Designing and Analysis of Pressure Vessel for Industry using PV Elite

K. Vijaya Lakshmi
PG Student,
Mechanical Department
G. Pulla Reddy Engineering College
Kurnool, India

Y. V. Mohan Reddy
Professor and Head,
Mechanical Department
G. Pulla Reddy Engineering College
Kurnool, India

***Abstract*—A study on designing the pressure vessel and quality check, to avoid the damage due to various conditions of nature was made. For any pressure vessel design, primary consideration is its safety. The main purpose is to design a pressure vessel according to company requirements and analyzing the pressure vessel using PV Elite with reference to the ASME Sec.VIII Division1 Codes and standard. In here, pressure vessel is a horizontal pressure vessel. Auto CAD is used for drafting the scaled construction drawing of pressure vessel. As the mathematical calculation of pressure vessel becomes tedious, graphical based software PV Elite was used for analysis on shell, head, nozzle and saddle supports. During the manufacturing, the Pressure vessel has to pass a series of Hydrostatic tests. This paper also discusses the fabrication and quality testing of pressure vessel. In Fabrication of pressure vessel, welding and fabrication assembly are discussed and in quality testing, non- destructive testing methods were used to examine the quality.**

Keywords—Pressure vessel, ASME Sec VIII Div 1, Auto CAD, PV Elite, Quality Testing.

I. INTRODUCTION

The pressure vessels are a closed vessel used for storing fluids at higher pressures different from the ambient pressure. According to ASME Section VIII, Div1, "Pressure Vessel is a container for either internal or external pressures in the vessel. The internal or external pressures obtained in the vessel are through by an external source or because of applying heat through a direct or indirect source or by any combinational means". For a successful manufacturing of pressure vessel to the industrial sector requires thorough knowledge of ASME codes and an approval technology along with justify engineering expertise. Pressure vessels that are been designed for storage and transportation of gases and liquids under high-pressure and high-temperature conditions may have an inherent chance of safety risks. Because of their wide range of utilization for the most demanding and critical storing and carrying applications, they are to be designed and fabricated strictly by following the safety rules and regulations. The vessel design and fabrication according to ASME section VIII, Div. 1 for the pressure vessel engineered to operate safely and efficiently at design pressure while meeting all of the unique requirements.

II. METHODOLOGY

A. SELECTION OF CODES

For pressure vessel designing, the code selection is very important for achieving safe pressure vessel condition under a reference guide. Pressure vessels are usually designed according to the ASME sec VIII codes. Division 1 is about the pressure vessel rules for construction; Division2 is about the alternative rules for pressure vessel.

B. MATERIAL SPECIFICATIONS

Based on the design requirements the appropriate materials are selected. The materials used for the manufacturing of this pressure vessel have to satisfy the requirements of the specified design codes and its details are:

Table 1: Part Material

Shell	SA516 Gr60
Dished End	SA516 Gr60
Nozzle	SA106 Gr B

The chemical and mechanical composition requirement of shell and dished end heads is as per table 2 and 3.

Table 2 Chemical Composition ASME SA516 Gr60

Composition	%	Composition	%
C	0.18	Cu	0.3
Si	0.4	Ni	0.3
Mn	0.95/ 1.50	Mo	0.08
P	0.015	Al	0.02
S	0.008	Ti	0.03
V	0.02		

Table3 Mechanical Values of ASME SA516 Gr 60

Properties	Value
Tensile Strength N/mm^2	415 - 580
Yield Stress / min N/mm^2	265

The chemical and mechanical composition requirement of Nozzle is as per table 4 and 5.

