	Primary	Secondary	Allowable	Combined	Allowable	Ratio
0	29.9	...	104.8	90.1	172.9	0.521
5	30.8	...	104.8	91.5	172.9	0.529
10	31.4	...	104.8	92.2	172.9	0.533
15	31.8	...	104.8	92.2	172.9	0.533
20	32.0	...	104.8	91.4	172.9	0.528
25	32.0	...	104.8	89.9	172.9	0.520
30	31.8	...	104.8	87.7	172.9	0.507
35	31.4	...	104.8	84.8	172.9	0.491
40	30.7	...	104.8	81.3	172.9	0.470
45	29.9	...	104.8	77.1	172.9	0.446
50	28.8	...	104.8	72.3	172.9	0.418
55	27.6	...	104.8	66.9	172.9	0.387
60	26.2	...	104.8	60.9	172.9	0.352
65	24.6	...	104.8	54.4	172.9	0.315
70	23.0	...	104.8	47.4	172.9	0.274
75	21.2	...	104.8	39.9	172.9	0.231
80	19.4	...	104.8	31.8	172.9	0.185
85	17.6	...	104.8	23.1	172.9	0.168
90	16.2	...	104.8	13.2	172.9	0.155

Computed Results:

Total vessel weight (No Liquid)	773.35 kgf
Design Reaction force at the tailing lug	638.53 kgf
Design Reaction force at the lifting lug	908.17 kgf
Worst Case Lift Angle for Primary Weld Stresses	22 deg
Tangential Force at this Angle	442.6 kgf
Axial Force at this Angle	178.8 kgf
Worst Case Lift Angle for Secondary Weld Stresses	0 deg
Tangential Force at this Angle	454.1 kgf
Axial Force at this Angle	0.0 kgf
Worst Case Lift Angle for Lug Stresses	12 deg
Tangential Force at this Angle	456.6 kgf
Axial Force at this Angle	97.0 kgf

Converting the weld leg dimension (tw) to the weld throat dimension.

Weld Group Inertia Calculations:

Weld Group Inertia about the Circumferential Axis	Ilc	330.701 cm^4
Weld Group Centroid distance in the Long. Direction	Yll	75.656 mm.
Dist. of Weld Group Centroid from Lug bottom	Yll_b	70.000 mm.
Weld Group Inertia about the Longitudinal Axis	Ill	12.927 cm^4
Weld Group Centroid Distance in the Circ. Direction	Ylc	11.656 mm.

Note: The Impact Factor is applied to the Forces acting on the Lug.

Primary Shear Stress in the Welds due to Shear Loads [Ssll]:
= sqrt(Fax^2 + Ft^2 + Fn^2)/((2 * (wl + wb)) * tw)
= sqrt(179^2+443^2+0^2)/((2*(140.0+12.0))*5.656)
= 2.72 N./mm^2

Shear Stress in the Welds due to Bending Loads [Sblf]:
= (Fn(h-Yll_b))Yll/Ilc + (Fax * off * Yll/Ilc) + (Ft * off * Ylc/Ill)
= (0(100.0-70.0))75.656/330.701 +
(179 * 68.0 * 75.656/330.701) +
(443 * 68.0 * 11.656/12.927)
= 29.34 N./mm^2

Total Shear Stress for Combined Loads [St]:
= Ssll + Sblf
= 2.723 + 29.34
= 32.06 N./mm^2

Allowable Shear Stress for Combined Loads [Sta]:
= 0.4 * Yield * Occfac (AISC Shear Allowable)
= 0.4 * 262 * 1.0
= 104.80 N./mm^2

Shear Stress in Lug above Hole [Shs]:
= sqrt(Pl^2 + Fax^2) / Sha
= sqrt(773^2 + 179^2)/5.76
= 13.51 N./mm^2

Allowable Shear Stress in Lug above Hole [Sas]:
= 0.4 * Yield * Occfac
= 0.4 * 262 * 1.0
= 104.80 N./mm^2

Pin Hole Bearing Width [Pbw]:
= Lug Thickness + 2 * Collar Thickness
= 12.0 + 2 * 0.0
= 12.000 mm.

Pin Hole Bearing Stress [Pbs]:
= sqrt(Pl^2 + $Faxial^2$) / (Pbw * dh)
= sqrt(773^2 + 179^2)/(12.0 * 32.0)
= 20.27 N./mm^2

Allowable Bearing Stress [Pba]:
= min(0.75 * Yield * Occfac, 0.9 * Yield) AISC Bearing All.
= min(0.75 * 262 * 1.0, 235.8)
= 196.51 N./mm^2

Bending Stress at the Base of the Lug [Fbs]:
= Ft * off/(w * t^2/6) + Fax * off/(w^2 * t/6)
= 457 * 68.0/(140.0 * 12.0^2/6) +
97 * 68.0/(140.0^2 * 12.0/6)
= 90.88 N./mm^2

Tensile Stress at the Base of the Lug [Fa]:
= Fn / (w * t)
= 0/(140.0 * 12.0)
= 0.00 N./mm^2

Total Combined Stress at the Base of the Lug:
= Fbs + Fa
= 90.9 + 0.0
= 90.88 N./mm^2

Lug Allowable Stress for Bending and Tension:
= min(0.66 * Yield * Occfac, 0.75 * Yield)
= min(0.66 * 262 * 1.0, 196.5)
= 172.93 N./mm^2

Required Shackle Pin Diameter [Spd]:
= sqrt((2(Fn^2 + Fax^2)$^{0.5}$/(pi * Sta)))
= sqrt(2(773^2 + 179^2)$^{0.5}$/(pi * 105))
= 6.8763 mm.

WRC 107/537 Stress Analysis for the Lifting Lug to Shell Junction in the new and Cold Condition (no corrosion applied).

Note: The full lug load is applied in both the circumferential and longitudinal directions simultaneously.

The ratio Beta1/Beta2 for rectangular attachments was outside the range of values in tables 7 & 8 and was set to be an acceptable (maximum or minimum) value. This generally results in one dimension being altered so that the aspect ratio does not exceed 4 to 1.

Attachment dimensions (C11P, C22P etc.) may be modified accounting for attachment welds where applicable.

Input Echo, WRC107/537 Item 1, Description: Lift Lug

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	0.0000	mm.
Vessel Diameter	Dv	600.000	mm.
Vessel Thickness	Tv	10.000	mm.

Note: Lifting lug calculations are performed at ambient temperature conditions.

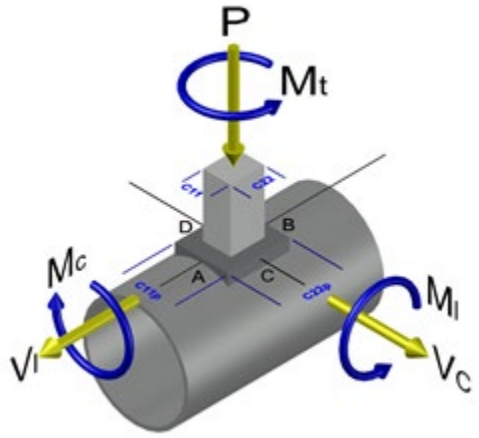
Attachment Type	Type	Rectangular	
Parameter C11	C11	12.00	mm.
Parameter C22	C22	48.00	mm.
Thickness of Reinforcing Pad	Tpad	10.000	mm.
Pad Parameter C11P	C11p	96.000	mm.
Pad Parameter C22P	C22p	198.000	mm.
Design Internal Pressure	Dp	0.000	bar(g)
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	0.0	kgf
Longitudinal Shear	(SUS)	Vl	773.3	kgf
Circumferential Shear	(SUS)	Vc	773.3	kgf
Circumferential Moment	(SUS)	Mc	52.6	Kg-m.
Longitudinal Moment	(SUS)	Ml	0.0	Kg-m.
Torsional Moment	(SUS)	Mt	0.0	Kg-m.

Use Interactive Control		No
WRC107 Version	Version	March 1979
Include Pressure Stress Indices per Div. 2		No
Compute Pressure Stress per WRC-368		No
Local Loads applied at end of Nozzle/Attachment		No

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 107/537 has dimensional limitations that can be found in the bulletin's Foreword and which can also be inferred by review of the non-dimensional curve limits.

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	0.0	kgf
Circumferential Shear	VC	773.3	kgf
Longitudinal Shear	VL	773.3	kgf
Circumferential Moment	MC	52.6	Kg-m.
Longitudinal Moment	ML	0.0	Kg-m.
Torsional Moment	MT	0.0	Kg-m.

Dimensionless Parameters used : Gamma = 15.50

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.057	4C	3.119	(A,B)
N(PHI) / (P/Rm)	0.057	3C	3.089	(C,D)
M(PHI) / (P)	0.034	2C1	0.233	(A,B)
M(PHI) / (P)	0.034	1C	0.265	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.031	3A	0.038	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.040	1A	0.105	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.049	3B	0.450	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.044	1B	0.064	(A,B,C,D)
N(x) / (P/Rm)	0.046	3C	3.136	(A,B)
N(x) / (P/Rm)	0.046	4C	3.146	(C,D)
M(x) / (P)	0.048	1C1	0.239	(A,B)
M(x) / (P)	0.048	2C	0.200	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.031	4A	0.063	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.056	2A	0.064	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.049	4B	0.110	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.060	2B	0.100	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm^2)

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	-0.1	-0.1	0.1	0.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-65.1	65.1	65.1	-65.1
Circ. Memb. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	0.0	0.0	0.0	0.0	-65.2	65.0	65.2	-65.0
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	-0.3	-0.3	0.3	0.3
Long. Bend. MC	0.0	0.0	0.0	0.0	-28.1	28.1	28.1	-28.1
Long. Memb. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	0.0	0.0	0.0	0.0	-28.4	27.8	28.4	-27.8
Shear VC	15.8	15.8	-15.8	-15.8	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-4.0	-4.0	4.0	4.0
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	15.8	15.8	-15.8	-15.8	-4.0	-4.0	4.0	4.0
Str. Int.	31.6	31.6	31.6	31.6	65.6	65.4	65.6	65.4

Dimensionless Parameters used : Gamma = 30.50

Dimensionless Loads for Cylindrical Shells at Pad Edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.301	4C	3.637	(A,B)
N(PHI) / (P/Rm)	0.301	3C	1.929	(C,D)
M(PHI) / (P)	0.207	2C1	0.040	(A,B)
M(PHI) / (P)	0.207	1C	0.070	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.200	3A	1.232	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.220	1A	0.079	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.255	3B	2.872	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.237	1B	0.023	(A,B,C,D)
N(x) / (P/Rm)	0.257	3C	2.313	(A,B)
N(x) / (P/Rm)	0.257	4C	3.945	(C,D)
M(x) / (P)	0.265	1C1	0.053	(A,B)
M(x) / (P)	0.265	2C !	0.031	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.200	4A	2.184	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.273	2A	0.032	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.255	4B	1.249	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.284	2B	0.030	(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./mm^2)

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	-2.0	-2.0	2.0	2.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-36.6	36.6	36.6	-36.6
Circ. Memb. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	0.0	0.0	0.0	0.0	-38.6	34.6	38.6	-34.6
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	-4.4	-4.4	4.4	4.4
Long. Bend. MC	0.0	0.0	0.0	0.0	-12.0	12.0	12.0	-12.0
Long. Memb. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	0.0	0.0	0.0	0.0	-16.4	7.6	16.4	-7.6
Shear VC	4.0	4.0	-4.0	-4.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.9	-1.9	1.9	1.9
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	4.0	4.0	-4.0	-4.0	-1.9	-1.9	1.9	1.9
Str. Int.	7.9	7.9	7.9	7.9	38.8	34.8	38.8	34.8

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pl (SUS)	0.0	0.0	0.0	0.0	-0.1	-0.1	0.1	0.1
Circ. Q (SUS)	0.0	0.0	0.0	0.0	-65.1	65.1	65.1	-65.1
Long. Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pl (SUS)	0.0	0.0	0.0	0.0	-0.3	-0.3	0.3	0.3
Long. Q (SUS)	0.0	0.0	0.0	0.0	-28.1	28.1	28.1	-28.1
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	15.8	15.8	-15.8	-15.8	-4.0	-4.0	4.0	4.0
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm+Pl (SUS)	31.6	31.6	31.6	31.6	7.9	7.9	7.9	7.9
Pm+Pl+Q (Total)	31.6	31.6	31.6	31.6	65.6	65.4	65.6	65.4

Vessel Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0.00	117.90	Passed
Pm+Pl (SUS)	31.60	176.86	Passed
Pm+Pl+Q (TOTAL)	65.61	353.71	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./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pl (SUS)	0.0	0.0	0.0	0.0	-2.0	-2.0	2.0	2.0
Circ. Q (SUS)	0.0	0.0	0.0	0.0	-36.6	36.6	36.6	-36.6
Long. Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pl (SUS)	0.0	0.0	0.0	0.0	-4.4	-4.4	4.4	4.4
Long. Q (SUS)	0.0	0.0	0.0	0.0	-12.0	12.0	12.0	-12.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	4.0	4.0	-4.0	-4.0	-1.9	-1.9	1.9	1.9
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm+Pl (SUS)	7.9	7.9	7.9	7.9	5.5	5.5	5.5	5.5

Pm+Pl+Q (Total)	7.9	7.9	7.9	7.9	38.8	34.8	38.8	34.8

Vessel Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0.00	117.90	Passed
Pm+Pl (SUS)	7.90	176.86	Passed
Pm+Pl+Q (TOTAL)	38.81	353.71	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.

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RESULTS FOR LEGS : Operating Case Description: LEGS

Legs attached to: MAIN SHELL

Section Properties : Single Angle L80X80X10

European Structural Steel Data

Overall Leg Length		960.000	mm.
Effective Leg Length	Leglen	940.000	mm.
Distance Leg Up Side of Vessel		170.000	mm.
Number of Legs	Nleg	3	
Cross Sectional Area for L80X80X10	Aleg	15.100	cm^2
Section Inertia (strong axis)		87.500	cm^4
Section Inertia (weak axis)		87.500	cm^4
Section Modulus (strong axis)		15400.062	mm.³
Section Modulus (weak axis)		15400.062	mm.³
Radius of Gyration (strong axis)		24.100	mm.
Radius of Gyration (weak axis)		24.100	mm.

Leg Orientation - Diagonal

Overturning Moment at top of Legs		331.8	Kg-m.
Total Weight Load at top of Legs	W	968.6	kgf
Total Shear force at top of Legs		340.9	kgf
Additional force in Leg due to Bracing	Fadd	0.0	kgf
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, Seismic, and Applied Load Effects.

Pad Width along Circumference	C11P	150.000	mm.
Pad Length along Vessel Axis	C22P	150.000	mm.
Pad Thickness	Tpad	10.000	mm.

