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Design of Horizontal Pressure Vessel in PVELITE Software

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ABSTRACT:

Pressure vessels are integral to numerous industries, facilitating the storage and processing of pressurized liquids, gases, chemicals, and more. This research focuses on the design of a horizontal pressure vessel, emphasizing safety and regulatory compliance to enhance industrial efficiency. The methodology involves identifying the problem statement, determining specifications including dimensions and materials, and utilizing PVELITE Software for design. References to standards such as ASME Sec VIII Div 1, ASME Sec II, IS 875, and IS 1893 are incorporated for material selection, manufacturing methods, and stress calculations considering wind and seismic loads. Proper design is paramount to prevent accidents and extend vessel lifespan, considering factors like corrosion resistance, suitable location, mounting, material choice, and maintenance. Furthermore, incorporating ANSYS structural analysis augments the depth of the study, providing additional insights into structural integrity and performance metrics. Results derived from these analyses are rigorously compared against industry standards to ensure compliance with safety regulations, thereby affirming the robustness and reliability of the designed horizontal pressure vessel.

Keywords: PVELITE, Horizontal Pressure Vessel, ASME Sec VIII Div 1, Design.

1. Introduction

Pressure vessels are very important across various industries, serving as containers for storing pressurized liquids, gases, chemicals, and other substances. There are various types of pressure vessels used in industries like horizontal, vertical, spherical, etc. The design of these vessels is very important, making sure they meet strict safety standards, regulatory requirements, and performance criteria while also being cost-effective. In this context, the focus is on using PVElite Software, a widely used tool in the industry, to simplify and improve the design process of pressure vessels. PVElite Software offers advanced capabilities for analyzing pressure vessel designs, allowing engineers to efficiently go through design iterations and optimize vessel design. Pressure Vessel Types are as follows: Types by Application: Storage Tanks, Process vessels, Heat exchangers; Types by Geometry: Vertical Pressure Vessels, Horizontal Pressure Vessels, Conical Pressure Vessels, Spherical Pressure Vessels; Types by Orientation: Available space, Manufacturing and installation, Seismic and wind, Stre

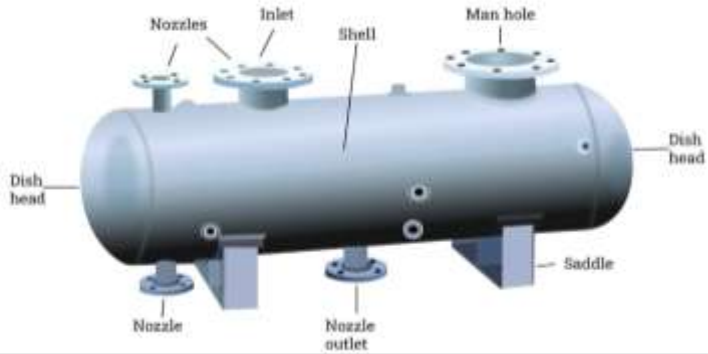


Fig. 1 - Horizontal Pressure Vessel

Nomenclature

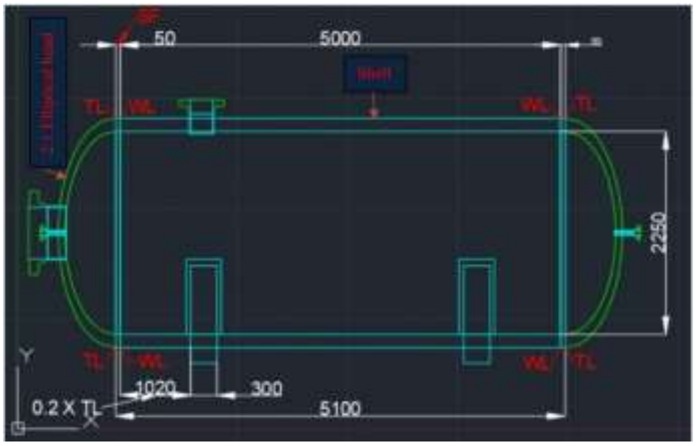


Fig. 2 - Nomenclature

Tan Line- The Tangent Line (TL) is defined as the common theoretical line between the straight.

Weld Line- A weld line (WL) in a vessel is the point where the closures attach to the shell.

Straight Face- Straight Face is straight section height provided in shell section to weld with Dish end.

Dish end- Dish ends are welded to the main body of a pressure vessel to seal pressure vessels and prevent leaks and spills. They can be produced in different shapes by Spinning method, during spinning there are always reduction in thickness of plate therefore always takes 10% minimum margin above required thickness obtained by calculation. There three major type of Dish end:

1. Tori spherical: The most common type of dish end, with a shape resembling a torus(donut).

2. Ellipsoidal: Has a shape resembling an ellipse, and is preferred for applications where the pressure constraint on the component is above 10 bars.

3. Hemispherical: Completely round like a hemisphere, with a maximum radial section that gives it the largest pressure dispersion zone.

Nozzles- Nozzles are crucial openings in pressure vessels for fluid entry or exit. They typically consist of a flange, nozzle neck, and reinforcing element if needed. Common types include inlet, outlet, instrumentation, and manway nozzles. Inlet and outlet nozzles accommodate fluid flow, while instrumentation nozzles are for installing instruments like gauges and sensors. Manways allow access for inspection and maintenance. Standard flanges, such as ASME B16.5, are commonly used for connection, ensuring precise assembly and construction.

Saddle Support- Saddle supports are U-shaped structures that support horizontal pressure vessels from below, providing excellent stability and weight distribution. They are made up of two half-round supports that extend along the length of the vessel, welded or bolted to the bottom, and rest on a pedestal or structural member.

1.1. ASME

ASME, organized in 1880 as an educational and technical society for mechanical engineers, took up the task. After years of development and public feedback, the first edition of the ASME Boiler and Pressure Vessel Code was published in 1914 and formally adopted in 1915. Subsequently, in 1925, the first Code rules for pressure vessels, titled "Rules for the Construction of Unfired Pressure Vessels," were introduced. Over time, the Code evolved into its present twelve-section document, with numerous subdivisions, parts, and subsections.

Sections	Description
I	Rules for Construction of Power Boilers (ASME-Part 1)
II	Materials (ASME-Part 2)
	Part A — Ferrous Material Specifications
	Part B — Nonferrous Material Specifications
	Part C — Specifications for Welding Rods, Electrodes, and Filler Metals
	Part D — Properties (Customary)
	Part D — Properties (Metric)
III	Rules for (Construction of Nuclear Facility Components ASME-Part 3)

	Subsection NCA — General Requirements for Division 1 and Division 2
	Division 1
	Subsection NB — Class 1 Components
	Subsection NC — Class 2 Components
	Subsection ND — Class 3 Components
	Subsection NE — Class MC Components
	Subsection NF — Component Supports
	Subsection NG — Core Support Structures
	Subsection NH — Class 1 (Components in Elevated Temperature Service)
	Appendices
	Division 2 — Code for Concrete Containments
	Division 3 — Containments for Transportation and Storage of Spent Nuclear Fuel and High-Level Radioactive Material and Waste
IV	Rules for Construction of Heating Boilers (ASME-Part 4)
V	Non-destructive Examinations (ASME-Part 5)
VI	Recommended Rules for the Care and Operation of Heating Boilers (ASME-Part 6)
VII	Recommended Guidelines for the Care of Power Boilers (ASME-Part 7)
VIII	Rules for Construction of Pressure Vessels (ASME-Part 8)
	Division 1: Rules for Construction of Pressure Vessels
	Division 2: Alternative Rules
	Division 3: Alternative Rules for Construction of High-Pressure Vessels
IX	Welding and Brazing Qualifications (ASME-Part 9)
X	Fiber-Reinforced Plastic Pressure Vessels (ASME-Part 10)
XI	Rules for In-service Inspection of Nuclear Power Plant Components (ASME-Part 11)
XII	Rules for Construction and Continued Service of Transport Tanks (ASME-Part 12)

2. Literature Review

2.1. ASME SEC VIII Div 1

ASME Section VIII Division 1 establishes the requirements for the design, fabrication, inspection, testing, and certification of pressure vessels. This division is divided as per below diagram given.