Table 4 Chemical Composition of SA 106 Gr B

Composition	%	Composition	%
Carbon	0.35	Chrome	0.30
Manganese	0.60 – 1.05	Copper	0.40
Phosphorus	0.035	Molybdenum	0.12
Sulphur	0.040	Nickel	0.40
Silicon	0.10 – 0.35	Vanadium	0.08

Table 5 Mechanical Values of SA 106 Gr B

Properties	Value
Tensile Strength N/mm^2	415
Yield Stress / min N/ mm^2	240

III. DESIGN ANALYSIS OF PRESSURE VESSEL USING PV ELITE

A. Design of Pressure Vessel

A pressure vessel horizontally placed on saddle supports was designed according to the design data input. SRAAC industry was planning to design a pressure vessel, as in need of a pressure vessel for storing chemical. As chemical storing pressure vessels are potentially hazardous equipment so designing and analysis should be done according to an approved code.

The design of pressure vessel is based on the ASME SEC VIII DIV.1 standards. The details are listed in the following table 6. The following dimensions were selected for designing purpose.

Design Code	ASME SEC VIII DIV.1
Capacity	50m³
Design Pressure	12.5 kg/cm²g
Design Temperature	60◦C
Working Pressure	10 Kg/cm²g
Working Temperature	43◦C
Corrosion Allowance	3mm
Joint Efficiency	1.0
Operating Weight	57794kgs
Total Empty Weight	17350kgs
Weight Full Of Water	66050kgs
Density	875 kg/cm³
Wind Velocity	140.4 Km/hr (IS:875, Part – 3)
Radiography	100 %
Hydro Test Pressure	16.25 Kg/cm²g

Table.6 Design Data

The designing of a pressure vessel based on ASME code standards according to the company requirement. The Auto CAD view of pressure vessel is shown in fig 1.

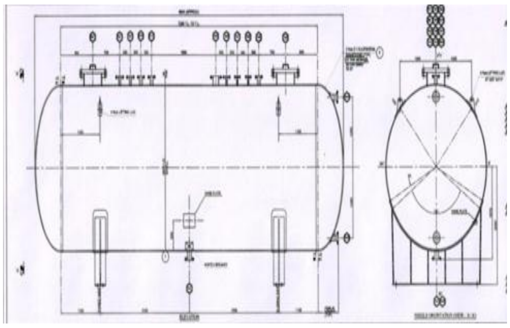


Fig.1 Design of Pressure Vessel in CAD

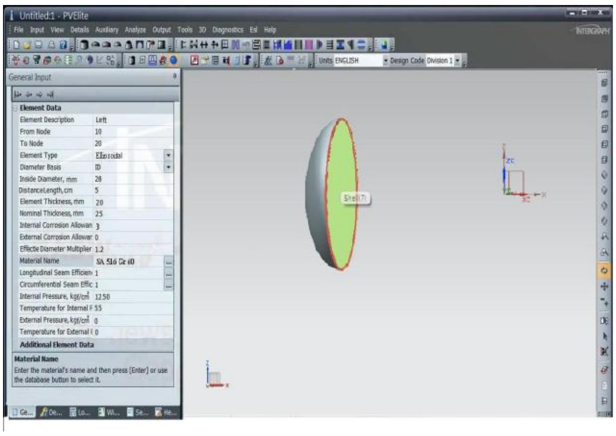
B. Analysis of Pressure Vessel in PV Elite

The SRAAC Company is using PV Elite software to analyze the design of the pressure vessel. PV Elite is complete software for pressure vessel design and analysis according to ASME codes and standards. This software considers the complete vessel for analysis along with the vessel dead weights, bending due to wind and seismic load. In general, for designing a pressure vessel in this software, the code and standard used are ASME Sec.VIII Div.1 and 2 and ASME ANSI B16.5. The design of pressure vessel is shown in fig 2. The analysis results are shown below.

The pressure vessel details consist of pressure vessel configuration from left to right view shown in fig 7. Pressure vessel body is described through the details of its Ellipsoidal head and cylindrical shell body.