Maximum Shear at top of one Leg [Vleg]:
```
= ( max( Wind, Seismic, Blast ) + applied forces )( Imax / Itot )
= ( 340.9 )( 141.2/214.72 )
= 224.22 kgf
```

Axial Compression, Leg furthest from the Neutral Axis [Sma]:
```
= W/Nleg + (Mleg/(Nlegm*Rn))/Aleg
= 9498/3 + (3253577/( 1 * 342.536 ))/1509.997
= 8.39 N./mm^2
```

Axial Compression, Leg closest to the Neutral Axis [Sva]:
```
= ( W / Nleg ) / Aleg
= ( 969/3 )/15.1
= 2.10 N./mm^2
```

Computing Principal Axis and Inertias for Angle:

Leg lengths and thickness:	80.000	80.000	10.0000
Distance to geometric centroid:	23.400	23.400	
Arm about YY:	18.400	21.600	
Arm about ZZ:	16.600	18.400	
Leg areas:	8.0000	7.0000	
Geometric inertia components YY:	27.751	61.242	
Geometric inertia components ZZ:	64.711	24.282	
Geometric inertias Iy & Iz:	88.993	88.993	

```
Product of inertia:              0.52256E+06
Mohrs Radius:                     31.888
Average Inertia:                  88.993

QFACT =   1.0000        FBZ         =  0.23431
Principal Axis Inertias (Z&W)       =   36.738      141.25
Angle to Principal Axis             =   45.000
Distances to extreme fibers CW & CZ =   56.568      23.476
FOB from Eq 5-5                     =   2.0722
Bending allowables Fby & Fbz        =  0.23431     0.23431

Shear Center Coordinates Wo & Zo:   25.095      0.0000
```

Values for Elastic Flexural-Torsional Buckling Stress:

```
E,    G,      J,   R0²:    29500.      11346.     0.12093      2.8032
AREA, LENGTH, Kw,  Kz:     2.3405      37.008      1.0000      1.0000
H,    Few,    Fez, Fej:   0.65177      308.23      80.168      209.13
Fe computed from C4-1:     154.77

Initial (Kl/r)max, & (Kl/r)equiv    =   60.264      43.373
Final (Kl/r)max, & Cc               =   60.264      106.34
Fa based on Eq 4-1                  =  0.16053
```

Leg Bending and Axial Stresses vs. Allowables: (N./mm^2)

```
                            Actual   Allowable
-----------------------------------------------
Weak Axis Bending    :         93.40      312.34
Strong Axis Bending  :         58.53      312.34
Axial Compression    :          8.39      213.99

UNITY CHECKS ARE: H1-1     0.000
                  H1-2     0.000
                  H1-3     0.526
```

AISC Unity Check : 0.526, should be <= to 1 for Code compliance, [Passed]

Bolting Size Requirement for Leg Baseplates :

```
Baseplate Material                                  SA-516 70
Baseplate Allowable Stress                   SBA     137.90 N./mm^2
Baseplate Length                               B   160.0000 mm.
Baseplate Width                                D   150.0000 mm.
Baseplate Thickness                         BTHK    20.0000 mm.
Leg Dimension Along Baseplate Length           d    79.9998 mm.
Leg Dimension Along Baseplate Width            b    79.9998 mm.
Bolt Circle Diameter                         BCD   570.0000 mm.
Bolt Material                                      SA-307 B
Bolt Allowable Tensile Stress               STBA      48.26 N./mm^2
Bolt Allowable Shear Stress               SBShear     28.96 N./mm^2
Anchor Bolt Nominal Diameter                 BOD    24.0000 mm.
Number of Anchor Bolts in Tension per Leg     NB          1
Total Number of Anchors Bolt per Leg         NBT          1
Bolt Corrosion Allowance                     bca     0.0000 mm.
Ultimate 28-day Concrete Strength         FCPRIME     20.685 N./mm^2
```

Leg Baseplate and Bolting Analysis, including Moments

Shear Stress in a Single Bolt [taub]:

```
  = Shear Force/( Bolt Area * Number of Bolts )
  = 340.9/( 3.127 * 3 )
  = 3.6 N./mm^2.  Must be less than 29.0 N./mm^2.
```

Plate thickness required (5/8"; 16mm) 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 * 332/570.0) - 773 )/3
= 518.340 kgf
```

Calculation of Load per Bolt, Seismic Operating [W,seismic]:
```
= (( 4 * Moment/BCD ) - Weight )/Num Bolts
= (( 4 * 0/570.0) - 1014 )/3
= -337.859 kgf
```

Calculation of Maximum Load per Bolt [Wmax]:
```
= max( W,wind, W,seismic )
= max( 518.3, -337.86 )
= 518.340 kgf
```

Area Available in a Single Bolt, corroded [Ab]:
```
= 3.127 cm^2
```

Required Area of a single Bolt, Simplified Method:
```
= Wmax / Bolt Allowable Stress
= 518.34/45161.199
= 1.053 cm^2
```

Note: The Wind case empty condition governs.

Review notes about nozzle loadings and supports in the Warnings report.

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RESULTS FOR LEGS : HydroTest Case Description: LEGS

Legs attached to: MAIN SHELL

Section Properties : Single Angle L80X80X10

European Structural Steel Data

Overall Leg Length		960.000	mm.
Effective Leg Length	Leglen	940.000	mm.
Distance Leg Up Side of Vessel		170.000	mm.
Number of Legs	Nleg	3	
Cross Sectional Area for L80X80X10	Aleg	15.100	cm^2
Section Inertia (strong axis)		87.500	cm^4
Section Inertia (weak axis)		87.500	cm^4
Section Modulus (strong axis)		15400.062	mm.³
Section Modulus (weak axis)		15400.062	mm.³
Radius of Gyration (strong axis)		24.100	mm.
Radius of Gyration (weak axis)		24.100	mm.

Leg Orientation - Diagonal

Overturning Moment at top of Legs		82.9	Kg-m.
Total Weight Load at top of Legs	W	1449.0	kgf
Total Shear force at top of Legs		85.2	kgf
Additional force in Leg due to Bracing	Fadd	0.0	kgf
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, Seismic, and Applied Load Effects.

Pad Width along Circumference	C11P	150.000	mm.
Pad Length along Vessel Axis	C22P	150.000	mm.
Pad Thickness	Tpad	10.000	mm.

Maximum Shear at top of one Leg [Vleg]:
= (max(Wind, Seismic, Blast) + applied forces)(Imax / Itot)
= (85.2)(141.2/214.72)
= 56.06 kgf

Axial Compression, Leg furthest from the Neutral Axis [Sma]:
= W/Nleg + (Mleg/(Nlegm*Rn))/Aleg
= 14210/3 + (813394/(1 * 342.536))/1509.997
= 4.71 N./mm^2

Axial Compression, Leg closest to the Neutral Axis [Sva]:
= (W / Nleg) / Aleg
= (1449/3)/15.1
= 3.14 N./mm^2

Computing Principal Axis and Inertias for Angle:

Leg lengths and thickness:	80.000	80.000	10.0000
Distance to geometric centroid:	23.400	23.400	
Arm about YY:	18.400	21.600	
Arm about ZZ:	16.600	18.400	
Leg areas:	8.0000	7.0000	
Geometric inertia components YY:	27.751	61.242	
Geometric inertia components ZZ:	64.711	24.282	
Geometric inertias Iy & Iz:	88.993	88.993	

```
Product of inertia:              0.52256E+06
Mohrs Radius:                     31.888
Average Inertia:                  88.993

QFACT =   1.0000        FBZ         =  0.23431
Principal Axis Inertias (Z&W)       =   36.738      141.25
Angle to Principal Axis             =   45.000
Distances to extreme fibers CW & CZ =   56.568      23.476
FOB from Eq 5-5                     =   2.0722
Bending allowables Fby & Fbz        =  0.23431     0.23431

Shear Center Coordinates Wo & Zo:   25.095      0.0000
```

Values for Elastic Flexural-Torsional Buckling Stress:

```
E,    G,      J,   R0²:    29500.      11346.     0.12093      2.8032
AREA, LENGTH, Kw,  Kz:     2.3405      37.008      1.0000      1.0000
H,    Few,    Fez, Fej:   0.65177      308.23      80.168      209.13
Fe computed from C4-1:     154.77

Initial (Kl/r)max, & (Kl/r)equiv    =   60.264      43.373
Final (Kl/r)max, & Cc               =   60.264      106.34
Fa based on Eq 4-1                  =  0.16053
```

Leg Bending and Axial Stresses vs. Allowables: (N./mm^2)

```
                            Actual   Allowable
-----------------------------------------------
Weak Axis Bending    :         23.35      312.34
Strong Axis Bending  :         14.63      312.34
Axial Compression    :          4.71      213.99

UNITY CHECKS ARE: H1-1     0.000
                  H1-2     0.000
                  H1-3     0.144
```

AISC Unity Check : 0.144, should be <= to 1 for Code compliance, [Passed]

Bolting Size Requirement for Leg Baseplates :

```
Baseplate Material                                  SA-516 70
Baseplate Allowable Stress                   SBA      137.90 N./mm^2
Baseplate Length                               B    160.0000 mm.
Baseplate Width                                D    150.0000 mm.
Baseplate Thickness                         BTHK     20.0000 mm.
Leg Dimension Along Baseplate Length           d     79.9998 mm.
Leg Dimension Along Baseplate Width            b     79.9998 mm.
Bolt Circle Diameter                         BCD    570.0000 mm.
Bolt Material                                       SA-307 B
Bolt Allowable Tensile Stress               STBA      48.26 N./mm^2
Bolt Allowable Shear Stress               SBShear     28.96 N./mm^2
Anchor Bolt Nominal Diameter                 BOD     24.0000 mm.
Number of Anchor Bolts in Tension per Leg     NB           1
Total Number of Anchors Bolt per Leg         NBT           1
Bolt Corrosion Allowance                     bca      0.0000 mm.
Ultimate 28-day Concrete Strength         FCPRIME     20.685 N./mm^2
```

Leg Baseplate and Bolting Analysis, including Moments

Shear Stress in a Single Bolt [taub]:

```
  = Shear Force/( Bolt Area * Number of Bolts )
  = 340.9/( 3.127 * 3 )
  = 3.6 N./mm^2.  Must be less than 29.0 N./mm^2.
```

Plate thickness required (5/8"; 16mm) 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.

Review notes about nozzle loadings and supports in the Warnings report.

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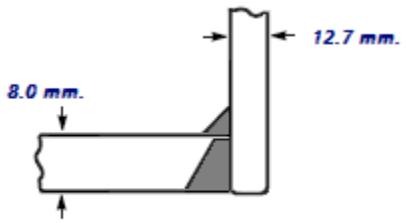
Input, Nozzle Desc: N3-LIQUID OUTLET From: 10

Pressure for Reinforcement Calculations	P	18.388	bar(g)
Temperature for Internal Pressure	Temp	80	°C
Parent Material [Normalized]		SA-516 60	
Parent Allowable Stress at Temperature	Sv	117.90	N./mm^2
Parent Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Elliptical Head	D	600.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	8.0000	mm.
Head Internal Corrosion Allowance	c	1.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	0.0000	mm.
User Entered Minimum Design Metal Temperature		-29.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		Inside	
Layout Angle		0.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	1.0000	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	8.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (bottom of element).



Reinforcement CALCULATION, Description: N3-LIQUID OUTLET

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation            1.000  in.
Actual Thickness Used in Calculation                  0.500  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Elliptical Head, tr [Int. Press]
```
  = P*D*K1/(2*Sv*E-0.2*P) per Appendix 1-4(c)
  = 18.39*602.0*0.8972/(2*117.9*1.0-0.2*18.39)
  = 4.2184 mm.
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 13.7(exp([18.39/(137.9*1.0]-1)
  = 0.1839 mm.
```

UG-40, Limits of Reinforcement: [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    64.8000  mm.
Parallel to Vessel Wall                          Rn+tn+t    32.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    17.5000  mm.
```

Taking a UG-36(c)(3)(a) exemption for nozzle: N3-LIQUID OUTLE.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 1.1839 mm.
Wall Thickness per UG16(b),                       tr16b = 2.5000 mm.
Wall Thickness, shell/head, internal pressure      trb1 = 5.6812 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 5.6812 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 2.5000 mm.
Wall Thickness per table UG-45                     tb3 = 4.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 4.42, max( 5.6812, 2.5 ) ]
  = 4.4200 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 1.1839, 4.42 )
  = 4.4200 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)), Curve: D

Govrn. thk, tg = 8.0, tr = 4.218, c = 1.0 mm., E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.603, Temp. Reduction = 22 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve D          -48 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit     -48 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -48 °C
```

Weld Size Calculations, Description: N3-LIQUID OUTLE

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      9.0000  mm.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          6.0000 = Min per Code 7.0700 = 0.7 * Wo mm.
```

Skipping the nozzle attachment weld strength calculations. Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a) (small nozzles) do not require a weld strength check.

The Drop for this Nozzle is : 0.5907 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 158.5907 mm.

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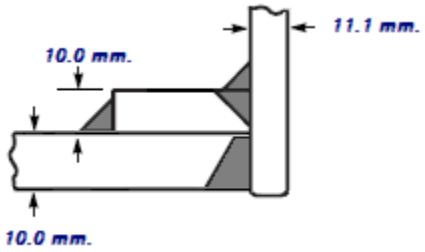
Input, Nozzle Desc: N1- GAS INLET From: 20

Pressure for Reinforcement Calculations	P	18.369	bar(g)
Temperature for Internal Pressure	Temp	80	°C
Parent Material [Normalized]		SA-516 60	
Parent Allowable Stress at Temperature	Sv	117.90	N./mm^2
Parent Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	600.00	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	1.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1260.00	mm.
User Entered Minimum Design Metal Temperature		-29.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		Outside	
Layout Angle		90.00	deg
Diameter		10.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness		XS	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	1.0000	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	9.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	373.0500	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		50.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (bottom of element).



Reinforcement CALCULATION, Description: N1- GAS INLET

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation          10.750  in.
Actual Thickness Used in Calculation                  0.438  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 18.37*301.0/(118*1.0-0.6*18.37)
  = 4.7339 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 18.37*136.525/(118*1.0+0.4*18.37)
  = 2.1139 mm.
```

UG-40, Limits of Reinforcement: [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)           Dl   505.6500  mm.
Parallel to Vessel Wall, opening length             d   252.8250  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp    22.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/117.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/117.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr4]:
```
  = min( 1, Sp/Sv )
  = min( 1, 137.9/117.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1., 1.0 )
  = 1.000
```

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	11.968	NA	NA
Area in Shell	A1	10.786	NA	NA
Area in Nozzle Wall	A2	3.599	NA	NA
Area in Inward Nozzle	A3	0.000	NA	NA

Area in Welds	A41+A42+A43	1.450	NA	NA
Area in Element	A5	10.000	NA	NA
TOTAL AREA AVAILABLE	Atot	25.835	NA	NA

The MAWP Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 degs.

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

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (252.825*4.7339*1.0+2*10.1125*4.7339*1.0*(1-1.))
= 11.968 cm^2

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 252.825(1.0 * 9.0 - 1.0 * 4.734) - 2 * 10.112
(1.0 * 9.0 - 1.0 * 4.7339) * (1 - 1.)
= 10.786 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 22.5) * (10.11 - 2.11) * 1.
= 3.599 cm^2

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 9.0² * 1. + (0.0)² * 1. + 8.0² * 1.0
= 1.450 cm^2

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (373.05 - 273.05) * 10.0 * 1.0
= 10.000 cm^2

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

Wall Thickness for Internal/External pressures	ta =	3.1139 mm.
Wall Thickness per UG16(b),	tr16b =	2.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 =	5.7339 mm.
Wall Thickness	tb1 = max(trb1, tr16b) =	5.7339 mm.
Wall Thickness	tb2 = max(trb2, tr16b) =	2.5000 mm.
Wall Thickness per table UG-45	tb3 =	9.1026 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[9.103, max(5.7339, 2.5)]
= 5.7339 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.1139, 5.7339)
= 5.7339 mm.

Available Nozzle Neck Thickness = 11.1125 mm. -> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code, (see 319.4.4 and 302.3.5):

Sustained :	28.2,	Allowable :	117.9 N./mm^2 Passed

```
Expansion  :      0.0,  Allowable :    266.6 N./mm^2  Passed
Occasional :     11.0,  Allowable :    156.8 N./mm^2  Passed
Shear      :     11.6,  Allowable :     82.5 N./mm^2  Passed
```

The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

Note:
This Material was specified as being an Impact Tested (Low Temperature) Material.