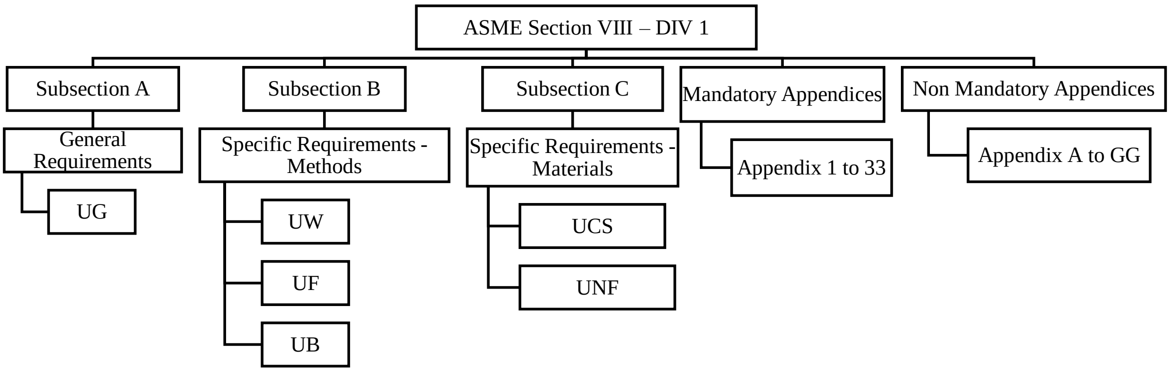


Fig. 3 - ASME Section VIII – DIV 1 Bifurcation.

2.2. UG - 27 Thickness of Shells Under Internal Pressure

It covers the formulae for calculating thickness of shells under internal pressure which is as below:

For Circumferential Stress (Longitudinal Joints) as shown in Fig (a)

$$t = \frac{PR}{SE-0.6P}+CA$$

All dimensions in code are in corroded condition

Symbols:

t = min. required thickness

P = internal design pressure

R = inside radius of shell

S = max. allowable stress value (Sec II D)

E = joint efficiency (UW-12)

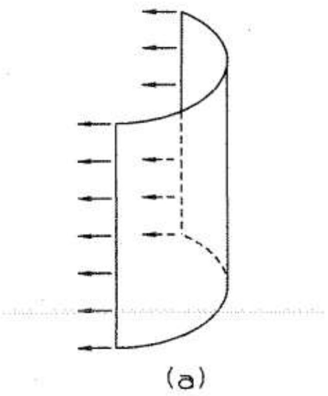


Fig. 4 – Circumferential Stress

2.3. UG – 32 Formed Heads, and Sections Pressure on Concave Side

The minimum thickness required for certain types of heads, like ellipsoidal heads, under pressure on the concave side, should be calculated using specific formulas as below:

$$t = \frac{PD}{2SE - 0.2P}$$

- $t/L \geq 0.002$
- Inside Depth = ¼ Inside diameter

t = minimum required thickness of head (forming)

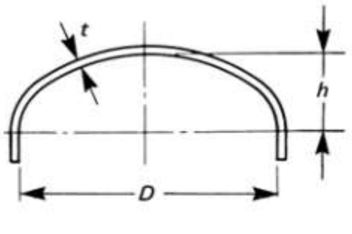
P = internal design pressure

D = inside diameter of the head skirt, or inside length of the major axis pf an ellipsoidal head

S = max. allowable stress value in tension (Sec II D)

E = lowest efficiency of joint in the head (any)

- 2:1 ellipsoidal Head- Approximation: Knuckle Radius = 0.17D , Spherical Radius = 0.90D



(a) Ellipsoidal

Fig.5 – Ellipsoidal Head.

2.4. UG - 99(c) Standard Hydrostatic Test

Hydrostatic tests are conducted on vessels after fabrication, excluding certain operations like weld end preparation. Completed vessels must pass this test, except those exempts under UG-100 and UG-101.Vessels designed for internal pressure must undergo a hydrostatic test with a pressure at least 1.3 times the maximum allowable working pressure, adjusted by the lowest stress ratio for vessel materials. The test considers all possible loadings and adjusts for static head conditions. A calculated pressure hydrostatic test may be agreed upon between the user and manufacturer. The test pressure is determined by multiplying the basis for calculated test pressure by 1.3 and adjusting for hydrostatic head. Inspectors reserve the right to review the calculations used for determining the test pressure.

2.5. UW - 3 Welded Joint Category

The term "Category" denotes the location of a joint in a vessel, not its type. Categories A, B, C, and D define special requirements for certain welded pressure joints based on service, material, and thickness. These requirements apply only to specified joints within each category. Category A includes longitudinal and spiral welded joints within the main shell, among others. Category B covers circumferential welded joints within the main shell and nozzles. Category C pertains to joints connecting flanges, tube sheets, or flat heads. Category D encompasses joints connecting communicating chambers or nozzles to various vessel components.

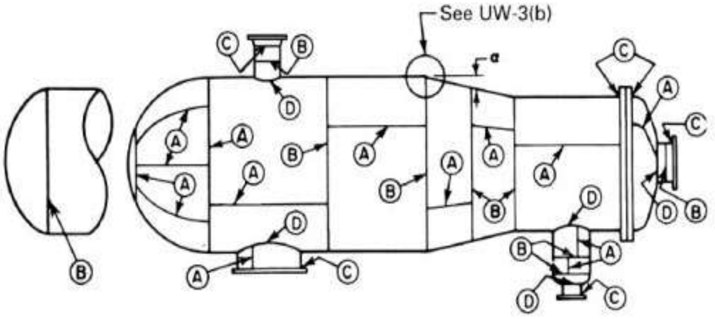


Fig. 6 Weld Joint Category.

3. Methodology

3.1. Problem Definition

Design the pressure vessels as per stated parameters with PVELITE software and calculate the thickness for shell & Heads & also calculate the weights (empty & test). Wind and Seismic loads as per IS875(Wind), IS 1893 SCM (Seismic) applicable for foundation design.

3.2. Pressure Vessel Specification

The pressure vessel chosen for this study is a horizontal pressure vessel used to contain liquid having density 800kg/m^3. This pressure vessel has 2:1 ellipsoidal heads and is designed to be used in fixed location on saddles. The pressure vessel will have an inner shell diameter 2250 mm and a shell length 5100mm. The pressure vessel is made of carbon steel SA-516 Gr70, which is the industry standard for pressure vessel design and creation.

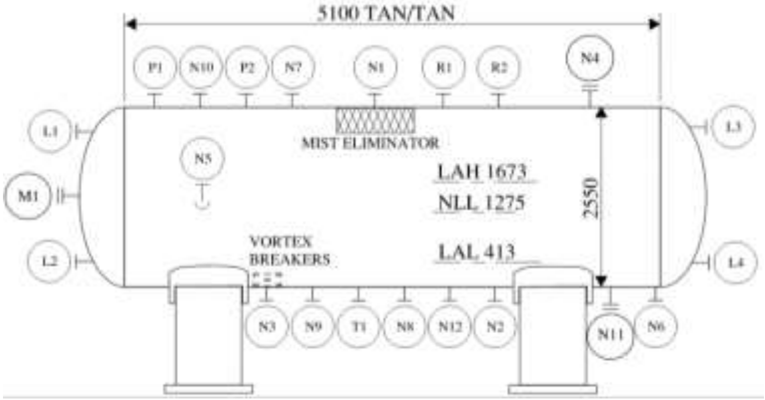


Fig. 7 - Vessel Sketch.

Parameters	Values
Design Internal Pressure	25 barg
Design external Pressure	FV (Full Vacuum) 1 Bar
Design Temp (Max./Min./external)	225 ºC / -10 ºC / 65 ºC
Corrosion allowance	3 mm for pressure part
Joint Efficiency	1 (RT-1)
Insulation	150 mm thickness, Mineral Wool, density 120Kg/m3
Wind Load	150 Km/hr

Fig. 8 – Design Specifications.