Table.7 Pressure Vessel Details

Element Type	Ellipsoidal	Cylindrical	Ellipsoidal
Description	Left	Middle	Right
Element Node From	10	20	30
Element Node To	20	30	40
Distance From - To	5 cm	710 cm	5 cm
Inside Diameter	2800 mm	2800 mm	2800 mm
Element Thickness	20 mm	18 mm	20 mm
Internal Corrosion Allow.	3 mm	3 mm	3 mm
Nominal Thickness	25 mm	18 mm	25 mm
External Corrosion Allow.	0 mm	0 mm	0 mm
Design Internal Pressure	12.50 kgf/cm^2	12.50 kgf/cm^2	12.50 kgf/cm^2
Design Temp. Internal Press.	55 c	55 c	55 c
Design External Pressure	0 kgf/cm^2	0.0kgf/cm^2	0kgf/cm^2
External Press. Design Temp.	0 °C	0 °C	0 °C
Effective Dia. Multiplier	1.2	1.2	1.2
Material Name (Normalized)	SA516 GR 60	SA516 GR 60	SA516 GR 60
Allowable Stress, Ambient Allowable Stress, Operating Allowable Stress, Hydrotest Material Density P Number Thickness Yield Stress, Operating Designation Of Chart Ucs-66 Curve Chart Name Of External Pressure Number Us Shape Of Product	1202.2 kgf/cm^2 1202.2 kgf/cm^2 2024.8 kgf/cm^2 0.00775 kgf/cm^2 30.988 mm 2143.0 kgf/cm^2 D CS2 k 02100 plates		
Longitudinal Seam Efficiency	1	1	1
Circumferential Seam Efficiency	1	1	1
Factor For Ellipsoidal Head	2.0		2.0



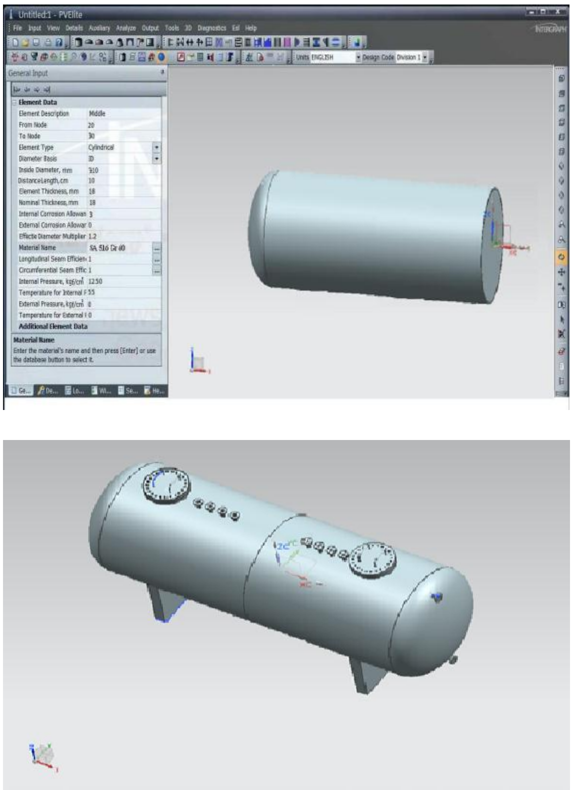


Fig.2 Pressure vessel in PV Elite

1. *Internal Pressure Calculation*

According to ASME Section VIII, Division 1 2010 EDITION, 2011a ADDENDA

❖Ellipsoidal head from 10 to 20 SA516 Gr 60, UCS66 CurveD at 55°C

Thickness of internal Pressures (tr) = (P* D* K) /(2* SE-0.2P) appendix1-4 (c) = (12.50*2806.00*0.997)/ (2*1202.20*1.00-0.2*12.50) = 17.5615 mm

For given thickness, max. Allowable working pressures, corrode (MAWP) = (2* S* E* t) / (K* D + 0.2t) per appendix1-4 (c) = (2*1202.20*1*20)/ (1*2800+0.2*20) =17.150kgf/cm^2

Max. Allowable pressures at New and Cold (MAPNC) = (2* S* E* t) / (K* D + 0.2t) per appendix1-4 (c)
= (2*1202.2*1*20) / (1*2800+ 0.2*20) = 17.15 kgf/cm^2