```
Impact Test Temperature provided per Specification         -46 °C

Calculated Minimum Design Metal Temperature               -104 °C
```

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

Note:
This Material was specified as being an Impact Tested (Low Temperature) Material.

```
Impact Test Temperature provided per Specification         -46 °C
```

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

Govrn. thk, tg = 10.0, c = 1.0 mm., E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.526, Temp. Reduction = 29 °C
Attachment governing, Attachment stress = Shell stress per Code

```
Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit        -46 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -48 °C
```

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

Govrn. thk, tg = 10.0, tr = 4.734, c = 1.0 mm., E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.526, Temp. Reduction = 29 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit        -46 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -48 °C
```

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

Govrn. thk, tg = 10.0, tr = 4.734, c = 1.0 mm., E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.526, Temp. Reduction = 29 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve D             -48 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit        -48 °C

Gov. MDMT of the Nozzle                                :   -46 °C
Gov. MDMT of the Reinforcement Pad                     :   -48 °C
Gov. MDMT of the nozzle to shell joint welded assembly :   -46 °C
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ASME B16.5/47 flange per Matl. Specification       -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)           -49 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
```
Design Pressure/Ambient Rating = 18.37/19.60 = 0.937
```

Weld Size Calculations, Description: N1- GAS INLET

```
Intermediate Calc. for nozzle/shell Welds   Tmin     10.0000  mm.
Intermediate Calc. for pad/shell Welds   TminPad      9.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	6.3630 = 0.7 * Wo mm.
Pad Weld	4.5000 = 0.5*TminPad	5.6560 = 0.7 * Wp mm.

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (11.9684 - 10.7858 + 2 * 10.1125 * 1. *
    (1.0 * 9.0 - 4.7339 ) )118)
  = 2459.15 kgf
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.5994 + 10.0 + 1.45 - 0.0 * 1. ) * 118
  = 18093.42 kgf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.5994 + 0.0 + 0.81 + ( 1.8202 ) ) * 118
  = 7489.67 kgf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.5994 + 0.0 + 1.45 + 10.0 + ( 1.8202 ) ) * 118
  = 20281.85 kgf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 273.05 * 9.0 * 0.49 * 118
  = 22741. kgf
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 373.05 * 8.0 * 0.49 * 118
  = 27617. kgf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 131.4687) * ( 11.1125 - 1.0 ) * 0.7 * 118
  = 35150. kgf
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 273.05 * 10.0 * 0.74 * 138
  = 44630. kgf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 273.05 * ( 10.0 - 1.0 ) * 0.74 * 118
  = 34343. kgf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
= (SPEW + SNW) = (27617 + 35150) = 62767 kgf

Failure Path [Path 2-2]:
= (Sonw + Tpgw + Tngw + Sinw)
= (22741 + 44630 + 34343 + 0) = 101714 kgf

Failure Path [Path 3-3]:
= (Spew + Tngw + Sinw)
= (27617 + 34343 + 0) = 61960 kgf

Summary of Failure Path Calculations:

```
Path 1-1 = 62767   kgf, must exceed W = 2459 kgf     or W1 = 18093 kgf
Path 2-2 = 101713  kgf, must exceed W = 2459 kgf     or W2 = 7489 kgf
Path 3-3 = 61960   kgf, must exceed W = 2459 kgf     or W3 = 20281 kgf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Maximum Allowable Pressure in the Operating case: 28 bar(g)
```

The Drop for this Nozzle is : 32.8654 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 192.8654 mm.

Input Echo, WRC107/537 Item 1, Description: N1- GAS INLET :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	1.0000	mm.
Vessel Diameter	Dv	600.000	mm.
Vessel Thickness	Tv	10.000	mm.
Design Temperature	T1	80.0	C
Vessel Material		SA-516 60	
Vessel UNS Number		K02100	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	117.90	N./mm^2

See ASME VIII Div. 1, UG-23(e), for determination of the SPS allowable.

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	1.0000	mm.
Nozzle Diameter	Dn	273.050	mm.
Nozzle Thickness	Tn	11.113	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	10.000	mm.
Diameter of Reinforcing Pad	Dpad	373.050	mm.
Design Internal Pressure	Dp	18.369	bar(g)
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

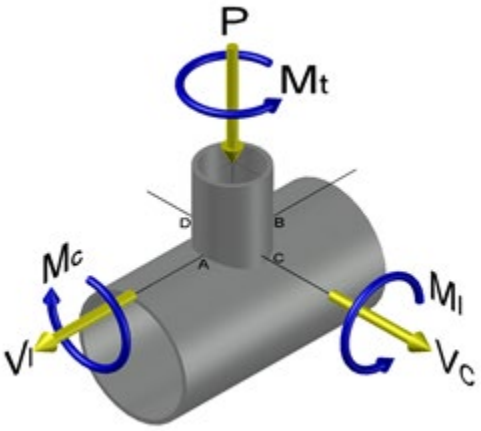
Radial Load	(SUS)	P	-1223.7	kgf
Longitudinal Shear	(SUS)	Vl	611.9	kgf

Circumferential Shear	(SUS)	Vc	917.8	kgf
Circumferential Moment	(SUS)	Mc	611.6	Kg-m.
Longitudinal Moment	(SUS)	Ml	795.1	Kg-m.
Torsional Moment	(SUS)	Mt	917.5	Kg-m.

Use Interactive Control		No
WRC107 Version	Version	March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

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 107/537 has dimensional limitations that can be found in the bulletin's Foreword and which can also be inferred by review of the non-dimensional curve limits.

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 273.05 + 2 * 1.65 * sqrt( 305.5 ( 10.0 - 1.0 ) )
  = 446.088 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	-1223.7	kgf
Circumferential Shear	VC	917.8	kgf
Longitudinal Shear	VL	611.9	kgf
Circumferential Moment	MC	611.6	Kg-m.
Longitudinal Moment	ML	795.1	Kg-m.
Torsional Moment	MT	917.5	Kg-m.

Dimensionless Parameters used : Gamma = 16.34

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.385	4C		2.048	(A,B)
N(PHI) / (P/Rm)	0.385	3C		1.252	(C,D)
M(PHI) / (P)	0.385	2C1		0.023	(A,B)
M(PHI) / (P)	0.385	1C	!	0.056	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.385	3A		0.683	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.385	1A		0.074	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.385	3B		1.482	(A,B,C,D)

M(PHI) / (ML/(Rm * Beta))	0.385	1B	0.019	(A,B,C,D)
N(x) / (P/Rm)	0.385	3C	1.252	(A,B)
N(x) / (P/Rm)	0.385	4C	2.048	(C,D)
M(x) / (P)	0.385	1C1	0.044	(A,B)
M(x) / (P)	0.385	2C !	0.030	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.385	4A	1.596	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.385	2A	0.034	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.385	4B	0.668	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.385	2B	0.032	(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./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	4.2	4.2	4.2	4.2	2.5	2.5	2.5	2.5
Circ. Bend. P	4.7	-4.7	4.7	-4.7	11.2	-11.2	11.2	-11.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-5.8	-5.8	5.8	5.8
Circ. Memb. MC	0.0	0.0	0.0	0.0	-61.7	61.7	61.7	-61.7
Circ. Memb. ML	-16.4	-16.4	16.4	16.4	0.0	0.0	0.0	0.0
Circ. Bend. ML	-20.1	20.1	20.1	-20.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-27.7	3.2	45.4	-4.2	-53.8	47.3	81.2	-64.5
Long. Memb. P	2.5	2.5	2.5	2.5	4.2	4.2	4.2	4.2
Long. Bend. P	8.8	-8.8	8.8	-8.8	6.0	-6.0	6.0	-6.0
Long. Memb. MC	0.0	0.0	0.0	0.0	-13.6	-13.6	13.6	13.6
Long. Bend. MC	0.0	0.0	0.0	0.0	-28.8	28.8	28.8	-28.8
Long. Memb. ML	-7.4	-7.4	7.4	7.4	0.0	0.0	0.0	0.0
Long. Bend. ML	-35.0	35.0	35.0	-35.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-31.1	21.4	53.8	-33.9	-32.2	13.4	52.6	-17.1
Shear VC	1.1	1.1	-1.1	-1.1	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	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Tot. Shear	5.1	5.1	2.9	2.9	3.3	3.3	4.8	4.8
Str. Int.	34.8	22.8	54.7	34.2	54.3	47.6	82.0	65.0

WARNING: Ratio of Pad Radius/Rm (.611) is not between 0.01 and 0.571.

Dimensionless Parameters used : Gamma = 33.94

Dimensionless Loads for Cylindrical Shells at Pad Edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.534	4C !	2.547	(A,B)
N(PHI) / (P/Rm)	0.534	3C !	0.971	(C,D)
M(PHI) / (P)	0.534	2C1 !	0.007	(A,B)
M(PHI) / (P)	0.534	1C !	0.061	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.534	3A !	0.813	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.534	1A !	0.061	(A,B,C,D)

```
N(PHI) / ( ML/(Rm**2 * Beta) )   0.534   3B  !     1.334   (A,B,C,D)
M(PHI) / ( ML/(Rm    * Beta) )   0.534   1B  !     0.006   (A,B,C,D)

N(x)   / ( P/Rm )                0.534   3C  !     0.971   (A,B)
N(x)   / ( P/Rm )                0.534   4C  !     2.547   (C,D)
M(x)   / ( P )                   0.534   1C1 !     0.015   (A,B)
M(x)   / ( P )                   0.534   2C  !     0.031   (C,D)
N(x)   / ( MC/(Rm**2 * Beta) )   0.534   4A  !     3.242   (A,B,C,D)
M(x)   / ( MC/(Rm    * Beta) )   0.534   2A  !     0.025   (A,B,C,D)
N(x)   / ( ML/(Rm**2 * Beta) )   0.534   4B  !     0.814   (A,B,C,D)
M(x)   / ( ML/(Rm    * Beta) )   0.534   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./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	11.1	11.1	11.1	11.1	4.2	4.2	4.2	4.2
Circ. Bend. P	5.8	-5.8	5.8	-5.8	54.2	-54.2	54.2	-54.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-10.9	-10.9	10.9	10.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-166.4	166.4	166.4	-166.4
Circ. Memb. ML	-23.2	-23.2	23.2	23.2	0.0	0.0	0.0	0.0
Circ. Bend. ML	-20.0	20.0	20.0	-20.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-26.2	2.1	60.1	8.5	-118.8	105.6	235.8	-205.6
Long. Memb. P	4.2	4.2	4.2	4.2	11.1	11.1	11.1	11.1
Long. Bend. P	13.7	-13.7	13.7	-13.7	27.9	-27.9	27.9	-27.9
Long. Memb. MC	0.0	0.0	0.0	0.0	-43.3	-43.3	43.3	43.3
Long. Bend. MC	0.0	0.0	0.0	0.0	-68.4	68.4	68.4	-68.4
Long. Memb. ML	-14.1	-14.1	14.1	14.1	0.0	0.0	0.0	0.0
Long. Bend. ML	-36.1	36.1	36.1	-36.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-32.3	12.4	68.2	-31.4	-72.7	8.2	150.7	-41.8
Shear VC	1.7	1.7	-1.7	-1.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.1	-1.1	1.1	1.1
Shear MT	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Tot. Shear	6.3	6.3	2.9	2.9	3.4	3.4	5.7	5.7
Str. Int.	36.2	16.3	69.1	40.4	119.1	105.7	236.2	205.8

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	28.2	30.0	28.2	30.0	28.2	30.0	28.2	30.0
Circ. Pl (SUS)	-12.2	-12.2	20.6	20.6	-3.3	-3.3	8.4	8.4
Circ. Q (SUS)	-15.4	15.4	24.8	-24.8	-50.6	50.6	72.9	-72.9

Long. Pm (SUS)	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1
Long. Pl (SUS)	-4.8	-4.8	9.9	9.9	-9.4	-9.4	17.7	17.7
Long. Q (SUS)	-26.3	26.3	43.8	-43.8	-22.8	22.8	34.8	-34.8
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.1	1.1	-1.1	-1.1	-0.7	-0.7	0.7	0.7
Shear Q (SUS)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Pm (SUS)	28.2	30.0	28.2	30.0	28.2	30.0	28.2	30.0
Pm+Pl (SUS)	16.2	18.0	48.8	50.7	25.0	26.8	36.7	38.5
Pm+Pl+Q (Total)	20.3	39.7	74.8	46.0	26.9	77.6	110.0	35.2

Vessel Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	30.05	117.90	Passed
Pm+Pl (SUS)	50.66	176.86	Passed
Pm+Pl+Q (TOTAL)	109.98	353.71	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm^2)

	Stress Intensity Values at							
Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	60.5	62.4	60.5	62.4	60.5	62.4	60.5	62.4
Circ. Pl (SUS)	-12.1	-12.1	34.3	34.3	-6.6	-6.6	15.1	15.1
Circ. Q (SUS)	-14.2	14.2	25.8	-25.8	-112.2	112.2	220.7	-220.7
Long. Pm (SUS)	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3
Long. Pl (SUS)	-9.9	-9.9	18.4	18.4	-32.2	-32.2	54.4	54.4
Long. Q (SUS)	-22.4	22.4	49.8	-49.8	-40.5	40.5	96.3	-96.3
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.7	1.7	-1.7	-1.7	-1.1	-1.1	1.1	1.1
Shear Q (SUS)	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Pm (SUS)	60.5	62.4	60.5	62.4	60.5	62.4	60.5	62.4
Pm+Pl (SUS)	48.6	50.4	94.9	96.7	55.9	57.7	84.9	84.9
Pm+Pl+Q (Total)	38.4	66.2	121.0	72.3	59.0	168.0	296.6	143.5

Vessel Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	62.37	117.90	Passed
Pm+Pl (SUS)	96.73	176.86	Passed
Pm+Pl+Q (TOTAL)	296.60	353.71	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

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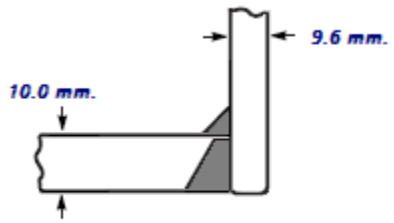
Input, Nozzle Desc: H1-INSPECTION PO From: 20

Pressure for Reinforcement Calculations	P	18.369	bar(g)
Temperature for Internal Pressure	Temp	80	°C
Parent Material [Normalized]		SA-516 60	
Parent Allowable Stress at Temperature	Sv	117.90	N./mm^2
Parent Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	600.00	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	1.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		280.00	mm.
User Entered Minimum Design Metal Temperature		-29.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		Outside	
Layout Angle		180.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness		XS	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	1.0000	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	9.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
This is a Manway or Access Opening.			
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (bottom of element).