Part	Materials
Shell	SA-516 Gr.70N
Heads	SA-516 Gr.70N
Nozzle pipe	SA-106 Gr. B / SA-516 Gr. 70N
Pipe Flanges	SA-105
Reinforcement pad	SA-516 Gr.70N
Saddle support	SA-516 Gr.70 / SA-36
Fasteners	SA-193 Gr. B7 / SA-194 Gr. 2H
Gasket	Spiral wound gasket

Fig. 9 -Material Specifications.

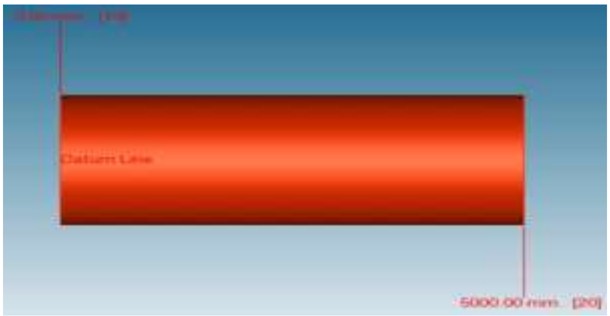
3.3. Shell Design

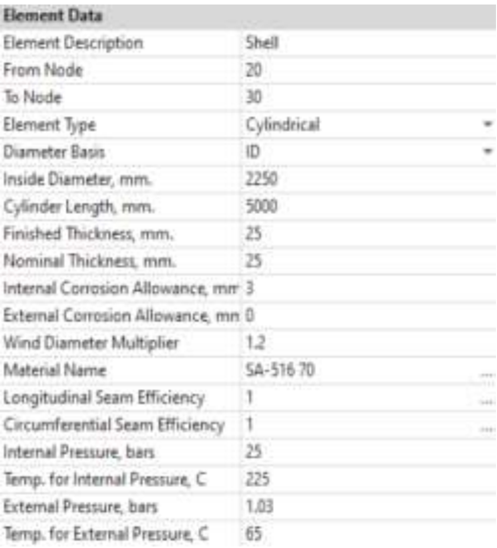
When designing the pressure vessel shell, we consider two main factors: the pressure it will handle and the 3mm corrosion allowance specified by ASME standards. This helps determine the thickness of the shell. Thickness Calculation of Shell:

$$t = \frac{PR}{SE-0.6P} + CA$$

$$t = \frac{0.2549*1125}{14.0689*1-0.6*0.2549} + 3$$

t = 23.24 mm





Element Data	
Element Description	Shell
From Node	20
To Node	30
Element Type	Cylindrical
Diameter Basis	ID
Inside Diameter, mm.	2250
Cylinder Length, mm.	5000
Finished Thickness, mm.	25
Nominal Thickness, mm.	25
Internal Corrosion Allowance, mm	3
External Corrosion Allowance, mm	0
Wind Diameter Multiplier	1.2
Material Name	SA-516 70
Longitudinal Seam Efficiency	1
Circumferential Seam Efficiency	1
Internal Pressure, bars	25
Temp. for Internal Pressure, C	225
External Pressure, bars	1.03
Temp. for External Pressure, C	65

Fig. 10 - (a) Shell ; (b) Shell Input in PVELITE.

3.4. Dish end Design

Thickness Calculation of Dishend:

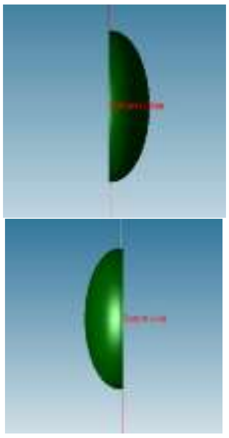
2:1 Ellipsoidal Head

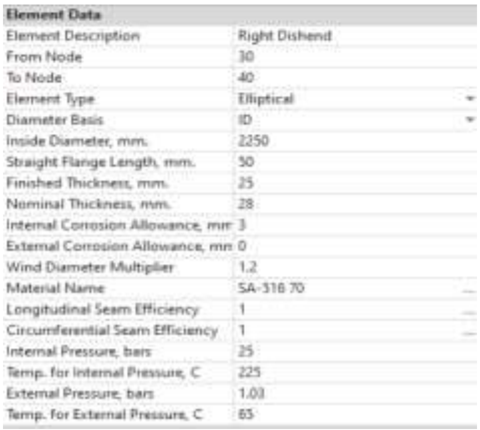
Inside Depth = ¼ Inside diameter

$$t = \frac{PR}{SE-0.2P} + 3$$

$$t = \frac{0.2549*1125}{14.0689*1-0.2*0.2549} + 3$$

t = 23.4569 mm





Element Data	
Element Description	Right Dishend
From Node	30
To Node	40
Element Type	Elliptical
Diameter Basis	ID
Inside Diameter, mm.	2250
Straight Flange Length, mm.	50
Finished Thickness, mm.	25
Nominal Thickness, mm.	28
Internal Corrosion Allowance, mm	3
External Corrosion Allowance, mm	0
Wind Diameter Multiplier	1.2
Material Name	SA-516 70
Longitudinal Seam Efficiency	1
Circumferential Seam Efficiency	1
Internal Pressure, bars	25
Temp. for Internal Pressure, C	225
External Pressure, bars	1.03
Temp. for External Pressure, C	65

Fig. 11 - (a) Head; (b) Head Input in PVELITE.

3.5. Nozzle Design

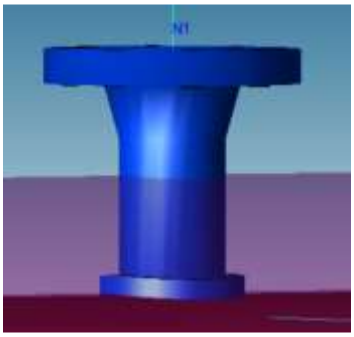


Fig. 12 - Nozzle.