For given pressure and thickness, actual stresses corroded (Sact) = (P* (K* D + 0.2t)) / (2* E* t)
= (12.5*(0.997*2806+0.2*17))/ (2* 1*17) = 1029.936 kgf/cm^2

Required thickness of straight flanges = (P * R) / (S* E -0.6P) + C Per UG-27 (c)(1) = (12.5*1403)/ (1202.2*1-0.6*12.5) +3.0 = 17.679 mm

❖Cylindrical shell from 20 to 30 SA516 Gr 60, UCS66 CurveD at 55°C

Thickness of internal pressure (tr)
= (P * D) / (S * E- 0.6P) Per UG27 (c)(1) = (12.5*1403)/ (1202.25*1-0.6*12.5) = 17.6788 mm

For given thickness, max. Allowable working pressure, corrode (MAWP) = (S *E * t) / (R + 0.6t) per UG 27 (c) (1) = (1202.25*1*15) / (1403+0.6*15) = 12.772 kgf/cm^2

Max. Allowable pressure at New and Cold (MAPNC) = (S * E * t) / (R + 0.6t) per UG27c (1) = (1202.25* 1*18) / (1400 + 0.6*18) = 15.339 kgf/cm^2

For given thickness and pressure, actual stress, corroded (Sact) = (P* (R + 0.6t)) / (E * t) =(12.5*(1403+0.6*15)) / (1*15) = 1176.667 kgf/cm^2

❖Ellipsoidal Head from 30 to 40 SA516 Gr 60, UCS66 Curve D at 55°C

Thickness of internal pressure (tr) = (P* D* K) / (2 * S* E - 0.2P) appendix1-4(c) = (12.5*2806*0.997) / (2*1202.25*1-0.2*12.5) = 17.5609 mm

For given thickness, Max. Allowable working pressure, corrode (MAWP) = (2*S*E*t) / (K*D+0.2t) per appendix1-4(c)=(2*1202.25*1*17)/(0.997*2806+0.2*17)=14.591kgf/cm^2

Max. Allowable pressure for New and Cold (MAPNC) = (2* S* E* t) / (K* D+ 0.2t) Per appendix1-4(c)
= (2*1202.2*1*20)/ (1*2800+0.2 *20) = 17.150 kgf/cm^2

For given thickness, actual stress, corrode (Sact) = (P* (K * D + 0.2t)) / (2 * E * t) = (12.5*(0.997*2806+ 0.2*17))/ (2* 1 *17) = 1029.936 kgf/cm^2

Required thickness of straight flanges = (P * R) / (S* E -0.6P) + C Per UG 27 (c)(1) =(12.5*1403) / (1202.2*1-0.6*12.5) +3.0 = 17.679 mm

2. *External Pressure Calculation*

❖ Ellipsoidal head from 10 to 20 Ext. Chart CS2 at 0°C

Module of elasticity in chart CS2 at 0°C = 0.204E+07 kgf/cm^2

Max. Allowable external pressure Results (MAEP)

Tca	OD	D / t	FACTOR A	B
17.00	2840.00	167.06	0.0008314	809.83

➢ EMAP = B/ (KO*(D/t)) = 809.8262/ (0.90*167.0588)
= 5.3862 kgf/cm^2

❖ Cylindrical shell from 20 to 30 Ext. Chart CS2 at 0°C

Module of Elasticity in chart CS2 at 0°C = 0.204E+07 kgf/cm^2

Max. Allowable external pressure Results (MAEP)

Tca	OD	SLEN	D /t	L / D	FACTOR A	B
15.0	2836	7766.67	189.07	2.738	0.0001801	183.58

➢ EMAP = (4*B) / (3*(D/t)) = (4*183.5779)/ (3*189.0667) = 1.2946 kgf/cm^2

Max. Stiffened length Results (Slen)