Reinforcement CALCULATION, Description: H1-INSPECTION PO

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	6.625	in.
Actual Thickness Used in Calculation	0.378	in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
= P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
= 18.37*301.0/(118*1.0-0.6*18.37)
= 4.7339 mm.

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
= P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= 18.37*84.1375/(118*1.0+0.4*18.37)
= 1.3028 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	302.1452	mm.
Parallel to Vessel Wall, opening length	d	151.0726	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	21.5030	mm.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 117.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1., 1.0)
= 1.000

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	7.152	NA	NA
Area in Shell	A1	6.445	NA	NA
Area in Nozzle Wall	A2	3.139	NA	NA
Area in Inward Nozzle	A3	0.000	NA	NA
Area in Welds	A41+A42+A43	0.810	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	10.394	NA	NA

The MAWP Case Governs the Analysis.

Nozzle Angle Used in Area Calculations	90.00	degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (151.0726*4.7339*1.0+2*8.6012*4.7339*1.0*(1-1.))
= 7.152 cm^2

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 151.073( 1.0 * 9.0 - 1.0 * 4.734 ) - 2 * 8.601
    ( 1.0 * 9.0 - 1.0 * 4.7339 ) * ( 1 - 1. )
  = 6.445 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 21.5 )( 8.6 - 1.3 ) 1.
  = 3.139 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 9.0² * 1. + ( 0.0 )² * 1.
  = 0.810 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement:
```
 Wall Thickness for Internal/External pressures      ta = 2.3028 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = ta
  = 2.3028 mm.
```

Available Nozzle Neck Thickness = 9.6012 mm. -> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

Note:
This Material was specified as being an Impact Tested (Low Temperature) Material.

```
 Impact Test Temperature provided per Specification         -46 °C

 Calculated Minimum Design Metal Temperature               -104 °C
```

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

Govrn. thk, tg = 9.601, tr = 1.303, c = 1.0 mm., E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.151, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -48 °C
 Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit        -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C

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

Flange MDMT including Temperature reduction per UCS-66.1:

```
 MDMT of ASME B16.5/47 flange per Matl. Specification       -46 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2)           -49 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
```
 Design Pressure/Ambient Rating = 18.37/19.60 = 0.937
```

Weld Size Calculations, Description: H1-INSPECTION P

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      8.6012  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	6.3630 = 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, (7.1516 - 6.4449 + 2 * 8.6012 * 1. *
  (1.0 * 9.0 - 4.7339 ) )118)
= 1731.90 kgf
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 3.1388 + 0.0 + 0.81 - 0.0 * 1. ) * 118
= 4747.48 kgf
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 3.1388 + 0.0 + 0.81 + ( 1.5482 ) ) * 118
= 6608.85 kgf
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 3.1388 + 0.0 + 0.81 + 0.0 + ( 1.5482 ) ) * 118
= 6608.85 kgf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 168.275 * 9.0 * 0.49 * 118
= 14015. kgf
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 79.8369) * ( 9.6012 - 1.0 ) * 0.7 * 118
= 18156. kgf
```

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
= ( 3.1416/2.0 ) * 168.275 * ( 10.0 - 1.0 ) * 0.74 * 118
= 21165. kgf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
= ( SONW + SNW ) = ( 14015 + 18156 ) = 32170 kgf
```

Failure Path [Path 2-2]:
```
= ( Sonw + Tpgw + Tngw + Sinw )
= ( 14015 + 0 + 21165 + 0 ) = 35179 kgf
```

Failure Path [Path 3-3]:
```
= ( Sonw + Tngw + Sinw )
= ( 14015 + 21165 + 0 ) = 35179 kgf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 32170   kgf, must exceed W = 1731 kgf     or W1 = 4747 kgf
 Path 2-2 = 35179   kgf, must exceed W = 1731 kgf     or W2 = 6608 kgf
 Path 3-3 = 35179   kgf, must exceed W = 1731 kgf     or W3 = 6608 kgf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 22 bar(g)
```

The Drop for this Nozzle is : 12.0402 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 172.0401 mm.

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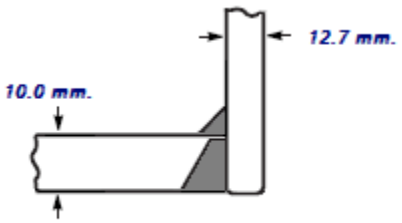
Input, Nozzle Desc: K1B-LT FOR ALARM From: 20

Pressure for Reinforcement Calculations	P	18.369	bar(g)
Temperature for Internal Pressure	Temp	80	°C
Parent Material [Normalized]		SA-516 60	
Parent Allowable Stress at Temperature	Sv	117.90	N./mm^2
Parent Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	600.00	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	1.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		350.00	mm.
User Entered Minimum Design Metal Temperature		-29.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		Inside	
Layout Angle		315.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	1.0000	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	9.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (bottom of element).



Reinforcement CALCULATION, Description: K1B-LT FOR ALARM

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation            1.000  in.
Actual Thickness Used in Calculation                  0.500  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 18.37*301.0/(118*1.0-0.6*18.37)
  = 4.7339 mm.
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 13.7(exp([18.37/(137.9*1.0]-1)
  = 0.1837 mm.
```

UG-40, Limits of Reinforcement: [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    68.8000  mm.
Parallel to Vessel Wall                          Rn+tn+t    34.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    22.5000  mm.
```

Taking a UG-36(c)(3)(a) exemption for nozzle: K1B-LT FOR ALAR.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 1.1837 mm.
Wall Thickness per UG16(b),                      tr16b = 2.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 5.7339 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 5.7339 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 2.5000 mm.
Wall Thickness per table UG-45                   tb3 = 4.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 4.42, max( 5.7339, 2.5 ) ]
  = 4.4200 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 1.1837, 4.42 )
  = 4.4200 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)), Curve: D

Govrn. thk, tg = 10.0, tr = 4.734, c = 1.0 mm., E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.526, Temp. Reduction = 29 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve D          -48 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit     -48 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -48 °C
```

Weld Size Calculations, Description: K1B-LT FOR ALAR

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      9.0000  mm.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          6.0000 = Min per Code 6.3630 = 0.7 * Wo mm.
```

Skipping the nozzle attachment weld strength calculations. Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a) (small nozzles) do not require a weld strength check.

The Drop for this Nozzle is : 1.0772 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 161.0772 mm.

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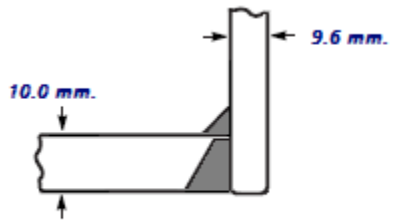
Input, Nozzle Desc: H2-INSPECTION PO From: 20

Pressure for Reinforcement Calculations	P	18.369	bar(g)
Temperature for Internal Pressure	Temp	80	°C
Parent Material [Normalized]		SA-516 60	
Parent Allowable Stress at Temperature	Sv	117.90	N./mm^2
Parent Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	600.00	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	1.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2070.00	mm.
User Entered Minimum Design Metal Temperature		-29.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		Outside	
Layout Angle		180.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness		XS	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	1.0000	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	9.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
This is a Manway or Access Opening.			
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (bottom of element).



Reinforcement CALCULATION, Description: H2-INSPECTION PO

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	6.625	in.
Actual Thickness Used in Calculation	0.378	in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
= P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
= 18.37*301.0/(118*1.0-0.6*18.37)
= 4.7339 mm.

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
= P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= 18.37*84.1375/(118*1.0+0.4*18.37)
= 1.3028 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	302.1452	mm.
Parallel to Vessel Wall, opening length	d	151.0726	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	21.5030	mm.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 117.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1., 1.0)
= 1.000

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	7.152	NA	NA
Area in Shell	A1	6.445	NA	NA
Area in Nozzle Wall	A2	3.139	NA	NA
Area in Inward Nozzle	A3	0.000	NA	NA
Area in Welds	A41+A42+A43	0.810	NA	NA
Area in Element	A5	0.000	NA	NA
TOTAL AREA AVAILABLE	Atot	10.394	NA	NA

The MAWP Case Governs the Analysis.

Nozzle Angle Used in Area Calculations	90.00	degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (151.0726*4.7339*1.0+2*8.6012*4.7339*1.0*(1-1.))
= 7.152 cm^2

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 151.073( 1.0 * 9.0 - 1.0 * 4.734 ) - 2 * 8.601
    ( 1.0 * 9.0 - 1.0 * 4.7339 ) * ( 1 - 1. )
  = 6.445 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 21.5 )( 8.6 - 1.3 ) 1.
  = 3.139 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 9.0² * 1. + ( 0.0 )² * 1.
  = 0.810 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement:
```
 Wall Thickness for Internal/External pressures      ta = 2.3028 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = ta
  = 2.3028 mm.
```

Available Nozzle Neck Thickness = 9.6012 mm. -> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

Note:
This Material was specified as being an Impact Tested (Low Temperature) Material.

```
 Impact Test Temperature provided per Specification         -46 °C

 Calculated Minimum Design Metal Temperature               -104 °C
```

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

Govrn. thk, tg = 9.601, tr = 1.303, c = 1.0 mm., E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.151, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -48 °C
 Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit        -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C

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

Flange MDMT including Temperature reduction per UCS-66.1:

```
 MDMT of ASME B16.5/47 flange per Matl. Specification       -46 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2)           -49 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
```
 Design Pressure/Ambient Rating = 18.37/19.60 = 0.937
```

Weld Size Calculations, Description: H2-INSPECTION P

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      8.6012  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	6.3630 = 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, (7.1516 - 6.4449 + 2 * 8.6012 * 1. *
  (1.0 * 9.0 - 4.7339 ) )118)
= 1731.90 kgf
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 3.1388 + 0.0 + 0.81 - 0.0 * 1. ) * 118
= 4747.48 kgf
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 3.1388 + 0.0 + 0.81 + ( 1.5482 ) ) * 118
= 6608.85 kgf
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 3.1388 + 0.0 + 0.81 + 0.0 + ( 1.5482 ) ) * 118
= 6608.85 kgf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 168.275 * 9.0 * 0.49 * 118
= 14015. kgf
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 79.8369) * ( 9.6012 - 1.0 ) * 0.7 * 118
= 18156. kgf
```

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
= ( 3.1416/2.0 ) * 168.275 * ( 10.0 - 1.0 ) * 0.74 * 118
= 21165. kgf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
= ( SONW + SNW ) = ( 14015 + 18156 ) = 32170 kgf
```

Failure Path [Path 2-2]:
```
= ( Sonw + Tpgw + Tngw + Sinw )
= ( 14015 + 0 + 21165 + 0 ) = 35179 kgf
```

Failure Path [Path 3-3]:
```
= ( Sonw + Tngw + Sinw )
= ( 14015 + 21165 + 0 ) = 35179 kgf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 32170   kgf, must exceed W = 1731 kgf     or W1 = 4747 kgf
 Path 2-2 = 35179   kgf, must exceed W = 1731 kgf     or W2 = 6608 kgf
 Path 3-3 = 35179   kgf, must exceed W = 1731 kgf     or W3 = 6608 kgf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 22 bar(g)
```

The Drop for this Nozzle is : 12.0402 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 172.0401 mm.

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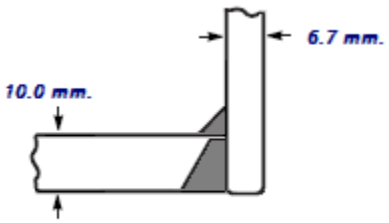
Input, Nozzle Desc: N4-VENT From: 20

Pressure for Reinforcement Calculations	P	18.369	bar(g)
Temperature for Internal Pressure	Temp	80	°C
Parent Material [Normalized]		SA-516 60	
Parent Allowable Stress at Temperature	Sv	117.90	N./mm^2
Parent Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	600.00	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	1.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2150.00	mm.
User Entered Minimum Design Metal Temperature		-29.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		Outside	
Layout Angle		0.00	deg
Diameter		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness		XS	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	1.0000	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	9.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (bottom of element).



Reinforcement CALCULATION, Description: N4-VENT

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation            3.500  in.
Actual Thickness Used in Calculation                   0.263  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 18.37*301.0/(118*1.0-0.6*18.37)
  = 4.7339 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 18.37*44.45/(118*1.0+0.4*18.37)
  = 0.6883 mm.
```

UG-40, Limits of Reinforcement: [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl   155.1300  mm.
Parallel to Vessel Wall, opening length              d    77.5650  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    14.1688  mm.
```

Taking a UG-36(c)(3)(a) exemption for nozzle: N4-VENT.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 1.6883 mm.
Wall Thickness per UG16(b),                      tr16b = 2.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 5.7339 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 5.7339 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 2.5000 mm.
Wall Thickness per table UG-45                   tb3 = 5.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 5.8, max( 5.7339, 2.5 ) ]
  = 5.7339 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 1.6883, 5.7339 )
  = 5.7339 mm.
```

Available Nozzle Neck Thickness = 6.6675 mm. -> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

Note:
This Material was specified as being an Impact Tested (Low Temperature) Material.

```
Impact Test Temperature provided per Specification        -46 °C

Calculated Minimum Design Metal Temperature              -104 °C
```

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

Govrn. thk, tg = 6.668, tr = 0.688, c = 1.0 mm., E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.121, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve D            -48 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit       -48 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C

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

Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ASME B16.5/47 flange per Matl. Specification      -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)          -49 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
`Design Pressure/Ambient Rating = 18.37/19.60 = 0.937`

Weld Size Calculations, Description: N4-VENT

```
Intermediate Calc. for nozzle/shell Welds   Tmin      5.6675  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	3.9673 = 0.7 * tmin.	6.3630 = 0.7 * Wo mm.

Skipping the nozzle attachment weld strength calculations. Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a) (small nozzles) do not require a weld strength check.

The Drop for this Nozzle is : 3.3113 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 163.3113 mm.

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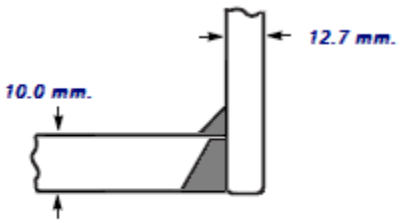
Input, Nozzle Desc: K1A-LT FOR ALARM From: 20

Pressure for Reinforcement Calculations	P	18.369	bar(g)
Temperature for Internal Pressure	Temp	80	°C
Parent Material [Normalized]		SA-516 60	
Parent Allowable Stress at Temperature	Sv	117.90	N./mm^2
Parent Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	600.00	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	1.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		810.00	mm.
User Entered Minimum Design Metal Temperature		-29.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		Inside	
Layout Angle		315.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	1.0000	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	9.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (bottom of element).