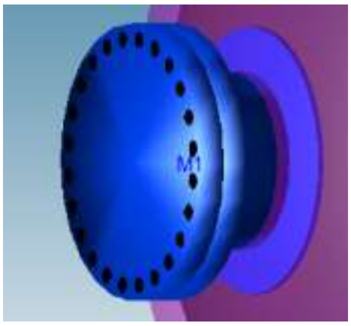
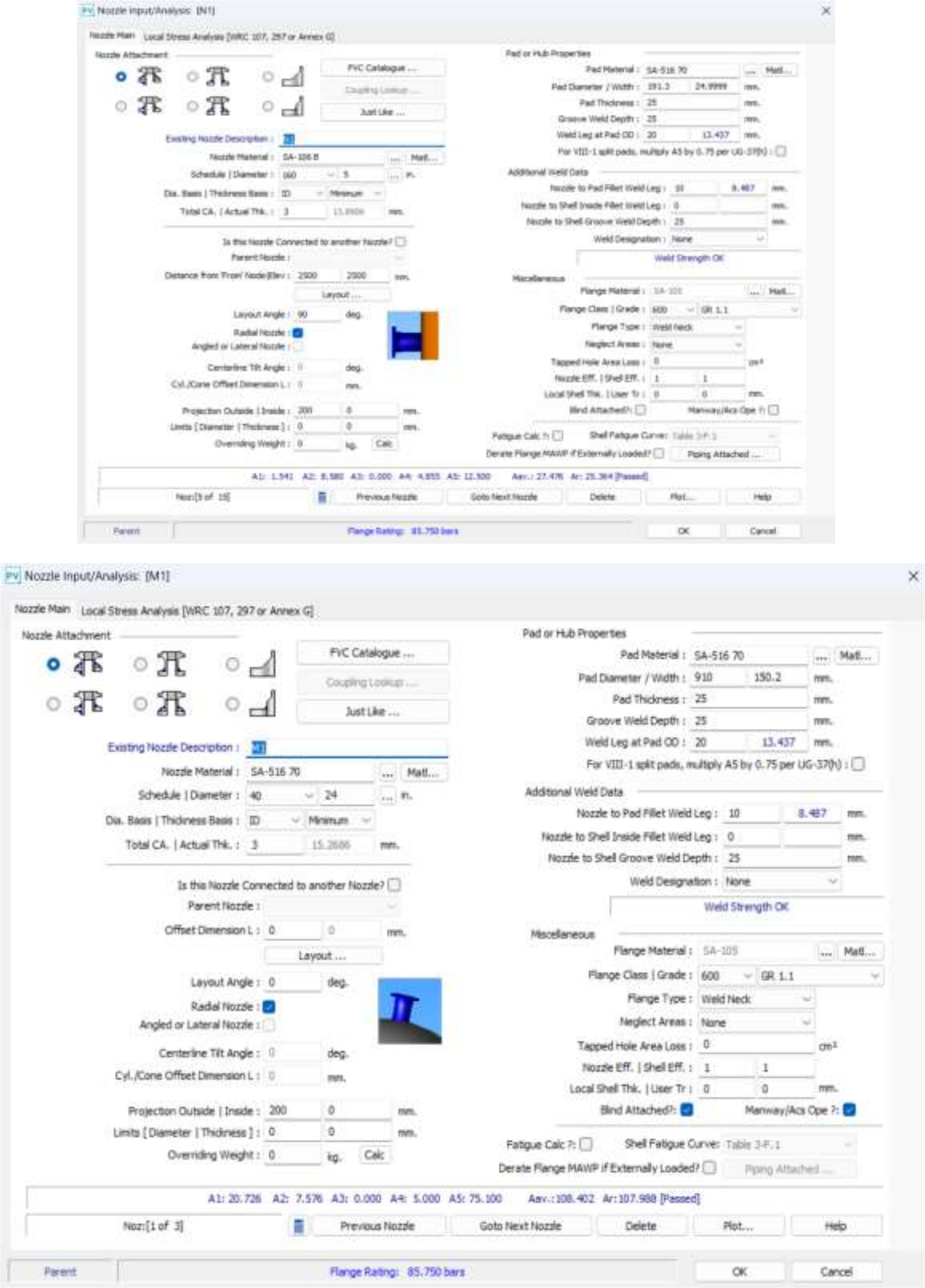


Fig. 13- Manhole

S.N.	Nozzle Mark	Nominal Diameter (DN)	Service	Flange Rating	Flange Type
1	N1	DN150	Steam outlet	600#	WNRF
2	N2	DN80	Boiler feed water	600#	WNRF
3	N3	DN250	Downcomer	600#	WNRF
4	N4	DN80	Spare	600#	WNRF
5	N5	DN250	Riser	600#	WNRF
6	N6	DN80	Boiler feed water	600#	WNRF
7	N7	DN100	Vent	600#	WNRF
8	N8	DN80	Continuous blowdown	600#	WNRF
9	N9	DN50	Intermittent blowdown	600#	LWNRF
10	N10	DN50	Steam injection	600#	LWNRF
11	N11	DN50	Spare	600#	LWNRF
12	N12	DN80	Drain	600#	WNRF
13	L1-L4	DN50	Level control	600#	LWNRF
14	P1-P2	DN50	Pressure	600#	LWNRF
15	T1	DN50	Temperature	600#	LWNRF
16	M1	DN600	Manhole	600#	WNRF

Fig. 14– Nozzle Table.



Nozzle Input/Analysis: [N1]

Existing Nozzle Description : N1
Nozzle Material : SA-106 B
Schedule | Diameter : 160 | 5 in.
Dia. Basis | Thickness Basis : ID | Minimum
Total CA. | Actual Thk. : 3 | [illegible] mm.
Is this Nozzle Connected to another Nozzle? ☐
Parent Nozzle :
Distance from 'From' Node/Elev : 2500 | 2500 mm.
Layout Angle : 90 deg.
Radial Nozzle : ☑
Angled or Lateral Nozzle : ☐
Centerline Tilt Angle : 0 deg.
Cyl./Cone Offset Dimension L : 0 mm.
Projection Outside | Inside : 200 | 0 mm.
Limits [Diameter | Thickness] : 0 | 0 mm.
Overriding Weight : 0 kg.

Pad or Hub Properties
Pad Material : SA-516 70
Pad Diameter / Width : 191.3 | 24.9999 mm.
Pad Thickness : 25 mm.
Groove Weld Depth : 25 mm.
Weld Leg at Pad OD : 20 | 13.437 mm.
For VIII-1 split pads, multiply A5 by 0.75 per UG-37(h) : ☐

Additional Weld Data
Nozzle to Pad Fillet Weld Leg : 10 | 8.487 mm.
Nozzle to Shell Inside Fillet Weld Leg : 0 mm.
Nozzle to Shell Groove Weld Depth : 25 mm.
Weld Designation : None
Weld Strength OK

Miscellaneous
Flange Material : SA-105
Flange Class | Grade : 600 | GR 1.1
Flange Type : Weld Neck
Neglect Areas : None
Tapped Hole Area Loss : 0 cm²
Nozzle Eff. | Shell Eff. : 1 | 1
Local Shell Thk. | User Tr : 0 | 0 mm.
Blind Attached?: ☐ Manway/Acs Ope ?: ☐
Fatigue Calc ?: ☐ Shell Fatigue Curve: Table 3-F.1
Derate Flange MAWP if Externally Loaded? ☐

A1: 1.541 A2: 8.580 A3: 0.000 A4: 4.855 A5: 12.500 Aav.: 27.476 Ar: 25.364 [Passed]
Noz:[5 of 15]
Flange Rating: 85.750 bars

Nozzle Input/Analysis: [M1]

Existing Nozzle Description : M1
Nozzle Material : SA-516 70
Schedule | Diameter : 40 | 24 in.
Dia. Basis | Thickness Basis : ID | Minimum
Total CA. | Actual Thk. : 3 | 15.2686 mm.
Is this Nozzle Connected to another Nozzle? ☐
Parent Nozzle :
Offset Dimension L : 0 | 0 mm.
Layout Angle : 0 deg.
Radial Nozzle : ☑
Angled or Lateral Nozzle : ☐
Centerline Tilt Angle : 0 deg.
Cyl./Cone Offset Dimension L : 0 mm.
Projection Outside | Inside : 200 | 0 mm.
Limits [Diameter | Thickness] : 0 | 0 mm.
Overriding Weight : 0 kg.

Pad or Hub Properties
Pad Material : SA-516 70
Pad Diameter / Width : 910 | 150.2 mm.
Pad Thickness : 25 mm.
Groove Weld Depth : 25 mm.
Weld Leg at Pad OD : 20 | 13.437 mm.
For VIII-1 split pads, multiply A5 by 0.75 per UG-37(h) : ☐

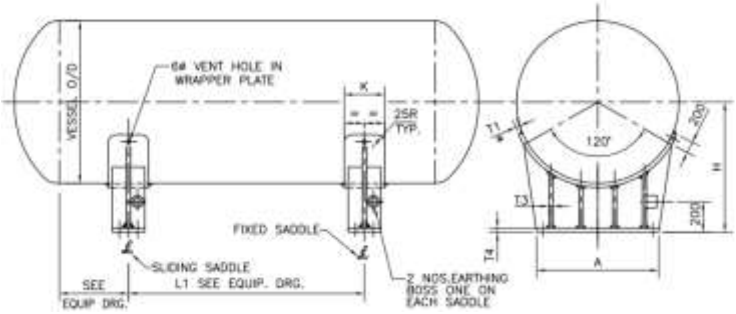
Additional Weld Data
Nozzle to Pad Fillet Weld Leg : 10 | 8.487 mm.
Nozzle to Shell Inside Fillet Weld Leg : 0 mm.
Nozzle to Shell Groove Weld Depth : 25 mm.
Weld Designation : None
Weld Strength OK