Tca	OD	SLEN	D / t	L / D	FACTOR A	B
15.00	2836.00	7766.67	189.07	2.7386	0.0001801	183.58

➢ EMAP = (4*B)/ (3*(D/t)) = (4*183.5779)/ (3*189.0667)
= 1.2946 kgf/cm^2

❖ Ellipsoidal head from 10 to 20 Ext. Chart CS2 at 0°C

Module of Elasticity in chart CS2 at 0°C = 0.204E+07 kgf/cm^2

Max. Allowable external pressure Results (MAEP)

Tca	OD	D / t	FACTOR A	B
17.00	2840	167.06	0.0008314	809.83

➢ EMAP = B / (Ko*(D / t)) = 809.8262/ (0.90 *167.0588)
= 5.3862 kgf/cm^2

4. *Center Of Gravity Calculations*

SHOP/ FIELD Installation Options

Saddles Center of Gravity = 362.500 cm
Nozzle Center of Gravity = 372.946 cm
Bare Shell New and Cold CG = 365.000 cm
Bare Shell Corroded CG = 365.000 cm
CG of Vessel in the Operating Condition = 365.713 cm
CG of Vessel in the Fabricated Condition = 365.621 cm

5. *Saddle Reaction Results Due To Wind or Seismic*

Force at saddle reaction due to wind Ft (Fwt) = Ftr * ((Ft / Num of saddles) + Z Force Load) * (B/E) = 3*(556 / 2+0) *(1700.0001/2470) = 574.0 kgf

Force at saddle reaction due to wind Fl or friction (Fw1) =Max (F1, Friction Load, Sum of X Forces)* (B/Ls) = Max (195.15, 0, 0) *(1700.0001 /4000.0002) =82.9kgf

Force at saddle reaction due to earthquake Fl or friction (Fs1) = Max (F1, Friction Force, Sum of X Forces) *(B/Ls) =Max (0.17, 0, 0) *(1700.0001/4000.0002) = 0.1 kgf

Force at saddle reaction due to earthquake Ft (Fst) = Ftr * (Ft + Z Force Load) *(B/E) = 3.00*(0+0) *1700.0001/2470.00 = 0.0 kgf

Results of load combination for Q of wind or seismic (Q) = Saddle Loads + Max (Fw1, Fwt, Fs1, Fst) = 6757+ Max (82, 573, 0, 0) = 7331.1 kgf

6. *Formulas and Substitutions for Horizontal Vessel Analysis*

Longitudinal Stress at Top of Shell (Sigma 1) = P * Rm/ (2t) – M2/ (pi * Rm²t) = 12.50 * 1410.500/ (2 * 15.000) – 11715.7/ (pi * 1410.5² * 15.000) = 575.21kgf/cm²

Longitudinal Stress at Bottom of Shell (Sigma 2) = P * Rm/ (2t) + M2/ (pi * Rm²t) = 12.50 * 1410.5/ (2 * 15.0) + 11715.7/ (pi * 1410.5² * 15.0) = 600.20kgf/cm²

Longitudinal Stress at Top of Shell at Support (Sigma 3) = P * Rm/ (2t) – M1/ (pi * Rm²t) = 12.50 * 1410.500/ (2 * 15.000) – 562.9/ (pi * 1410.5² * 15.000) = 587.11kgf/cm²

Longitudinal Stress at Bottom of Shell at Support (Sigma 4) = P * Rm/ (2t) + M1/ (pi * Rm²t) = 12.50 * 1410.500/ (2 * 15.000) + 562.9/ (pi * 1410.5² * 15.000) = 588.31kgf/cm²

Maximum Shear Force in the Saddle (T) = Q (L – 2a) / (L + (4 * h2 / 3)) = 7331 (730.00 – 2 * 11.00) / (730.00 + (4 * 70.30 / 3)) = 6301.1 kgf

Shear Stress in the Head, Shell Stiffened (tau3*) = K3 * Q / (Rm * th) = 0.8799 * 7331 / (1410.49999 * 17.0000) = 26.90 kgf/cm²