Reinforcement CALCULATION, Description: K1A-LT FOR ALARM

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation            1.000  in.
Actual Thickness Used in Calculation                  0.500  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 18.37*301.0/(118*1.0-0.6*18.37)
  = 4.7339 mm.
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 13.7(exp([18.37/(137.9*1.0]-1)
  = 0.1837 mm.
```

UG-40, Limits of Reinforcement: [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    68.8000  mm.
Parallel to Vessel Wall                          Rn+tn+t    34.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    22.5000  mm.
```

Taking a UG-36(c)(3)(a) exemption for nozzle: K1A-LT FOR ALAR.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 1.1837 mm.
Wall Thickness per UG16(b),                      tr16b = 2.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 5.7339 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 5.7339 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 2.5000 mm.
Wall Thickness per table UG-45                   tb3 = 4.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 4.42, max( 5.7339, 2.5 ) ]
  = 4.4200 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 1.1837, 4.42 )
  = 4.4200 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)), Curve: D

Govrn. thk, tg = 10.0, tr = 4.734, c = 1.0 mm., E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.526, Temp. Reduction = 29 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve D          -48 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit     -48 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -48 °C
```

Weld Size Calculations, Description: K1A-LT FOR ALAR

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      9.0000  mm.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          6.0000 = Min per Code 6.3630 = 0.7 * Wo mm.
```

Skipping the nozzle attachment weld strength calculations. Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a) (small nozzles) do not require a weld strength check.

The Drop for this Nozzle is : 1.0772 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 161.0772 mm.

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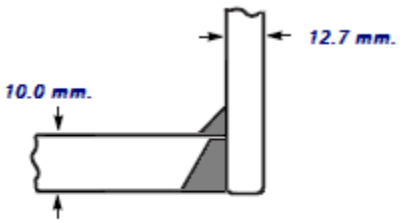
Input, Nozzle Desc: K3-PT From: 20

Pressure for Reinforcement Calculations	P	18.369	bar(g)
Temperature for Internal Pressure	Temp	80	°C
Parent Material [Normalized]		SA-516 60	
Parent Allowable Stress at Temperature	Sv	117.90	N./mm^2
Parent Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	600.00	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	1.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2150.00	mm.
User Entered Minimum Design Metal Temperature		-29.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		Inside	
Layout Angle		60.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	1.0000	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	9.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (bottom of element).



Reinforcement CALCULATION, Description: K3-PT

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation            1.000  in.
Actual Thickness Used in Calculation                  0.500  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 18.37*301.0/(118*1.0-0.6*18.37)
  = 4.7339 mm.
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 13.7(exp([18.37/(137.9*1.0]-1)
  = 0.1837 mm.
```

UG-40, Limits of Reinforcement: [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    68.8000  mm.
Parallel to Vessel Wall                          Rn+tn+t    34.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    22.5000  mm.
```

Taking a UG-36(c)(3)(a) exemption for nozzle: K3-PT.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 1.1837 mm.
Wall Thickness per UG16(b),                      tr16b = 2.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 5.7339 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 5.7339 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 2.5000 mm.
Wall Thickness per table UG-45                   tb3 = 4.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 4.42, max( 5.7339, 2.5 ) ]
  = 4.4200 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 1.1837, 4.42 )
  = 4.4200 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)), Curve: D

Govrn. thk, tg = 10.0, tr = 4.734, c = 1.0 mm., E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.526, Temp. Reduction = 29 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve D          -48 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit     -48 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -48 °C
```

Weld Size Calculations, Description: K3-PT

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      9.0000  mm.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          6.0000 = Min per Code 6.3630 = 0.7 * Wo mm.
```

Skipping the nozzle attachment weld strength calculations. Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a) (small nozzles) do not require a weld strength check.

The Drop for this Nozzle is : 1.0772 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 161.0772 mm.

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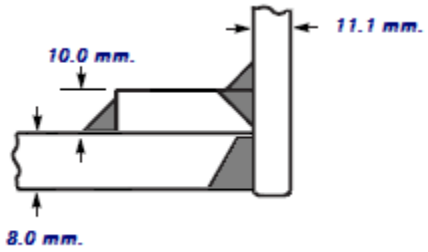
Input, Nozzle Desc: N2-GAS OUTLET From: 30

Pressure for Reinforcement Calculations	P	18.300	bar(g)
Temperature for Internal Pressure	Temp	80	°C
Parent Material [Normalized]		SA-516 60	
Parent Allowable Stress at Temperature	Sv	117.90	N./mm^2
Parent Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Elliptical Head	D	600.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	8.0000	mm.
Head Internal Corrosion Allowance	c	1.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	0.0000	mm.
User Entered Minimum Design Metal Temperature		-29.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		Outside	
Layout Angle		0.00	deg
Diameter		10.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness		XS	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	1.0000	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	9.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 60	
Pad Allowable Stress at Temperature	Sp	117.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	117.90	N./mm^2
Diameter of Pad along vessel surface	Dp	373.0500	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		50.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (bottom of element).



Reinforcement CALCULATION, Description: N2-GAS OUTLET

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation          10.750  in.
Actual Thickness Used in Calculation                  0.438  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Elliptical Head, tr [Int. Press]
```
= P*D*K/(2*Sv*E-0.2*P) per Appendix 1-4(c)
= 18.3*602.0*0.996/(2*117.9*1.0-0.2*18.3)
= 4.6587 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
= P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= 18.3*136.525/(118*1.0+0.4*18.3)
= 2.1061 mm.
```

UG-40, Limits of Reinforcement: [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl   505.6500  mm.
Parallel to Vessel Wall, opening length              d   252.8250  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp    17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
= min( 1, Sn/Sv )
= min( 1, 117.9/117.9 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:
```
= min( 1, Sn/Sv )
= min( 1, 117.9/117.9 )
= 1.000
```

Weld Strength Reduction Factor [fr4]:
```
= min( 1, Sp/Sv )
= min( 1, 117.9/117.9 )
= 1.000
```

Weld Strength Reduction Factor [fr3]:
```
= min( fr2, fr4 )
= min( 1., 1.0 )
= 1.000
```

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	11.778	NA	NA
Area in Shell	A1	5.919	NA	NA
Area in Nozzle Wall	A2	2.802	NA	NA
Area in Inward Nozzle	A3	0.000	NA	NA

Area in Welds	A41+A42+A43	1.427	NA	NA
Area in Element	A5	10.000	NA	NA
TOTAL AREA AVAILABLE	Atot	20.149	NA	NA

The MAWP 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:	289.3445	10.0000	mm.
Based on given Pad Diameter:	373.0500	1.6295	mm.
Based on Shell or Nozzle Thickness:	293.4182	8.0000	mm.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (252.825*4.6587*1.0+2*10.1125*4.6587*1.0*(1-1.))
= 11.778 cm^2

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 252.825(1.0 * 7.0 - 1.0 * 4.659) - 2 * 10.112
(1.0 * 7.0 - 1.0 * 4.6587) * (1 - 1.)
= 5.919 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 17.5) * (10.11 - 2.11) * 1.
= 2.802 cm^2

Area Available in Welds [A41 + A42 + A43]:
= (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
= (0.7875) * 1. + (0.0) * 1. + 8.0² * 1.0
= 1.427 cm^2

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (373.05 - 273.05) * 10.0 * 1.0
= 10.000 cm^2

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

Wall Thickness for Internal/External pressures	ta =	3.1061 mm.
Wall Thickness per UG16(b),	tr16b =	2.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 =	5.6587 mm.
Wall Thickness	tb1 = max(trb1, tr16b) =	5.6587 mm.
Wall Thickness	tb2 = max(trb2, tr16b) =	2.5000 mm.
Wall Thickness per table UG-45	tb3 =	9.1026 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[9.103, max(5.6587, 2.5)]
= 5.6587 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.1061, 5.6587)
= 5.6587 mm.

Available Nozzle Neck Thickness = 11.1125 mm. -> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code, (see 319.4.4 and 302.3.5):

Sustained :	28.1,	Allowable :	117.9 N./mm^2	Passed
Expansion :	0.0,	Allowable :	266.6 N./mm^2	Passed
Occasional :	11.0,	Allowable :	156.8 N./mm^2	Passed
Shear :	11.6,	Allowable :	82.5 N./mm^2	Passed

The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

Note:
This Material was specified as being an Impact Tested (Low Temperature) Material.

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

Note:
This Material was specified as being an Impact Tested (Low Temperature) Material.

Impact Test Temperature provided per Specification	-46 °C

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

Govrn. thk, tg = 10.0, c = 1.0 mm., E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.666, Temp. Reduction = 19 °C
Attachment governing, Attachment stress = Shell stress per Code

Min Metal Temp. w/o impact per UCS-66, Curve C	-44 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit	-48 °C

Shell to Pad Weld Junction at Pad OD, min(Curve:C, Curve:D)

Govrn. thk, tg = 8.0, tr = 4.659, c = 1.0 mm., E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.666, Temp. Reduction = 19 °C

Min Metal Temp. w/o impact per UCS-66, Curve C	-48 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit	-48 °C

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

Govrn. thk, tg = 8.0, tr = 4.659, c = 1.0 mm., E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.666, Temp. Reduction = 19 °C

Min Metal Temp. w/o impact per UCS-66, Curve D		-48 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit		-48 °C
Gov. MDMT of the Nozzle	:	-46 °C
Gov. MDMT of the Reinforcement Pad	:	-48 °C
Gov. MDMT of the nozzle to shell joint welded assembly	:	-46 °C

Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ASME B16.5/47 flange per Matl. Specification	-46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)	-49 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
Design Pressure/Ambient Rating = 18.30/19.60 = 0.934

Weld Size Calculations, Description: N2-GAS OUTLET

```
Intermediate Calc. for nozzle/shell Welds   Tmin     10.0000  mm.
Intermediate Calc. for pad/shell Welds   TminPad      9.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	6.3630 = 0.7 * Wo mm.
Pad Weld	4.5000 = 0.5*TminPad	5.6560 = 0.7 * Wp mm.

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (11.7785 - 5.9193 + 2 * 10.1125 * 1. *
(1.0 * 7.0 - 4.6587))118)
= 7613.65 kgf

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

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (2.8022 + 10.0 + 1.4275 - 0.0 * 1.) * 118
= 17108.03 kgf

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (2.8022 + 0.0 + 0.81 + (1.4157)) * 118
= 6045.01 kgf

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (2.8022 + 0.0 + 1.4275 + 10.0 + (1.4157)) * 118
= 18810.14 kgf

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
= (pi/2) * Dlo * Wo * 0.49 * Snw
= (3.1416/2.0) * 273.05 * 9.0 * 0.49 * 118
= 22741. kgf

Shear, Pad Element Weld [Spew]:
= (pi/2) * DP * WP * 0.49 * SEW
= (3.1416/2.0) * 373.05 * 8.0 * 0.49 * 118
= 27617. kgf

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 131.4687) * (11.1125 - 1.0) * 0.7 * 118
= 35150. kgf

Tension, Pad Groove Weld [Tpgw]:
= (pi/2) * Dlo * Wgpn * 0.74 * Seg
= (3.1416/2) * 273.05 * 10.0 * 0.74 * 118
= 38159. kgf

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
= ( 3.1416/2.0 ) * 273.05 * ( 8.0 - 1.0 ) * 0.74 * 118
= 26711. kgf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
= ( SPEW + SNW ) = ( 27617 + 35150 ) = 62767 kgf
```

Failure Path [Path 2-2]:
```
= ( Sonw + Tpgw + Tngw + Sinw )
= ( 22741 + 38159 + 26711 + 0 ) = 87611 kgf
```

Failure Path [Path 3-3]:
```
= ( Spew + Tngw + Sinw )
= ( 27617 + 26711 + 0 ) = 54328 kgf
```

Summary of Failure Path Calculations:
```
Path 1-1 = 62767   kgf, must exceed W = 7613 kgf     or W1 = 17108 kgf
Path 2-2 = 87610   kgf, must exceed W = 7613 kgf     or W2 = 6045 kgf
Path 3-3 = 54328   kgf, must exceed W = 7613 kgf     or W3 = 18810 kgf
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
Converged Maximum Allowable Pressure in the Operating case: 23 bar(g)
```

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

The Drop for this Nozzle is : 17.3311 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.3311 mm.

Input Echo, WRC107/537 Item 1, Description: N2-GAS OUTLET :

```
Diameter Basis for Vessel                Vbasis      ID
Cylindrical or Spherical Vessel          Cylsph      Spherical
Internal Corrosion Allowance                Cas      1.0000  mm.
Vessel Diameter                              Dv    1080.000  mm.
Vessel Thickness                             Tv       8.000  mm.

Design Temperature                           T1        80.0  C
Vessel Material                                   SA-516 60
Vessel UNS Number                                 K02100
Vessel Cold S.I. Allowable                  Smc      117.90  N./mm^2
Vessel Hot  S.I. Allowable                  Smh      117.90  N./mm^2
```

See ASME VIII Div. 1, UG-23(e), for determination of the SPS allowable.

```
Attachment Type                            Type      Round
WRC107 Attachment Classification         Holsol      Hollow

Diameter Basis for Nozzle                Nbasis      OD
Corrosion Allowance for Nozzle              Can      1.0000  mm.
Nozzle Diameter                              Dn     273.050  mm.
Nozzle Thickness                             Tn      11.113  mm.
Nozzle Material                                   SA-333 6
Nozzle UNS Number                                 K03006
Nozzle Cold S.I. Allowable                 SNmc      117.90  N./mm^2
Nozzle Hot  S.I. Allowable                 SNmh      117.90  N./mm^2

Thickness of Reinforcing Pad                Tpad      10.000  mm.
```

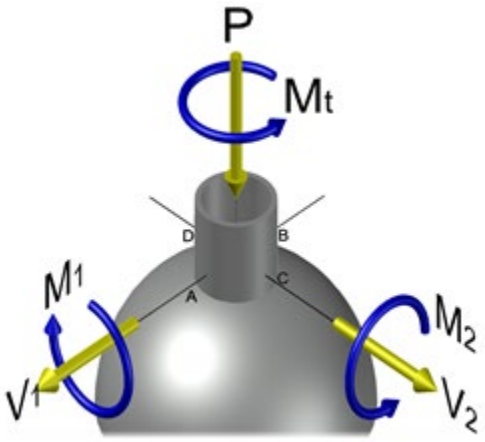
Diameter of Reinforcing Pad			Dpad	373.050	mm.
Design Internal Pressure			Dp	18.300	bar(g)
Include Pressure Thrust				No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)		P	-1223.7	kgf
Longitudinal Shear	(SUS)	(Vl)	V1	611.9	kgf
Circumferential Shear	(SUS)	(Vc)	V2	917.8	kgf
Circumferential Moment	(SUS)	(Mc)	M1	611.6	Kg-m.
Longitudinal Moment	(SUS)	(Ml)	M2	795.1	Kg-m.
Torsional Moment	(SUS)		Mt	917.5	Kg-m.

Use Interactive Control		No
WRC107 Version	Version	March 1979
Include Pressure Stress Indices per Div. 2		No
Compute Pressure Stress per WRC-368		No
Local Loads applied at end of Nozzle/Attachment		No

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 107/537 has dimensional limitations that can be found in the bulletin's Foreword and which can also be inferred by review of the non-dimensional curve limits.

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 273.05 + 2 * 1.65 * sqrt( 544.5 ( 8.0 - 1.0 ) )
= 476.783 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load		P	-1223.7	kgf
Circumferential Shear	(VC)	V2	917.8	kgf
Longitudinal Shear	(VL)	V1	611.9	kgf
Circumferential Moment	(MC)	M1	611.6	Kg-m.
Longitudinal Moment	(ML)	M2	795.1	Kg-m.
Torsional Moment		MT	917.5	Kg-m.