Miscellaneous
Flange Material : SA-105
Flange Class | Grade : 600 | GR 1.1
Flange Type : Weld Neck
Neglect Areas : None
Tapped Hole Area Loss : 0 cm²
Nozzle Eff. | Shell Eff. : 1 | 1
Local Shell Thk. | User Tr : 0 | 0 mm.
Blind Attached?: ☑ Manway/Acs Ope ?: ☑
Fatigue Calc ?: ☐ Shell Fatigue Curve: Table 3-F.1
Derate Flange MAWP if Externally Loaded? ☐

A1: 20.726 A2: 7.576 A3: 0.000 A4: 5.000 A5: 75.100 Aav.:108.402 Ar:107.988 [Passed]
Noz:[1 of 3]
Flange Rating: 85.750 bars

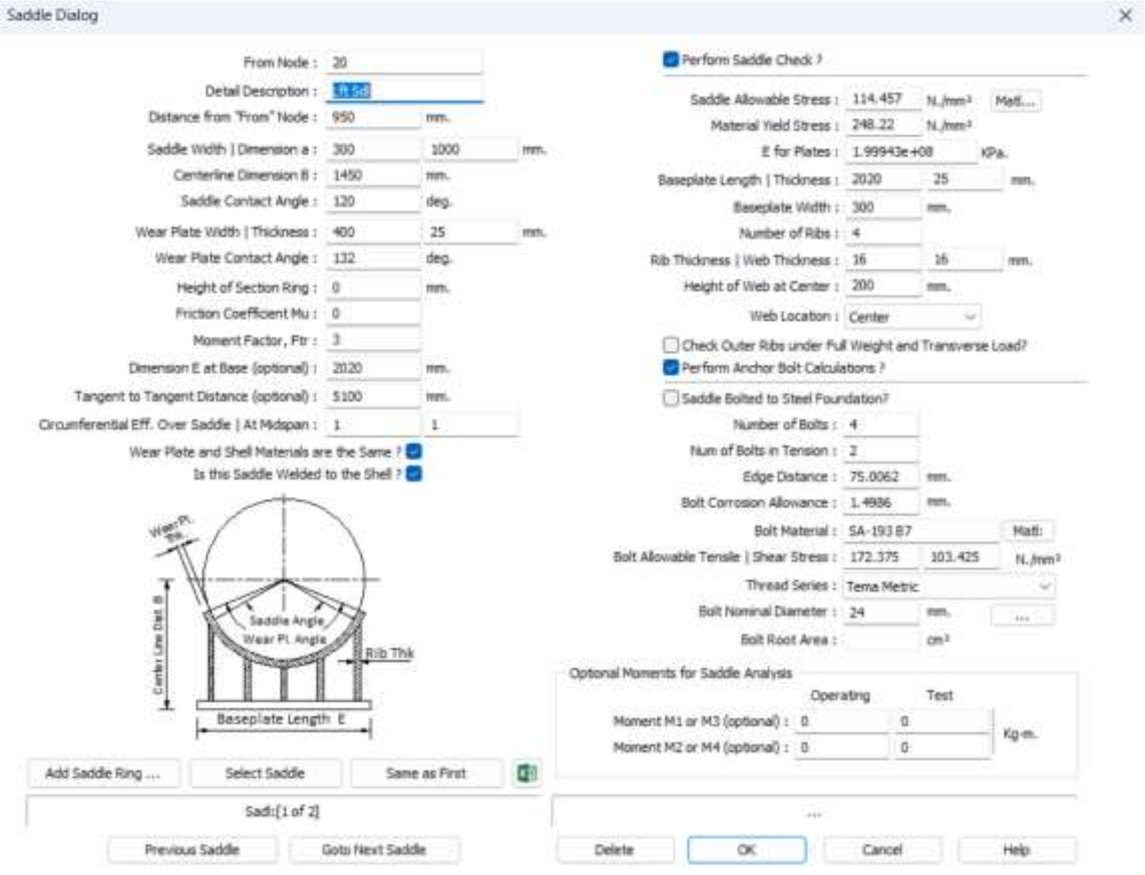
Fig. 15 - (a) Nozzle Input in PVELITE; (b) Manhole Input in PVELITE.

3.6. Supports(Saddles) Designs



Vessel OD	≤2300 mm
A	2020 mm
B	880 mm
C	940 mm
T1	16 mm
T2	16 mm
T3	16 mm
T4	20 mm
K	400 mm
H (Max) Saddle Height	1450 mm
Weight Per Saddle	445 kg
Max. Load Per Saddle	24000 kg

Fig. 16 - (a) Saddle Sketch; (b) Saddle Specifications.



From Node : 20
Detail Description : Rt Sd
Distance from "From" Node : 950 mm.
Saddle Width | Dimension a : 300 1000 mm.
Centerline Dimension B : 1450 mm.
Saddle Contact Angle : 120 deg.
Wear Plate Width | Thickness : 400 25 mm.
Wear Plate Contact Angle : 132 deg.
Height of Section Ring : 0 mm.
Friction Coefficient Mu : 0
Moment Factor, Ftr : 3
Dimension E at Base (optional) : 2020 mm.
Tangent to Tangent Distance (optional) : 5100 mm.
Circumferential Eff. Over Saddle | At Midspan : 1 1
Wear Plate and Shell Materials are the Same ? ☑
Is this Saddle Welded to the Shell ? ☑

☑ Perform Saddle Check ?
Saddle Allowable Stress : 114.457 N./mm²
Material Yield Stress : 248.22 N./mm²
E for Plates : 1.99943e+08 KPa.
Baseplate Length | Thickness : 2020 25 mm.
Baseplate Width : 300 mm.
Number of Ribs : 4
Rib Thickness | Web Thickness : 16 16 mm.
Height of Web at Center : 200 mm.
Web Location : Center
☐ Check Outer Ribs under Full Weight and Transverse Load?
☑ Perform Anchor Bolt Calculations ?
☐ Saddle Bolted to Steel Foundation?
Number of Bolts : 4
Num of Bolts in Tension : 2
Edge Distance : 75.0062 mm.
Bolt Corrosion Allowance : 1.4986 mm.
Bolt Material : SA-193 B7
Bolt Allowable Tensile | Shear Stress : 172.375 103.425 N./mm²
Thread Series : Tema Metric
Bolt Nominal Diameter : 24 mm.
Bolt Root Area : cm²

Optional Moments for Saddle Analysis

	Operating	Test	
Moment M1 or M3 (optional) :	0	0	Kg-m.
Moment M2 or M4 (optional) :	0	0	

Fig. 17 – Saddle Input in PVELITE.

3.7. Software Output

Internal Pressure Calculation Results

ASME Code, Section VIII Division 1, 2017

Elliptical Head From 10 To 20 SA-516 70 , UCS-66 Crv. D at 225 °C

Left Dishend

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

= (PDKcor)/(2SE-0.2P) Appendix 1-4(c)

= (25.1772256.00.996)/(2137.91.0-0.225.177)

= 20.5601 + 3.0000 = 23.5601 mm.

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

Less Operating Hydrostatic Head Pressure of 0.177 bars

= (2SEt)/(KcorD+0.2t) per Appendix 1-4 (c)

= (2137.91.022.0)/(0.9962256.0+0.222.0)

= 26.936 - 0.177 = 26.760 bars

Cylindrical Shell **From 20 To 30 SA-516 70 , UCS-66 Crv. D at 225 °C**

Shell

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

= (PR)/(SE-0.6P) per UG-27 (c)(1)

= (25.1771128.0)/(137.91.0-0.625.177)

= 20.8234 + 3.0000 = 23.8234 mm.

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

Less Operating Hydrostatic Head Pressure of 0.177 bars

= (SEt)/(R+0.6t) per UG-27 (c)(1)

= (137.91.022.0)/(1128.0+0.622.0)

= 26.583 - 0.177 = 26.406 bars

Elliptical Head From 30 To 40 SA-516 70 , UCS-66 Crv. D at 225 °C

Right Dishend

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

= (PDKcor)/(2SE-0.2P) Appendix 1-4(c)

= (25.1772256.00.996)/(2137.91.0-0.225.177)

= 20.5601 + 3.0000 = 23.5601 mm.