Decay length (X1, X2) = 0.78 * sqrt (Rm * t) = 0.78 * sqrt (1410.500 * 15.000) = 113.456 mm

Circumferential Stress at Wear plate (Sigma6,r) = -K5 *Q *K/ (B1(t +eta*tr)) = -0.7603 * 7331 * 0.1/ (220 (15 + 1 * 18)) =-7.68 kgf/cm²

Circumferential Compression Stress at Horn of Saddle = -Q/(4*(t+eta*tr) b1) - 12*K7*Q*Rm/ (L(t +eta* tr)²) = -7331/ (4(15+1.0*18)220) -2*0.013*7331*1410.5/ (730(15+1*18)²) = - 45.87 kgf/cm²

Free saddles thermal expansion, un- restrained (Exp) =Alpha* Ls* (Design Temp –ambient Temp) = 0.118E^-04 * 4000*(60 -21.1) =1.842 mm

7. *Nozzle Calculation*

ASME Sec.VIII Div.1 Codes: 2010, 2011a, UG37 to UG45
Reinforcement Computing, Description: Nozzle
Actual inside diameter for calculations = 42.850 mm
Actual thickness for calculation = 8.732 mm

Cylindrical shell required thickness, Tr (internal pressure) = (P * R) /(S * E- 0.6*P) = (12.50*1403.00)/ (1202*1.00-0.6*12.50) =14.6788 mm

Nozzle wall required thickness, Trn (internal pressure) = (P* Ro)/ (S* E- 0.6*P) = (12.50*24.42)/ (1202*1- 0.6*12.50) = 0.2555 mm

UG45 min. Thk. for nozzle neck requirement: Internal press.
Internal or external wall thickness, tra = 3.4882 mm
Thickness for wall Per UG16b, tr16b = 4.5000 mm
Shell or head thickness for wall internal pressures, trb1 = 17.6788 mm
Thickness for wall, trb1 = Max (trb1, tr16b) = 17.6788 mm
Thickness for wall, trb2 = Max (trb2, tr16b) = 4.5000 mm
Thickness for wall Per UG4, tb3 = 8.258 mm
Thickness of nozzle candidate determined (tb) = min (tb3, max (tb1, tb2)) =min (8.258, max (17.679, 4.5)) =8.258 mm
Nozzle necks min. wall thickness (tUG45) = max (ta, tb) = max (3.4882, 8.2578) = 8.2578 mm
Thickness of available nozzle neck = 0.875 * 13.487 = 11.801 mm → OK

UG40 Reinforcement limits: Internal Pressure
Diameter limit, parallel to vessel wall, D1 =163.0074 mm
Opening length, parallel to vessel wall, d =81.5037 mm
Thickness limit, normal to vessel wall pad side, Tlwp = 42.3130 mm
Reduction factor for welds strength (fr1) = min (1, Sn/S) = min (1, 1202.2/1202.2) = 1.000
Reduction factor for welds strength (fr2) = min (1, Sn/S) = min (1, 1202.2/1202.2) = 1.000
Reduction factor for welds strength (fr4) = min (1, Sp/S) = min (1, 1202.2/1202.2) = 1.000
Reduction factor for welds strength (fr3) = min (fr2, fr4) = min (1, 1) = 1

Area Results for Nozzle Reinforcement Calculations

Available areas, A1 to A5	Design	External	MAPNC
Required areas Ar	10.690	-	- cm²
Shell area A1	3.166	-	- cm²
Nozzle wall area A2	7.220	-	- cm²
Inward nozzles area A3	0	-	- cm²
Welds areas A41+A42+A43	0.907	-	- cm²
Elements areas A5	10.440	-	- cm²
Total	21.733	-	- cm²

Analysis of the Internal Pressure:
Area calculation by nozzle angle = 63.05 Degrees.
Insufficient area is by without pad.
Sufficient area is by with pad.