Dimensionless Parameters: U = 1.41 TAU = 13.00 RHO = 1.68

Dimensionless Loads for Spherical Shells at Attachment Junction:

Curves read for 1979	Figure	Value	Location
N(x) * T / P	SP 2	0.02306	(A,B,C,D)
M(x) / P	SP 2	0.01962	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / MC	SM 2	0.02660	(A,B,C,D)
M(x) * SQRT(Rm * T) / MC	SM 2	0.02500	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / ML	SM 2	0.02660	(A,B,C,D)
M(x) * SQRT(Rm * T) / ML	SM 2	0.02500	(A,B,C,D)
N(y) * T / P	SP 2	0.08075	(A,B,C,D)
M(y) / P	SP 2	0.01053	(A,B,C,D)
N(y) * T * SQRT(Rm * T) / MC	SM 2	0.07949	(A,B,C,D)
M(y) * SQRT(Rm * T) / MC	SM 2	0.01578	(A,B,C,D)
N(y) * T * SQRT(Rm * T) / ML	SM 2	0.07949	(A,B,C,D)
M(y) * SQRT(Rm * T) / ML	SM 2	0.01578	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Rad. Memb. P	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Rad. Bend. P	4.9	-4.9	4.9	-4.9	4.9	-4.9	4.9	-4.9
Rad. Memb. MC	0.0	0.0	0.0	0.0	-5.7	-5.7	5.7	5.7
Rad. Memb. MC	0.0	0.0	0.0	0.0	-32.2	32.2	32.2	-32.2
Rad. Memb. ML	-7.4	-7.4	7.4	7.4	0.0	0.0	0.0	0.0
Rad. Bend. ML	-41.9	41.9	41.9	-41.9	0.0	0.0	0.0	0.0
Tot. Rad. Str.	-43.4	30.5	55.1	-38.4	-32.1	22.6	43.8	-30.4
Tang. Memb. P	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Tang. Bend. P	2.6	-2.6	2.6	-2.6	2.6	-2.6	2.6	-2.6
Tang. Memb. MC	0.0	0.0	0.0	0.0	-17.1	-17.1	17.1	17.1
Tang. Bend. MC	0.0	0.0	0.0	0.0	-20.3	20.3	20.3	-20.3
Tang. Memb. ML	-22.2	-22.2	22.2	22.2	0.0	0.0	0.0	0.0
Tang. Bend. ML	-26.4	26.4	26.4	-26.4	0.0	0.0	0.0	0.0
Tot. Tang. Str.	-42.6	5.0	54.6	-3.5	-31.4	4.0	43.4	-2.5
Shear VC	1.2	1.2	-1.2	-1.2	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	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Tot. Shear	5.8	5.8	3.3	3.3	3.7	3.7	5.3	5.3
Str. Int.	48.8	31.7	58.2	38.7	35.5	23.3	48.9	31.4

Unitless Prm: U = 3.02 TAU = 0.00 (17.94) RHO = 0.00 (0.69)

Dimensionless Loads for Spherical Shells at Pad edge:

Curves read for 1979	Figure	Value	Location
N(x) * T / P	SR 2	0.02175	(A,B,C,D)
M(x) / P	SR 2	0.00990	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / MC	SR 3	0.01691	(A,B,C,D)
M(x) * SQRT(Rm * T) / MC	SR 3	0.01053	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / ML	SR 3	0.01691	(A,B,C,D)

M(x) * SQRT(Rm * T) / ML	SR 3	0.01053	(A,B,C,D)
N(y) * T / P	SR 2	0.00650	(A,B,C,D)
M(y) / P	SR 2	0.00300	(A,B,C,D)
N(y) * T * SQRT(Rm * T) / MC	SR 3	0.00507	(A,B,C,D)
M(y) * SQRT(Rm * T) / MC	SR 3	0.00317	(A,B,C,D)
N(y) * T * SQRT(Rm * T) / ML	SR 3	0.00507	(A,B,C,D)
M(y) * SQRT(Rm * T) / ML	SR 3	0.00317	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Rad. Memb. P	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Rad. Bend. P	14.5	-14.5	14.5	-14.5	14.5	-14.5	14.5	-14.5
Rad. Memb. MC	0.0	0.0	0.0	0.0	-33.5	-33.5	33.5	33.5
Rad. Memb. MC	0.0	0.0	0.0	0.0	-125.2	125.2	125.2	-125.2
Rad. Memb. ML	-43.6	-43.6	43.6	43.6	0.0	0.0	0.0	0.0
Rad. Bend. ML	-162.8	162.8	162.8	-162.8	0.0	0.0	0.0	0.0
Tot. Rad. Str.	-186.5	110.0	226.3	-128.4	-138.9	82.5	178.6	-100.9
Tang. Memb. P	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Tang. Bend. P	4.4	-4.4	4.4	-4.4	4.4	-4.4	4.4	-4.4
Tang. Memb. MC	0.0	0.0	0.0	0.0	-10.0	-10.0	10.0	10.0
Tang. Bend. MC	0.0	0.0	0.0	0.0	-37.8	37.8	37.8	-37.8
Tang. Memb. ML	-13.1	-13.1	13.1	13.1	0.0	0.0	0.0	0.0
Tang. Bend. ML	-49.1	49.1	49.1	-49.1	0.0	0.0	0.0	0.0
Tot. Tang. Str.	-56.2	33.2	68.2	-38.9	-41.8	24.9	53.8	-30.5
Shear VC	2.2	2.2	-2.2	-2.2	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.5	-1.5	1.5	1.5
Shear MT	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
Tot. Shear	8.1	8.1	3.7	3.7	4.4	4.4	7.3	7.3
Str. Int.	187.0	110.8	226.4	128.6	139.1	82.8	179.1	101.7

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Rad. Pm (SUS)	29.1	29.1	29.1	29.1	29.1	29.1	29.1	29.1
Rad. Pl (SUS)	-6.5	-6.5	8.4	8.4	-4.8	-4.8	6.7	6.7
Rad. Q (SUS)	-37.0	37.0	46.8	-46.8	-27.3	27.3	37.1	-37.1
Long. Pm (SUS)	29.1	29.1	29.1	29.1	29.1	29.1	29.1	29.1
Long. Pl (SUS)	-18.8	-18.8	25.5	25.5	-13.7	-13.7	20.4	20.4
Long. Q (SUS)	-23.8	23.8	29.1	-29.1	-17.7	17.7	23.0	-23.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.2	1.2	-1.2	-1.2	-0.8	-0.8	0.8	0.8

Shear Q (SUS)	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Pm (SUS)	29.1	29.1	29.1	29.1	29.1	29.1	29.1	29.1
Pm+Pl (SUS)	22.8	22.8	54.8	54.8	24.5	24.5	49.6	49.6
Pm+Pl+Q (Total)	19.7	60.9	87.3	35.5	7.4	52.4	78.1	29.9

Vessel Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	29.14	117.90	Passed
Pm+Pl (SUS)	54.77	176.86	Passed
Pm+Pl+Q (TOTAL)	87.30	353.71	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm^2)

Type of Stress	Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Rad.	Pm (SUS)	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7
Rad.	Pl (SUS)	-38.3	-38.3	48.9	48.9	-28.2	-28.2	38.9	38.9
Rad.	Q (SUS)	-148.3	148.3	177.4	-177.4	-110.7	110.7	139.8	-139.8
Long.	Pm (SUS)	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7
Long.	Pl (SUS)	-11.5	-11.5	14.7	14.7	-8.5	-8.5	11.6	11.6
Long.	Q (SUS)	-44.7	44.7	53.5	-53.5	-33.4	33.4	42.2	-42.2
Shear	Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear	Pl (SUS)	2.2	2.2	-2.2	-2.2	-1.5	-1.5	1.5	1.5
Shear	Q (SUS)	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
Pm (SUS)		70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7
Pm+Pl (SUS)		59.4	59.4	119.8	119.8	62.4	62.4	109.7	109.7
Pm+Pl+Q (Total)		131.4	181.6	297.1	89.9	97.5	153.5	249.8	71.9

Vessel Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	70.73	117.90	Passed
Pm+Pl (SUS)	119.79	176.86	Passed
Pm+Pl+Q (TOTAL)	297.10	353.71	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

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Loads for Foundation/Support Design:

Total Wind Shear on top of all Legs	341.	kgf
Total Wind Moment at top of all Legs	332.	Kg-m.
Wind Load Case Test Moment on Support	83.	Kg-m.
Test Case Wind Shear on Support	85.	kgf
Max. Wind Shear on one Leg (top & bottom)	224.	kgf
Max. Wind Moment at base of one Leg	215.	Kg-m.
Max. Vertical Load (Wt. + Wind) on one Leg	1292.	kgf
Max. Vertical Load (Wt. + Eq.) on one Leg	323.	kgf

For the Pressure Test Case:

Max. Wind Shear on one Leg (top & bottom)	56.	kgf
Max. Wind Moment at base of one Leg	54.	Kg-m.
Max. Vertical Load (Wt. + Wind) on one Leg	740.	kgf
Max. Vertical Load (Wt. + Eq.) on one Leg	498.	kgf

The Wind and Seismic loads were not load factored in this analysis.

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
Lift Lug	WRC-107/537	0.185	n/a	Passed
N1- GAS INLET	WRC-107/537	0.839	n/a	Passed
N2-GAS OUTLET	WRC-107/537	0.840	n/a	Passed

Weights:

Fabricated	- Bare W/O Removable Internals	773.3	kg.
Shop Test	- Fabricated + Water (Full)	1494.0	kg.
Shipping	- Fab. + Rem. Intls.+ Shipping App.	773.3	kg.
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	773.3	kg.
Empty	- Fab. + Intls. + Details + Wghts.	773.3	kg.
Operating	- Empty + Operating Liquid (No CA)	1013.6	kg.
Field Test	- Empty Weight + Water (Full)	1494.0	kg.

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Input Data:

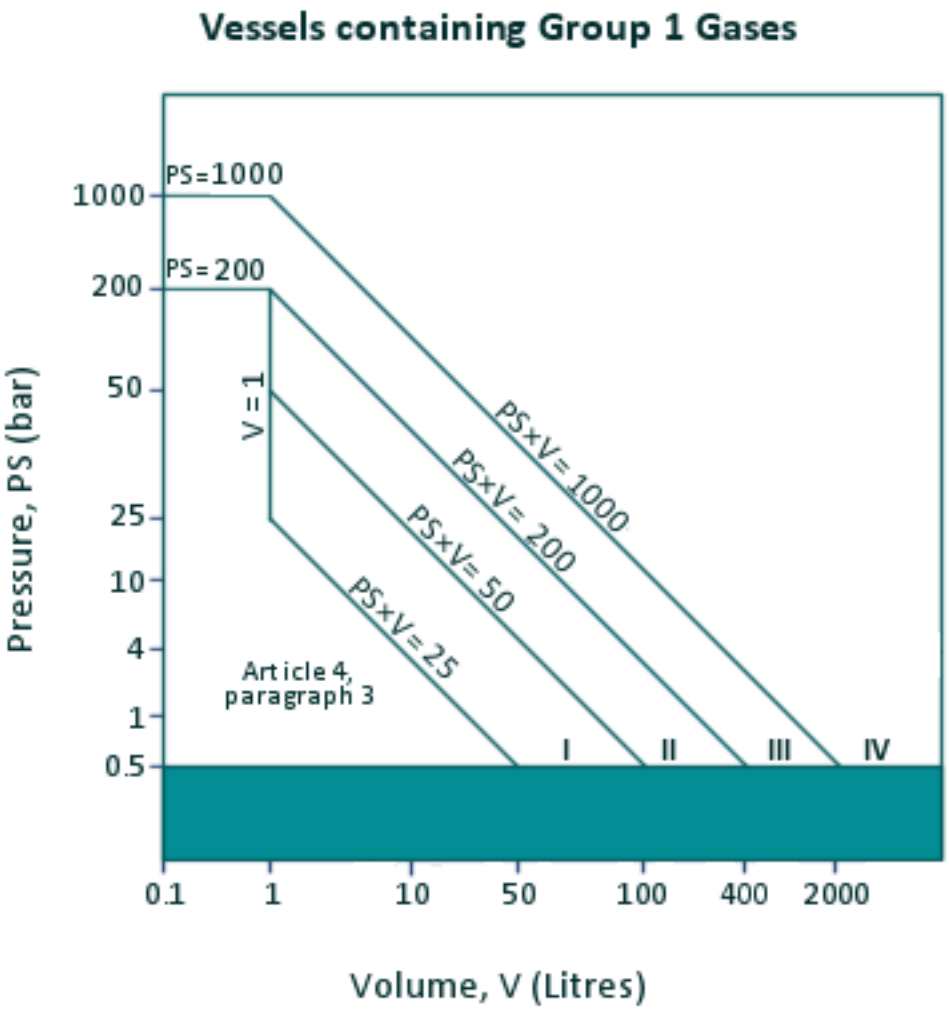
PED Version	PED 2014/68/EU
Maximum Allowable (Design) Pressure	3.500 bar(g)
Maximum Volume	721124.750 cm³
Equipment type per Article 4	1.1 Vessels
Fluid State	Gaseous
Fluid Group	1: Hazardous

Calculated Results:

Maximum Allowable Pressure	3.5 bar
Volume	721.0 litres
Pressure * Volume	2523.3 bar-litres
Category	4
Conformity Assessment Table	1

Modules B (production type) + D, B (production type) + F, G, H1

Exceptionally, vessels intended to contain an unstable gas and falling within categories I or II on the basis of table 1 must be classified in category III.



Pressure Equipment Directive

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3. MODULE B: EU-TYPE EXAMINATION

3.1. EU-Type examination – production type

1. EU-type examination - production type is the part of a conformity assessment procedure in which a notified body examines the technical design of the pressure equipment and verifies and attests that the technical design of the pressure equipment meets the requirements of this Directive.

2. EU-type examination - production type shall consist of an assessment of the adequacy of the technical design of the pressure equipment through examination of the technical documentation and supporting evidence referred to in point 3, plus examination of a specimen, representative of the production envisaged, of the complete pressure equipment.

3. The manufacturer shall lodge an application for EU-type examination with a single notified body of his choice.

   The application shall include:

   - the name and address of the manufacturer and, if the application is lodged by the authorised representative, his name and address as well,
   - a written declaration that the same application has not been lodged with any other notified body,EN L 189/222 Official Journal of the European Union 27.6.2014
   - the technical documentation. The technical documentation shall make it possible to assess the conformity of the pressure equipment with the applicable requirements of this Directive and shall include an adequate analysis and assessment of the risk(s). The technical documentation shall specify the applicable requirements and cover, as far as relevant for the assessment, the design, manufacture and operation of the pressure equipment. The technical documentation shall contain, wherever applicable, at least the following elements:
   - a general description of the pressure equipment,
   - conceptual design and manufacturing drawings and diagrams of components, sub-assemblies, circuits, etc.,
   - descriptions and explanations necessary for the understanding of those drawings and diagrams and the operation of the pressure equipment,
   - a list of the harmonised standards the references of which have been published in the Official Journal of the European Union, applied in full or in part, and descriptions of the solutions adopted to meet the essential safety requirements of this Directive where those harmonised standards have not been applied. In the event of partly applied harmonised standards, the technical documentation shall specify the parts which have been applied,
   - results of design calculations made, examinations carried out, etc.,
   - test reports,
   - information concerning the tests provided for in manufacture,
   - information concerning the qualifications or approvals required under points 3.1.2 and 3.1.3 of Annex I,
   - the specimens representative of the production envisaged.