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

Less Operating Hydrostatic Head Pressure of 0.177 bars

= (2SEt)/(KcorD+0.2t) per Appendix 1-4 (c)

= (2137.91.022.0)/(0.9962256.0+0.222.0)

= 26.936 - 0.177 = 26.760 bars

Hydrostatic Test Pressure Results:

Pressure per UG99b = 1.30 M.A.W.P. Sa/S 32.561 bars

Pressure per UG99b[36] = 1.30 Design Pres Sa/S 32.500 bars

Pressure per UG99c = 1.30 M.A.P. - Head(Hyd) 39.091 bars

Pressure per UG100 = 1.10 M.A.W.P. Sa/S 27.551 bars

Pressure per PED = max(1.43DP, 1.25DPratio) 35.750 bars

Pressure per App 27-4 = M.A.W.P. 25.047 bars

UG-99(b), Test Pressure Calculation:

= Test Factor MAWP Stress Ratio

= 1.3 25.047 1.0

= 32.561 bars

External Pressure Calculation Results :

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Elliptical Head From 10 to 20 Ext. Chart: CS-2 at 65 °C

Left Dishend

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

= (PDKcor)/(2SE-0.2P) Appendix 1-4(c)

= (1.722256.00.996)/(2137.91.0-0.21.72)

= 1.4023 + 3.0000 = 4.4023 mm.

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

= ((2SEt)/(KcorD+0.2t))/1.67 per Appendix 1-4 (c)

= ((2137.91.022.0)/(0.9962256.0+0.222.0))/1.67

= 16.130 bars

Maximum Allowable External Pressure [MAEP]:

= min(MAEP, MAWP)

= min(9.94, 16.1296)

= 9.942 bars

Elliptical Head From 30 to 40 Ext. Chart: CS-2 at 65 °C

Right Dishend

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

= (PDKcor)/(2SE-0.2P) Appendix 1-4(c)

= (1.722256.00.996)/(2137.91.0-0.21.72)

= 1.4023 + 3.0000 = 4.4023 mm.

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

= ((2SEt)/(KcorD+0.2t))/1.67 per Appendix 1-4 (c)

= ((2137.91.022.0)/(0.9962256.0+0.222.0))/1.67

= 16.130 bars

Maximum Allowable External Pressure [MAEP]:

= min(MAEP, MAWP)

= min(9.94, 16.1296)

= 9.942 bars

Weight Summary:

```
Fabricated Wt.  - Bare Weight without Removable Internals            13127.4 kg.

Shop Test Wt.   - Fabricated Weight + Water ( Full )                 36377.4 kg.

Shipping Wt.    - Fab. Weight + removable Intls.+ Shipping App.      14105.2 kg.

Erected  Wt.    - Fab. Wt + or - loose items (trays,platforms etc    14105.2 kg.

Ope. Wt. no Liq - Fab. Weight + Internals. + Details + Weights       14105.2 kg.

Operating Wt.   - Empty Weight + Operating Liq. Uncorroded           32705.2 kg.

Oper. Wt. + CA  - Corr Wt. + Operating Liquid                        31520.5 kg.

Field Test Wt.  - Empty Weight + Water (Full)                        37355.3 kg.
```

Wind Load Calculation:

```
    |    |    Wind  |     Wind |     Wind |     Wind  |   Element |

 From| To |   Height  |  Diameter |     Area |  Pressure  |  Wind Load |

    |    |      mm. |      mm. |      cm² |    Kgs/m² |       Kgf |

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

   10|  20|     1450 |     3120 |    16620 |   118.219 |   139.092 |

   20|  30|     1450 |     3120 |   156000 |   118.219 |   1305.56 |

   30|  40|     1450 |     3120 |    16620 |   118.219 |   139.092 |

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

Seismic Analysis Results per IS-1893 (1984), Seismic Coefficient Method.

Earthquake Load Calculation:

```
    |    | Earthquake | Earthquake |   Element |

 From| To |    Height |    Weight | Ope  Load |

    |    |      mm. |      Kgf |      Kgf |

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

   10|  20|     1125 |    6304.1 |   94.5614 |

   20|Sadl|     1125 |    6304.1 |   94.5614 |

 Sadl|  30|     1125 |    6304.1 |   94.5614 |

   20|  30|     1125 |    6304.1 |   94.5614 |

   30|  40|     1125 |    6304.1 |   94.5614 |

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

Nozzle Calculation Summary:

```
 Description       |      MAWP |   Ext |      MAPNC | UG-45    [tr] |    Weld |   Areas or

                   |      bars |       |       bars |       |  mm. |    Path |  Stresses

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

```
M1        |   25.05 |   OK |      ... |  ... |     |   OK  |    Passed
L1        |   26.76 |  ... |      ... |   OK |  7.80 |   OK  | No Calc[]
L1        |   26.76 |  ... |      ... |   OK |  7.80 |   OK  | No Calc[]
L2        |   26.76 |  ... |      ... |   OK |  7.80 |   OK  | No Calc[]
L2        |   26.76 |  ... |      ... |   OK |  7.80 |   OK  | No Calc[]
P1        |   26.41 |  ... |      ... |   OK |  7.80 |   OK  | No Calc[]
N2        |   26.09 |   OK |      ... |   OK |  7.80 |   OK  |    Passed
N4        |   26.27 |   OK |      ... |   OK |  7.80 |   OK  |    Passed
N6        |   26.41 |   OK |      ... |   OK |  7.80 |   OK  |    Passed
N1        |   26.03 |   OK |      ... |   OK |  8.73 |   OK  |    Passed
N3        |   25.24 |   OK |      ... |   OK | 11.10 |   OK  |    Passed
N7        |   25.84 |   OK |      ... |   OK |  8.26 |   OK  |    Passed
P2        |   26.41 |  ... |      ... |   OK |  7.80 |   OK  | No Calc[]
N5        |   25.12 |   OK |      ... |   OK | 11.10 |   OK  |    Passed
N8        |   26.22 |   OK |      ... |   OK |  7.80 |   OK  |    Passed
N9        |   26.41 |  ... |      ... |   OK |  7.52 |   OK  | No Calc[]
N10       |   26.41 |  ... |      ... |   OK |  7.52 |   OK  | No Calc[]
N12       |   26.41 |   OK |      ... |   OK |  7.80 |   OK  |    Passed
T1        |   26.41 |  ... |      ... |   OK |  7.52 |   OK  | No Calc[]
N11       |   26.41 |  ... |      ... |   OK |  6.42 |   OK  | No Calc[]
L3        |   26.76 |  ... |      ... |   OK |  7.80 |   OK  | No Calc[]
L3        |   26.76 |  ... |      ... |   OK |  7.80 |   OK  | No Calc[]
L4        |   26.76 |  ... |      ... |   OK |  7.80 |   OK  | No Calc[]
```

Nozzle Schedule:

```
          Nominal or |  Schd | Flg | Nozzle |   Wall | Reinforcing Pad |   Cut |  Flg
             Actual | or FVC | Type |  O/Dia |    Thk | Diameter   Thk | Length | Class
 Description    Size |  Type |      |    in |    mm. |     mm.    mm. |    mm. |
 ------------------------------------------------------------------------------------------
L1      | 2.000 in | Actual |  LWN|  3.202 | 15.269 |    ... |   ... | 240.46 |  600
L2      | 2.000 in | Actual |  LWN|  3.202 | 15.269 |    ... |   ... | 240.46 |  600
P1      | 2.000 in | Actual |  LWN|  3.310 | 16.640 |    ... |   ... | 225.79 |  600
P2      | 2.000 in | Actual |  LWN|  3.310 | 16.640 |    ... |   ... | 225.79 |  600
N9      | 2.000 in | Actual |  LWN|  2.602 |  7.645 |  90.00 | 26.00 | 225.49 |  600
N10     | 2.000 in | Actual |  LWN|  2.602 |  7.645 |  90.00 | 26.00 | 225.49 |  600
T1      | 2.000 in | Actual |  LWN|  2.766 |  9.735 |    ... |   ... | 225.55 |  600
N11     | 2.000 in |    160 |  LWN|  2.375 |  8.738 |  70.00 | 26.00 | 225.40 |  600
L3      | 2.000 in | Actual |  LWN|  3.202 | 15.269 |    ... |   ... | 240.46 |  600
L4      | 2.000 in | Actual |  LWN|  3.202 | 15.269 |    ... |   ... | 240.46 |  600
N2      | 3.000 in |    160 |  WNF|  3.500 | 11.125 | 120.00 | 25.00 | 225.88 |  600
```