   The specimen may cover several versions of the pressure equipment provided that the differences between the versions do not affect the level of safety.

   The notified body may request further specimens if needed for carrying out the test programme;

   - the supporting evidence for the adequacy of the technical design solution. This supporting evidence shall mention any documents that have been used, in particular where the relevant harmonised standards have not been applied in full. The supporting evidence shall include, where necessary, the results of tests carried out by the appropriate laboratory of the manufacturer applying other relevant technical specifications, or by

another testing laboratory on his behalf and under his responsibility.

4. The notified body shall:

4.1. examine the technical documentation and supporting evidence to assess the adequacy of the technical design of the pressure equipment and the manufacturing procedures. In particular, the notified body shall:

- assess the materials where these are not in conformity with the relevant harmonised standards or with a European approval for pressure equipment materials, and check the certificate issued by the material manufacturer in accordance with point

4.3 of Annex I,

- approve the procedures for the permanent joining of pressure equipment parts, or check that they have been previously approved in accordance with point 3.1.2 of Annex I,EN 27.6.2014 Official Journal of the European Union L 189/223
- verify that the personnel undertaking the permanent joining of pressure equipment parts and the non-destructive tests are qualified or approved in accordance with points 3.1.2 or 3.1.3 of Annex I.

4.2. verify that the specimen(s) have been manufactured in conformity with the technical documentation and identify the elements which have been designed in accordance with the applicable provisions of the relevant harmonised standards as well as the elements which have been designed using other relevant technical specifications without applying the relevant provisions of those standards.

4.3. carry out appropriate examinations and necessary tests to check whether when the manufacturer has chosen to apply the solutions in the relevant harmonised standards, these have been applied correctly.

4.4. carry out appropriate examinations and necessary tests to check whether, where the solutions in the relevant harmonised standards have not been applied, the solutions adopted by the manufacturer applying other relevant technical specifications meet the corresponding essential safety requirements of this Directive.

4.5. agree with the manufacturer on a location where the examinations and tests will be carried out.

5. The notified body shall draw up an evaluation report that records the activities undertaken in accordance with point 4 and their outcomes. Without prejudice to its obligations vis-à-vis the notifying authority, the notified body shall release the content of that report, in full or in part, only with the agreement of the manufacturer.

6. Where the type meets the requirements of this Directive, the notified body shall issue an EU-type examination certificate – production type to the manufacturer. Without prejudice to point 7, the certificate shall be valid for 10 years and be renewable and shall contain the name and address of the manufacturer, the conclusions of the examination, the conditions (if any) for its validity and the necessary data for identification of the approved type.

A list of the relevant parts of the technical documentation shall be annexed to the certificate and a copy kept by the notified body.

The certificate and its annexes shall contain all relevant information to allow the conformity of manufactured pressure equipment with the examined type to be evaluated and to allow for in-service control.

Where the type does not satisfy the applicable requirements of this Directive, the notified body shall refuse to issue an EU-type examination certificate – production type and shall inform the applicant accordingly, giving detailed reasons for its refusal. Provision shall be made for an appeals procedure.

7. The notified body shall keep itself apprised of any changes in the generally acknowledged state of the art which indicate that the approved type may no longer comply with the applicable requirements of this Directive, and shall determine whether such changes require further investigation. If so, the notified body shall inform the manufacturer accordingly.

   The manufacturer shall inform the notified body that holds the technical documentation relating to the EU-type examination certificate – production type of all modifications to the approved type that may affect the conformity of the pressure equipment with the essential safety requirements of this Directive or the conditions for validity of the certificate. Such modifications shall require additional approval in the form of an addition to the original EU- type examination certificate – production type.

8. Each notified body shall inform its notifying authority concerning the EU-type examination certificates – production type and/or any additions thereto which it has issued or withdrawn, and shall, periodically or upon request, make available to its notifying authorities the list of certificates and/or any additions thereto refused, suspended or otherwise restricted.EN L 189/224 Official Journal of the European Union 27.6.2014.

   Each notified body shall inform the other notified bodies concerning the EU-type examination certificates – production type and/or any additions thereto which it has refused, withdrawn, suspended or otherwise restricted, and, upon request, concerning the certificates and/or additions thereto which it has issued.

   The Commission, the Member States and the other notified bodies may, on request, obtain a copy of the EU-type examination certificates – production type and/or additions thereto. On request, the Commission and the Member States may obtain a copy of the technical documentation and the results of the examinations carried out by the notified body. The notified body shall keep a copy of the EU-type examination certificate – production type, its annexes and additions, as well as the technical file including the documentation submitted by the manufacturer, until the expiry of the validity of the certificate.

9. The manufacturer shall keep a copy of the EU-type examination certificate – production type, its annexes and additions together with the technical documentation at the disposal of the national authorities for 10 years after the pressure equipment has been placed on the market.

10. The manufacturer’s authorised representative may lodge the application referred to in point 3 and fulfil the obligations set out in points 7 and 9, provided that they are specified in the mandate.

5. MODULE D: CONFORMITY TO TYPE BASED ON QUALITY ASSURANCE OF THE PRODUCTION PROCESS

1. Conformity to type based on quality assurance of the production process is that part of a conformity assessment procedure whereby the manufacturer fulfils the obligations laid down in points 2 and 5, and ensures and declares on his sole responsibility that the pressure equipment or assembly concerned is in conformity with the type described in the EU-type examination certificate and satisfies the requirements of this Directive that apply to it.

2. Manufacturing

   The manufacturer shall operate an approved quality system for production, final product inspection and testing of the pressure equipment concerned as specified in point 3 and shall be subject to surveillance as specified in point 4.EN L 189/228 Official Journal of the European Union 27.6.2014.

3. Quality system

3.1. The manufacturer shall lodge an application for assessment of his quality system

with the notified body of his choice for the pressure equipment concerned.

The application shall include:

- the name and address of the manufacturer and, if the application is lodged by the authorised representative, his name and address as well,
- a written declaration that the same application has not been lodged with any other notified body,
- all relevant information on the pressure equipment type envisaged,
- the documentation concerning the quality system,
- the technical documentation of the approved type and a copy of the EU-type examination certificate.

3.2. The quality system shall ensure that the pressure equipment is in conformity with the type described in the EU-type examination certificate and comply with the requirements of this Directive that apply to it.

All the elements, requirements and provisions adopted by the manufacturer shall be documented in a systematic and orderly manner in the form of written policies, procedures and instructions. This quality system documentation shall permit a consistent interpretation of the quality programmes, plans, manuals and records.

It shall, in particular, contain an adequate description of:

- the quality objectives and the organisational structure, responsibilities and powers of the management with regard to the quality of the pressure equipment,
- the corresponding manufacturing, quality control and quality assurance techniques, processes and systematic actions that will be used, particularly the procedures used for the permanent joining of parts as approved in accordance with point 3.1.2 of Annex I,
- the examinations and tests that will be carried out before, during and after manufacture, and the frequency with which they will be carried out,
- the quality records, such as inspection reports and test data, calibration data, reports concerning the qualifications or approvals of the personnel concerned, particularly those of the personnel undertaking the permanent joining of parts and the non-destructive tests in accordance with points 3.1.2 and 3.1.3 of Annex I, etc., and
- the means of monitoring the achievement of the required quality and the effective operation of the quality system.

3.3. The notified body shall assess the quality system to determine whether it satisfies the requirements referred to in point 3.2.

It shall presume conformity with those requirements in respect of the elements of the quality system that comply with the corresponding specifications of the relevant harmonised standard.EN 27.6.2014 Official Journal of the European Union L 189/229

In addition to experience in quality management systems, the auditing team shall have at least one member with experience of evaluation in the relevant pressure equipment field and pressure equipment technology concerned, and knowledge of the applicable requirements of this Directive. The audit shall include an inspection visit to the manufacturer’s premises.

The auditing team shall review the technical documentation referred to in point 3.1, fifth indent, to verify the manufacturer’s ability to identify the relevant requirements of this Directive and to carry out the necessary examinations with a view to ensuring compliance of the product with those requirements.

The decision shall be notified to the manufacturer. The notification shall contain the conclusions of the audit and the reasoned assessment decision.

3.4. The manufacturer shall undertake to fulfil the obligations arising out of the quality system as approved and to maintain it so that it remains adequate and efficient.

3.5. The manufacturer shall keep the notified body that has approved the quality system informed of any intended change to the quality system.

The notified body shall evaluate the proposed changes and decide whether the modified quality system will continue to satisfy the requirements referred to in point 3.2 or whether a reassessment is necessary.

It shall notify the manufacturer of its decision. The notification shall contain the conclusions of the examination and the reasoned assessment decision.

4. Surveillance under the responsibility of the notified body

4.1. The purpose of surveillance is to make sure that the manufacturer duly fulfils the obligations arising out of the approved quality system.

4.2. The manufacturer shall, for assessment purposes, allow the notified body access to the manufacture, inspection, testing and storage sites and shall provide it with all necessary information, in particular:

- the quality system documentation,
- the quality records, such as inspection reports and test data, calibration data, qualification reports of the personnel concerned, etc.

4.3. The notified body shall carry out periodic audits to make sure that the manufacturer maintains and applies the quality system and provide the manufacturer with an audit report. The frequency of periodic audits shall be such that a full reassessment is carried out every three years.

4.4. In addition the notified body may pay unexpected visits to the manufacturer. The need for such additional visits, and the frequency thereof, will be determined on the basis of a visit control system operated by the notified body. In particular, the following factors shall be considered in the visit control system:

- the category of the pressure equipment,
- the results of previous surveillance visits,
- the need to follow up corrective actions,
- special conditions linked to the approval of the system, where applicable,
- significant changes in manufacturing organisation, policy or techniques.EN L 189/230 Official Journal of the European Union 27.6.2014

During such visits the notified body may, if necessary, carry out product tests or have them carried out in order to verify that the quality system is functioning correctly. The notified body shall provide the manufacturer with a visit report and, if tests have been carried out, with a test report.

5. CE marking and EU declaration of conformity

5.1. The manufacturer shall affix the CE marking and, under the responsibility of the notified body referred to in point 3.1, the latter’s identification number to each individual pressure equipment that is in conformity with the type described in the EU-type examination certificate and satisfies the applicable requirements of this Directive.

5.2. The manufacturer shall draw up a written EU declaration of conformity for each pressure equipment model and keep it at the disposal of the national authorities for 10 years after the pressure equipment has been placed on the market. The EU declaration of conformity shall identify the pressure equipment model for which it has been drawn up.

A copy of the EU declaration of conformity shall be made available to the relevant authorities upon request.

6. The manufacturer shall, for a period ending 10 years after the pressure equipment has been placed on the market, keep at the disposal of the national authorities:

- the documentation referred to point 3.1,
- the change referred to in point 3.5, as approved,
- the decisions and reports of the notified body referred to in points 3.3, 3.5, 4.3 and 4.4.

7. Each notified body shall inform its notifying authorities of the quality system approvals issued or withdrawn, and shall, periodically or upon request, make available to its notifying authorities the list of quality system approvals refused, suspended or otherwise restricted.

   Each notified body shall inform the other notified bodies of the quality system approvals which it has refused, suspended, withdrawn or otherwise restricted, and, upon request, of quality system approvals which it has issued.

8. Authorised representative

   The manufacturer’s obligations set out in points 3.1, 3.5, 5 and 6 may be fulfilled by his authorised representative, on his behalf and under his responsibility, provided that they are specified in the mandate.

9. MODULE F: CONFORMITY TO TYPE BASED ON PRESSURE EQUIPMENT VERIFICATION

1. Conformity to type based on pressure equipment verification is the part of a conformity assessment procedure whereby the manufacturer fulfils the obligations laid down in points 2 and 5, and ensures and declares on his sole responsibility that the pressure equipment concerned, which has been subject to the provisions of point 3, is in conformity with the type described in the EU-type examination certificate and satisfies the requirements of this Directive which apply to it.

2. Manufacturing

   The manufacturer shall take all measures necessary so that the manufacturing process and its monitoring ensure conformity of the manufactured products with the approved type described in the EU-type examination certificate and with the requirements of this Directive which apply to them.

3. Verification

   A notified body chosen by the manufacturer shall carry out the appropriate examinations and tests in order to check the conformity of the pressure equipment with the approved type described in the EU-type examination certificate and with the appropriate requirements of this Directive.

   The examinations and tests to check the conformity of the pressure equipment with the appropriate requirements shall be carried out by examination and testing of every product as specified in point 4.

4. Verification of conformity by examination and testing of every item of pressure equipment

4.1. All pressure equipment shall be individually examined and appropriate tests set out in the relevant harmonised standard(s) or equivalent tests shall be carried out in order to verify conformity with the approved type and described in the EU-type examination certificate and with the appropriate requirements of this Directive. In the absence of such a harmonised standard, the notified body concerned shall decide on the appropriate tests to be carried out.

   In particular, the notified body shall:

   - verify that the personnel undertaking the permanent joining of parts and the non-destructive tests are qualified or approved in accordance with points 3.1.2 and 3.1.3

of Annex I,
- verify the certificate issued by the materials manufacturer in accordance with point 4.3 of Annex I,
- carry out or have carried out the final inspection and proof test referred to in point 3.2 of Annex I and examine the safety devices, if applicable.

4.2. The notified body shall issue a certificate of conformity in respect of the examinations and tests carried out, and shall affix its identification number or have it affixed under its responsibility to each approved item of pressure equipment.

The manufacturer shall keep the certificates of conformity available for inspection by the national authorities for 10 years after the pressure equipment has been placed on the market.

5. CE marking and EU declaration of conformity

5.1. The manufacturer shall affix the CE marking and, under the responsibility of the notified body referred to in point 3, the latter’s identification number to each individual item of pressure equipment that is in conformity with the approved type described in the EU-type examination certificate and satisfies the applicable requirements of this Directive.EN27.6.2014 Official Journal of the European Union L 189/241

5.2. The manufacturer shall draw up a written EU declaration of conformity for each pressure equipment model and keep it at the disposal of the national authorities, for 10 years after the pressure equipment has been placed on the market. The EU declaration of conformity shall identify the pressure equipment model for which it has been drawn up.

A copy of the EU declaration of conformity shall be made available to the relevant authorities upon request.

If the notified body referred to in point 3 agrees and under its responsibility, the manufacturer may also affix the notified body’s identification number to the pressure equipment.

6. If the notified body agrees and under its responsibility, the manufacturer may affix the notified body’s identification number to the pressure equipment during the manufacturing process.

7. Authorised representative

The manufacturer’s obligations may be fulfilled by his authorised representative, on his behalf and under his responsibility, provided that they are specified in the mandate. An authorised representative may not fulfil the manufacturer’s obligations set out in point 2.

10. MODULE G: CONFORMITY BASED ON UNIT VERIFICATION

1. Conformity based on unit verification is the conformity assessment procedure whereby the manufacturer fulfils the obligations laid down in points 2, 3 and 5, and ensures and declares on his sole responsibility that the pressure equipment concerned, which has been subject to the provisions of point 4, is in conformity with the requirements of this Directive that apply to it.

2. Technical documentation

The manufacturer shall establish the technical documentation and make it available to the notified body referred to in point 4.

The documentation shall make it possible to assess the conformity of the pressure equipment with the relevant requirements and shall include an adequate analysis and assessment of the risk(s). The technical documentation shall specify the applicable

requirements and cover, as far as relevant for the assessment, the design, manufacture and operation of the pressure equipment.