```
N4    | 3.000 in |  160 |  WNF|  3.500 |  11.125 |  120.00 | 25.00 | 225.88 |  600
N6    | 3.000 in |  160 |  WNF|  3.500 |  11.125 |  128.90 | 25.00 | 225.88 |  600
N8    | 3.000 in |  160 |  WNF|  3.500 |  11.125 |  118.90 | 26.00 | 225.88 |  600
N12   | 3.000 in |  160 |  WNF|  3.500 |  11.125 |  190.00 | 26.00 | 225.88 |  600
N7    | 4.000 in |  120 |  WNF|  4.500 |  11.125 |  164.30 | 25.00 | 226.45 |  600
N1    | 5.000 in |  160 |  WNF|  5.563 |  15.875 |  191.30 | 25.00 | 227.22 |  600
N3    | 10.000 in |  80 |  WNF| 10.750 |  15.088 |  433.05 | 25.00 | 233.31 |  600
N5    | 10.000 in |  80 |  WNF| 10.750 |  15.088 |  423.05 | 26.00 | 233.31 |  600
M1    | 24.000 in |  40 |  WNF| 24.000 |  17.450 |  910.00 | 25.00 | 247.84 |  600
```

Saddle Parameters:

Saddle Width	300.000 mm.
Saddle Bearing Angle	120.000 deg.
Centerline Dimension	1450.000 mm.
Wear Pad Width	400.000 mm.
Wear Pad Thickness	25.000 mm.
Wear Pad Bearing Angle	132.000 deg.
Distance from Saddle to Tangent	1000.000 mm.
Baseplate Length	2020.000 mm.
Baseplate Thickness	25.000 mm.
Baseplate Width	300.000 mm.
Number of Ribs (including outside ribs)	4
Rib Thickness	16.000 mm.
Web Thickness	16.000 mm.
Height of Center Web	200.000 mm.
Number of Bolts in Baseplate	4

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	20433.23 Kgf
Maximum Transverse Saddle Shear Load	261.32 Kgf
Maximum Longitudinal Saddle Shear Load	194.50 Kgf

Weights:

Fabricated - Bare W/O Removable Internals	13127.4 kg.
Shop Test - Fabricated + Water (Full)	36377.4 kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	14105.2 kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	14105.2 kg.
Empty - Fab. + Intls. + Details + Wghts.	14105.2 kg.
Operating - Empty + Operating Liquid (No CA)	32705.2 kg.
Field Test - Empty Weight + Water (Full)	37355.3 kg.

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Diameter Spec : 2250.000 mm. ID

Vessel Design Length, Tangent to Tangent	5100.00 mm.
Specified Datum Line Distance	50.00 mm.
Internal Design Temperature	225 °C
Internal Design Pressure	25.000 bars
External Design Temperature	65 °C
External Design Pressure	1.030 bars
Maximum Allowable Working Pressure	25.047 bars
External Max. Allowable Working Pressure	6.390 bars
Hydrostatic Test Pressure	32.561 bars
Required Minimum Design Metal Temperature	-10.0 °C
Warmest Computed Minimum Design Metal Temperature	-29.0 °C
Wind Design Code	IS-875
Earthquake Design Code	IS-1893 SCM

Materials of Construction:

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

Normalized is determined based on the UCS-66 material curve selection and Figure UCS-66.

Impact Tested is based on material selection and material data properties.

3.8. Structural Analysis in Ansys

ANSYS Static Structural is a software widely used for analyzing pressure vessels. It helps to evaluate the stresses and deformations caused by both the internal pressure and the weight of the vessel and the fluid it contains. SolidWorks software complements this by allowing engineers to create detailed three-dimensional models of the pressure vessels. The mathematical model employed in this analysis encompasses various aspects such as defining boundary conditions, formulating equations to calculate total deformation and equivalent stress, and utilizing numerical analysis methods for accurate simulations. In summary, ANSYS Static Structural and SolidWorks together provide a comprehensive solution for designing and analyzing pressure vessels, ensuring their safety and performance, as shown in the figure below

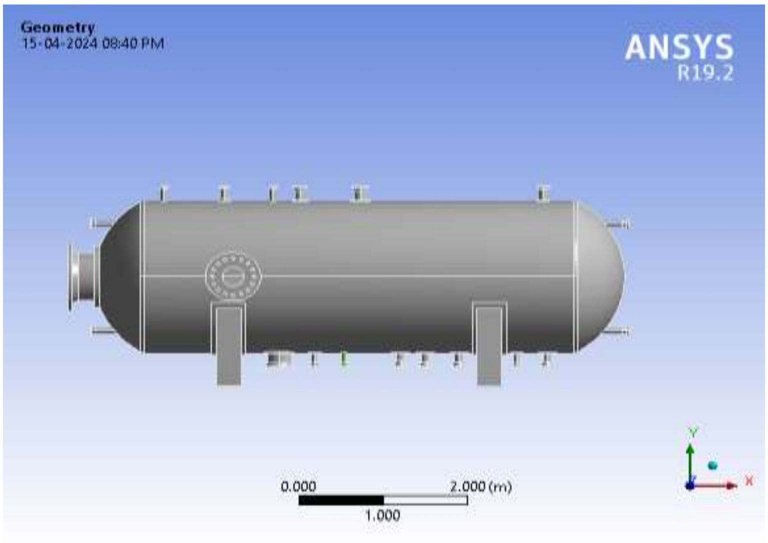


Fig. 18 - Ansys.

In this study, we employed a mesh consisting of 243,204 nodes and 129,585 elements. We selected this mesh due to its excellent overall quality, ensuring accurate results. Our analysis revealed that the cell aspect ratio was consistently low, with the vast majority of elements (99.8%) having an aspect ratio not exceeding 0.27. This indicates that the mesh effectively captures the geometry and details of the pressure vessel without distortion. Additionally, all three mesh quality criteria were met, further confirming the suitability of the chosen mesh for our analysis. Therefore, we confidently adopted this mesh for our study, ensuring reliable and precise simulation results. We set a boundary condition where the pressure inside the vessel is constant, caused by the fluid it contains. We fixed this pressure at 2.5 MPa, which represents the total pressure inside the vessel is subjected to as shown in the figure below

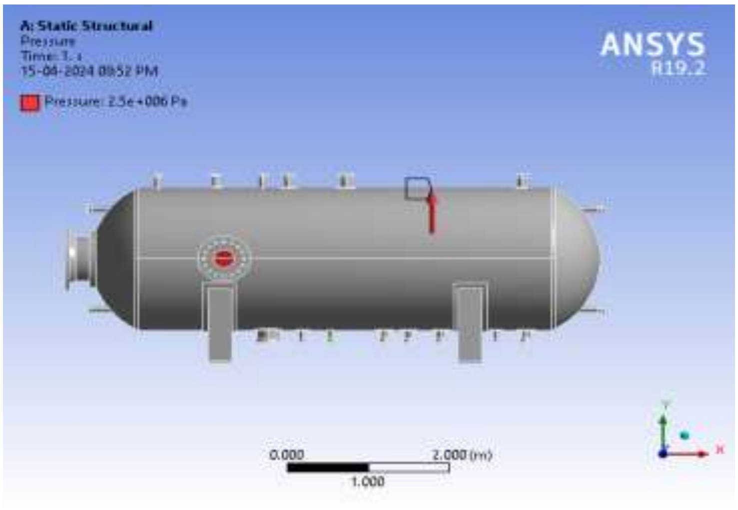

A: Static Structural
Pressure
Time: 1. s
15-04-2024 08:52 PM
🟥 Pressure: 2.5e+006 Pa

Fig. 19 – Total Pressure.

The highest equivalent elastic stress experienced by the pressure vessel is 42.18% as shown in the figure is lower than the maximum tensile strength of the material, which is 481.6 MPa. The total deformation experienced by the pressure vessel is 2.617mm

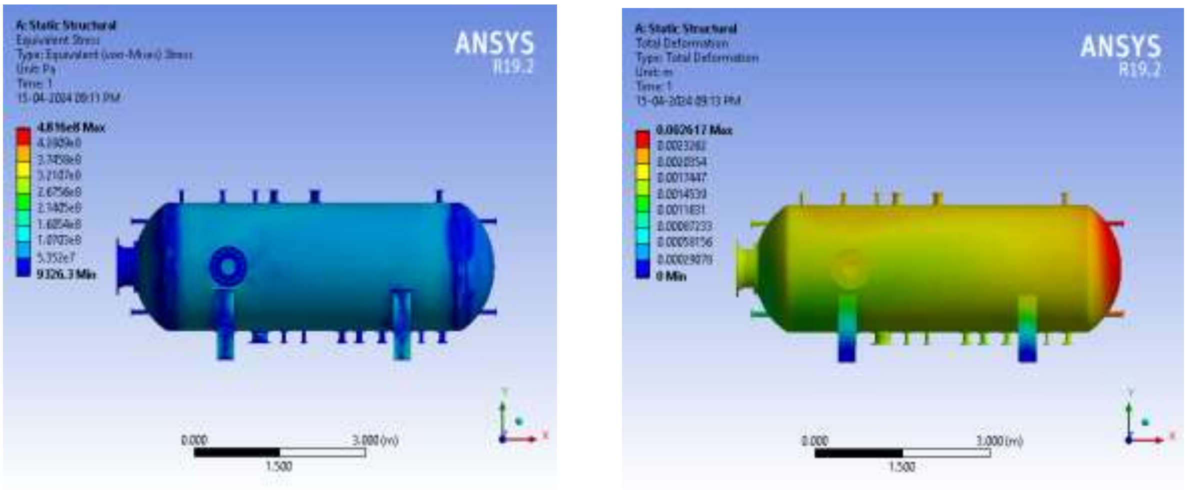


Fig. 20 - (a) Equivalent Stress; (b) Total Deformation.

The maximum principle stress experienced by the pressure vessel is 54.45% as shown in the figure is lower than the maximum tensile strength of the material, which is 527.27MPa.

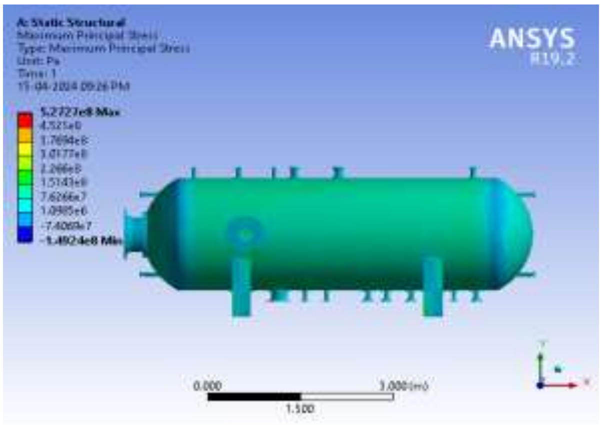


Fig. 21 – Maximum Principal Stress.

4. Result

The experimentation calculations yielded the following results:

Parameters	Values (Kg)
Erected Weight	14100
Operating Weight	32700
Field Test Weight	37400

	Shear Forces (lbf)
Wind	306.65
Seismic	208.47

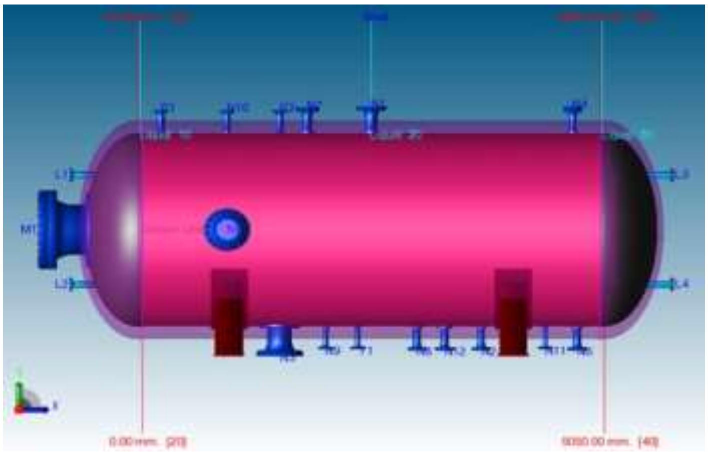
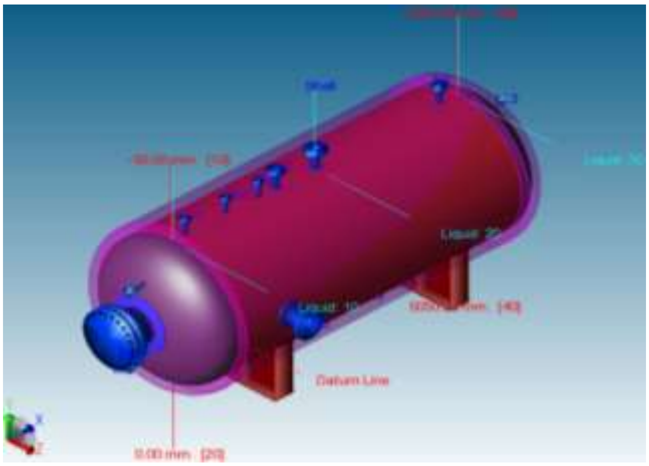


Fig. 22 - (a) Weights, Wind & Seismic Load;

(b) Horizontal Pressure Vessel In PVELITE.



Parameters	Shell	Dishend
Nominal thickness	25 mm	28 mm
Actual Stress at given Design temperature	130.606 N/mm2	128.891 N/mm2
Max. Allowable Pressure	30.239 bars	30.575 bars
Max. Allowable Working Pressure	26.406 bars	26.760 bars

Fig. 23 - (a) Horizontal Pressure Vessel In PVELITE; (b) Shell & Dishend Summary

Nozzle Mark	Nozzle Schedule	Wall Thickness
N1	600	15.875 mm
N2	160	11.125 mm
N3	80	15.088 mm
N4	160	11.125 mm
N5	80	15.088 mm
N6	160	11.125 mm
N7	120	11.125 mm
N8	160	11.125 mm
N9	NONE	7.645 mm
N10	NONE	7.645 mm
N11	160	8.738 mm
N12	160	11.125 mm
L1 to L4	NONE	15.269 mm
P1 & P2	NONE	16.640 mm
T1	NONE	9.735 mm
M1	40	17.450 mm

Fig. 24 – Nozzle Summary.

5. Conclusion

During this study, we designed a horizontal pressure vessel using PVELITE software as per the ASME Sec VIII Div I and calculated thickness of shell and head and weights. Also calculated wind and seismic loads. Then, we used ANSYS Static Structural to model, mesh, and simulate the vessel to test its strength and study how stress and deformation are distributed across it. Hence, from result obtained from PVELITE, it's evident that the design of Horizontal Pressure Vessel ensures that stresses, pressures, and loads are within safe limits which is crucial for maintaining the safety of the vessel. Nozzle loads were within allowable limits, ensuring the integrity of the vessel connections and attached components. In Ansys, our study employed a high-quality mesh with 243,204 nodes and 129,585 elements, ensuring accurate results. The mesh effectively captured the pressure vessel's geometry, with low cell aspect ratios indicating minimal distortion. All mesh quality criteria were met, confirming the suitability of the chosen mesh. A constant pressure boundary condition of 2.5 MPa was applied to represent internal pressure. Results showed that the highest equivalent elastic stress and maximum principle stress were both below the material's maximum tensile strength, ensuring structural integrity. The total deformation experienced by the vessel was 2.617mm, confirming its ability to withstand pressure within safe limits.

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