The technical documentation shall, wherever applicable, contain at least the following elements:

- a general description of the pressure equipment,
- conceptual design and manufacturing drawings and diagrams of components, sub-assemblies, circuits, etc.,
- descriptions and explanations necessary for an understanding of those drawings and diagrams and the operation of the pressure equipment,
- a list of the harmonised standards the references of which have been published in the Official Journal of the European Union, applied in full or in part, and descriptions of the solutions adopted to meet the essential safety requirements of this Directive where those harmonised standards, have not been applied. In the event of partly applied harmonised standards, the technical documentation shall specify the parts which have been applied,
- results of design calculations made, examinations carried out, etc.,
- test reports,
- appropriate details relating to the approval of the manufacturing and test procedures and of the qualifications or approvals of the personnel concerned in accordance with points 3.1.2 and 3.1.3 of Annex I.EN L 189/242 Official Journal of the European Union 27.6.2014

The manufacturer shall keep the technical documentation at the disposal of the relevant national authorities for 10 years after the pressure equipment has been placed on the market.

3. Manufacturing

The manufacturer shall take all measures necessary so that the manufacturing process and its monitoring ensure conformity of the manufactured pressure equipment with the applicable requirements of this Directive.

4. Verification

A notified body chosen by the manufacturer shall carry out appropriate examinations and tests, set out in the relevant harmonised standard(s) and/or equivalent tests, to check the conformity of the pressure equipment with the applicable requirements of this Directive, or have them carried out. In the absence of such a harmonised standard the notified body concerned shall decide on the appropriate tests to be carried out applying other technical specifications.

In particular the notified body shall:

- examine the technical documentation with respect to the design and the manufacturing procedures,
- assess the materials used where these are not in conformity with the relevant harmonised standards or with a European approval for pressure equipment materials, and check the certificate issued by the material manufacturer in accordance with point 4.3 of Annex I,
- approve the procedures for the permanent joining of parts or check that they have been previously approved in accordance with point 3.1.2 of Annex I,
- verify the qualifications or approvals required under points 3.1.2 and 3.1.3 of Annex I,
- carry out the final inspection referred to in point 3.2.1 of Annex I, perform or have performed the proof test referred to in point 3.2.2 of Annex I, and examine the safety devices, if applicable.

The notified body shall issue a certificate of conformity in respect of the examinations and tests carried out and shall affix its identification number to the approved pressure equipment, or have it affixed under its responsibility. The manufacturer shall keep the certificates of conformity at the disposal of the national

authorities for 10 years after the pressure equipment has been placed on the market.

5. CE marking and EU declaration of conformity

5.1. The manufacturer shall affix the CE marking and, under the responsibility of the notified body referred to in point 4, the latter's identification number to each item of pressure equipment that satisfies the applicable requirements of this Directive.

5.2. The manufacturer shall draw up a written EU declaration of conformity and keep it at the disposal of the national authorities for 10 years after the pressure equipment has been placed on the market. The EU declaration of conformity shall identify the pressure equipment for which it has been drawn up.

A copy of the EU declaration of conformity shall be made available to the relevant authorities upon request.

6. Authorised representative

The manufacturer's obligations set out in points 2 and 5 may be fulfilled by his authorised representative, on his behalf and under his responsibility, provided that they are specified in the mandate.EN 27.6.2014 Official Journal of the European Union L 189/243

12. MODULE H1: CONFORMITY BASED ON FULL QUALITY ASSURANCE PLUS DESIGN EXAMINATION

1. Conformity based on full quality assurance plus design examination and special surveillance of the final assessment is the conformity assessment procedure whereby the manufacturer fulfils the obligations laid down in points 2 and 6, and ensures and declares on his sole responsibility that the pressure equipment concerned satisfy the requirements of the Directive that apply to it.

2. Manufacturing

The manufacturer shall operate an approved quality system for design, manufacture and final product inspection and testing of the products concerned as specified in point 3 and shall be subject to surveillance as specified in point 5. The adequacy of the technical design of the pressure equipment shall have been examined in accordance with point 4.

3. Quality system

3.1. The manufacturer shall lodge an application for assessment of his quality system with the notified body of his choice, for the pressure equipment concerned.

The application shall include:

- the name and address of the manufacturer and, if the application is lodged by the authorised representative, his name and address as well,EN 27.6.2014 Official Journal of the European Union L 189/247
- the technical documentation for one model of each type of pressure equipment intended to be manufactured. The technical documentation shall, wherever applicable, contain at least the following elements:
- a general description of the pressure equipment,
- conceptual design and manufacturing drawings and diagrams of components, sub-assemblies, circuits, etc.,
- descriptions and explanations necessary for the understanding of those drawings and diagrams and the operation of the pressure equipment,
- a list of the harmonised standards the references of which have been published in the Official Journal of the European Union, applied in full or in part, and descriptions of the solutions adopted to meet the essential safety requirements of this Directive where those harmonised standards have not been applied. In the event of partly applied harmonised standards, the technical documentation shall specify the parts which have been applied,

- results of design calculations made, examinations carried out, etc.,
- test reports,
- the documentation concerning the quality system,
- a written declaration that the same application has not been lodged with any other notified body.

3.2. The quality system shall ensure compliance of the pressure equipment with the requirements of this Directive that apply to it.

All the elements, requirements and provisions adopted by the manufacturer shall be documented in a systematic and orderly manner in the form of written policies, procedures and instructions. This quality system documentation shall permit a consistent interpretation of the quality programmes, plans, manuals and records.

It shall, in particular, contain an adequate description of:

- the quality objectives and the organisational structure, responsibilities and powers of the management with regard to design and product quality,
- the technical design specifications, including standards, that will be applied and, where relevant harmonised standards will not be applied in full, the means that will be used to ensure that the essential safety requirements of the Directive that apply to the pressure equipment will be met,
- the design control and design verification techniques, processes and systematic actions that will be used when designing the pressure equipment pertaining to the pressure equipment type covered, particularly with regard to materials in accordance with point 4 of Annex I,
- the corresponding manufacturing, quality control and quality assurance techniques, processes and systematic actions that will be used, particularly the procedures for the permanent joining of parts as approved in accordance with point 3.1.2 of Annex I,
- the examinations and tests that will be carried out before, during and after manufacture, and the frequency with which they will be carried out,EN L 189/248 Official Journal of the European Union 27.6.2014
- the quality records, such as inspection reports and test data, calibration data, reports concerning the qualifications or approvals of the personnel concerned, particularly those of the personnel undertaking the permanent joining of parts and the non-destructive tests in accordance with points 3.1.2 and 3.1.3 of Annex I, etc.,
- the means of monitoring the achievement of the required design and pressure equipment quality and the effective operation of the quality system.

3.3. The notified body shall assess the quality system to determine whether it satisfies the requirements referred to in point 3.2.

It shall presume conformity with those requirements in respect of the elements of the quality system that comply with the corresponding specifications of the relevant harmonised standard. In addition to experience in quality management systems, the auditing team shall have at least one member experienced as an assessor in the relevant pressure equipment field and pressure equipment technology concerned, and knowledge of the applicable requirements of this Directive. The audit shall include an assessment visit to the manufacturer’s premises.

The auditing team shall review the technical documentation referred to in point 3.1, second indent, to verify the manufacturer’s ability to identify the applicable requirements of this Directive and to carry out the necessary examinations with a view to ensuring compliance of the pressure equipment with those requirements.

The manufacturer or his authorised representative shall be notified of the decision.

The notification shall contain the conclusions of the audit and the reasoned assessment decision.

3.4. The manufacturer shall undertake to fulfil the obligations arising out of the quality system as approved and to maintain it so that it remains adequate and efficient.

3.5. The manufacturer shall keep the notified body that has approved the quality system informed of any intended change to the quality system.

The notified body shall evaluate any proposed changes and decide whether the modified quality system will continue to satisfy the requirements referred to in point 3.2 or whether a re-assessment is necessary.

It shall notify the manufacturer of its decision. The notification shall contain the conclusions of the examination and the reasoned assessment decision.

3.6. Each notified body shall inform its notifying authorities of quality system approvals issued or withdrawn, and shall, periodically or upon request, make available to its notifying authorities the list of quality system approvals refused, suspended or otherwise restricted.

Each notified body shall inform the other notified bodies of quality system approvals which it has refused, suspended or withdrawn, and, upon request, of quality system approvals which it has issued.

4. Design examination

4.1. The manufacturer shall lodge an application for examination of the design of each item of pressure equipment not covered by a previous design examination with the notified body referred to in point 3.1.

4.2. The application shall make it possible to understand the design, manufacture and operation of the pressure equipment, and to assess the conformity with the requirements of this Directive that apply to it. It shall include:

- the name and address of the manufacturer,EN 27.6.2014 Official Journal of the European Union L 189/249
- a written declaration that the same application has not been lodged with any other notified body,
- the technical documentation. The documentation shall make it possible to assess the conformity of the pressure equipment with the relevant requirements, and shall include an adequate analysis and assessment of the risk(s). The technical documentation shall specify the applicable requirements and cover, as far as relevant for the assessment, the design and operation of the pressure equipment. The technical documentation shall, wherever applicable, contain at least the following elements:
- a general description of the pressure equipment,
- conceptual design and manufacturing drawings and diagrams of components, sub-assemblies, circuits, etc.,
- descriptions and explanations necessary for the understanding of those drawings and diagrams and the operation of the pressure equipment,
- a list of the harmonised standards the references of which have been published in the Official Journal of the European Union, applied in full or in part, and descriptions of the solutions adopted to meet the essential safety requirements of this Directive, where those harmonised standards have not been applied. In the event of partly applied harmonised standards, the technical documentation shall specify the parts which have been applied,
- results of design calculations made, examinations carried out, etc., and
- test reports,
- the supporting evidence for the adequacy of the technical design. This supporting evidence shall mention any documents that have been used, in particular where the relevant harmonised standards have not been applied in full, and shall include, where necessary, the results of tests carried out by the appropriate laboratory of the manufacturer or by another testing laboratory on his behalf and under his responsibility.

4.3. The notified body shall examine the application, and where the design meets the requirements of this Directive that apply to the pressure equipment it shall issue an EU design examination certificate to the manufacturer. The certificate shall give the name and address of the manufacturer, the conclusions of the examination, the conditions (if

any) for its validity and the data necessary for identification of the approved design. The certificate may have one or more annexes attached.

The certificate and its annexes shall contain all relevant information to allow the conformity of manufactured products with the examined design to be evaluated, and to allow for in-service control, where applicable.

Where the design does not satisfy the applicable requirements of this Directive, the notified body shall refuse to issue a design examination certificate and shall inform the applicant accordingly, giving detailed reasons for its refusal.

4.4. The notified body shall keep itself apprised of any changes in the generally acknowledged state of the art which indicate that the approved design may no longer comply with the applicable requirements of this Directive, and shall determine whether such changes require further investigation. If so, the notified body shall inform the manufacturer accordingly.

The manufacturer shall keep the notified body that has issued the EU design examination certificate informed of any modification to the approved design that may affect the conformity with the essential safety requirements of this Directive or the conditions for validity of the certificate. Such modifications shall require additional approval - from the notified body that issued the EU design examination certificate - in the form of an addition to the original EU design examination certificate.EN L 189/250 Official Journal of the European Union 27.6.2014

4.5. Each notified body shall inform its notifying authorities of the EU design examination certificates and/or any additions thereto which it has issued or withdrawn, and shall, periodically or upon request, make available to its notifying authorities the list of certificates and/or any additions thereto refused, suspended or otherwise restricted.

Each notified body shall inform the other notified bodies of the EU design examination certificates and/or any additions thereto which it has refused, withdrawn, suspended or otherwise restricted, and, upon request, of the certificates and/or additions thereto which it has issued.

The Commission, the Member States and the other notified bodies may, on request, obtain a copy of the EU design examination certificates and/or additions thereto. On request, the Commission and the Member States may obtain a copy of the technical documentation and of the results of the examinations carried out by the notified body.

The notified body shall keep a copy of the EU design examination certificate, its annexes and additions, as well as the technical file including the documentation submitted by the manufacturer until the expiry of the validity of the certificate.

4.6. The manufacturer shall keep a copy of the EU design examination certificate, its annexes and additions together with the technical documentation at the disposal of the national authorities for 10 years after the pressure equipment has been placed on the market.

5. Surveillance under the responsibility of the notified body

5.1. The purpose of surveillance is to make sure that the manufacturer duly fulfils the obligations arising out of the approved quality system.

5.2. The manufacturer shall, for assessment purposes, allow the notified body access to the design, manufacture, inspection, testing and storage sites, and shall provide it with all necessary information, in particular:

- the quality system documentation,
- the quality records as provided for by the design part of the quality system, such as results of analyses, calculations, tests, etc.,
- the quality records as provided for by the manufacturing part of the quality

system, such as inspection reports and test data, calibration data, qualification reports on the personnel concerned, etc.

5.3. The notified body shall carry out periodic audits to make sure that the manufacturer maintains and applies the quality system and shall provide the manufacturer with an audit report. The frequency of periodic audits shall be such that a full reassessment is carried out every three years.

5.4. In addition, the notified body may pay unexpected visits to the manufacturer.

The need for such additional visits, and the frequency thereof, will be determined on the basis of a visit control system operated by the notified body. In particular, the following factors must be considered in the visit control system:

- the category of the equipment,
- the results of previous surveillance visits,
- the need to follow up corrective action(s),EN 27.6.2014 Official Journal of the European Union L 189/251
- special conditions linked to the approval of the system, where applicable,
- significant changes in manufacturing organisation, policy or techniques.

During such visits, the notified body may, if necessary, carry out product tests, or have them carried out, in order to check the proper functioning of the quality system. It shall provide the manufacturer with a visit report and, if tests have been carried out, with a test report.

5.5. Special surveillance of the final assessment

Final assessment as referred to in section 3.2 of Annex I is subject to increased surveillance in the form of unexpected visits by the notified body. In the course of such visits, the notified body shall conduct examinations on the pressure equipment.

It shall provide the manufacturer with a visit report and, if tests have been carried out, with a test report.

6. CE marking and EU declaration of conformity

6.1. The manufacturer shall affix the CE marking and, under the responsibility of the notified body referred to in point 3.1, the latter’s identification number to each individual item of pressure equipment that satisfies the applicable requirements of this Directive.

6.2. The manufacturer shall draw up a written EU declaration of conformity for each pressure equipment model and keep it at the disposal of the national authorities for 10 years after the pressure equipment has been placed on the market. The EU declaration of conformity shall identify the pressure equipment model for which it has been drawn up and shall mention the number of the design examination certificate.

A copy of the EU declaration of conformity shall be made available to the relevant authorities upon request.

7. The manufacturer shall, for a period ending 10 years after the pressure equipment has been placed on the market, keep at the disposal of the national authorities:

- the documentation concerning the quality system referred to in point 3.1,
- the change referred to in point 3.5, as approved,
- the decisions and reports of the notified body referred to in points 3.5, 5.3 and 5.4.

8. Authorised representative

The manufacturer’s authorised representative may lodge the application referred to in points 4.1 and 4.2 and fulfil the obligations set out in points 3.1, 3.5, 4.4, 4.6, 6

and 7, on his behalf and under his responsibility, provided that they are specified in the mandate.

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