Reinforcing Pads selection	Diameter	Thickness
Acc. To thickness of pad	88.90	22 mm
Acc. To diameter of pad	190	0 mm
Acc. To thickness of shell or nozzle	99.7346	11.1252 mm

Required area (A) = (d*tr *F + 2*tn*tr*F* (1- frl)) UG37c = 81.5037 *13.1154*1.0+2*8.1252*13.1154*1.0*(1-1) = 10.690 cm²

Minimum Design Metal Temperature (MDMT) For Nozzle Junction Calculation

➢ Governing Thickness, tg = 7.645, tr =0.256, c=3.000 mm, E* =1.00, stress ratio = tr* (E*)/ (tg-c) = 0.055, Temperature reduction = 78°C

MDMT between Nozzle neck and flange welds: Curve: B

Min. metal temperature without impact per UCS66
= -29 °C

Min. metal temperature at reqd. Thk.(UCS66.1) = -104 °C

MDMT between nozzle and shell or head welds of the nozzle (UCS66 (a)1(b)): Curve B

Min. metal temperature without impact per UCS66 = -29 °C

Min. metal temperature at reqd. Thk. (UCS66.1) = - 104 °C

At all sub joints for this junction, governing MDMT = -104 °C

Temperature reduction in ANSI Flange MDMT per UCS66.1

Unadjusted MDMT of ANSI B 16.5/ 47 flange per UCS66c
= -29 °C

Temp. Reduction in Flange MDMT per UCS66 (b) 1(b)
= -104 °C

Temp. Reduction in Flange MDMT per UCS66 (b) 1(c)
= -104 °C

Stress reduction Ratio per UCS66 (b) 1(b) = Design Pressure /Ambient Rating =12.50/52.11 =0.24

Summary of Nozzle Pressure/ Stress Results

Allowed Local Primary Membrane Stress, Sallow
= 1803.37 kgf/cm²

Stresses of primary membrane for local, PL
= 1169.17 kgf/cm²

Max. Allowable pressures working, Pmax
= 12.85 kgf/cm²

Calculation For Weld Sizes, Description: Nozzle

Nozzle or shell weld intermediate calculations, Tmin = 5.7376 mm

Result Per UW16.1

	Thickness required	Actual Thickness
Nozzle Welds	4.0163 = 0.7* tmin	6.7342 =0.7*Wo mm

➢ Nozzle N1 Max. Allowable pressure at this location

Converged Maximum Allowable pressures for operating case = 12.772 kgf/cm^2

IV FABRICATION AND QUALITY TESTING FOR PRESSURE VESSEL

A. Fabrication for Pressure Vessel

For any construction to be started in an industry, first the drafting design of main pressure vessel and its components are to be approved by the purchaser and the inspection authority, then only the manufacturer can start over the process. Along with the dimensions and Thickness of fully dimensioned drawing for the main pressure vessel and its components, they included the details also:

- ❖ Conditions of design
- ❖ Selection of material
- ❖ Welding details
- ❖ Heat treatments to process
- ❖ Non destructive testing
- ❖ Pressure testing

Main objective of manufacturing is to provide a definite process for recognition. For construction, specified materials of required standards are to be used so that any material can locate to its source. The process to form the material sheets into cylindrical shells and ellipsoidal head plates through hot or cold forming completely depends upon the selected material thickness and dimensioning. The tolerances of allowable assembly and forming for cylindrical shell and end heads depend on the standards and codes used. The stresses produced by the outer roundness and joint misalignment can be prevented by using these tolerance limits. Based on the material and thickness of the part, the welding is carried out for the weld joints through preheating or through post welding treatments. Preheating is conducted to the local weld areas where as post welding is heating the vessel in enclosed furnace.

1. *Design Conditions*

For a pressure vessel fabrication, it has to follow the codes and standards, rules and regulations. Codes and standards listed below:

❖ASME BPV code, SecII partC – material specification for welding rod, electrode and filler metals.

❖ASME BPV code, SecV – Non destructive Examine (NDE)

❖ASME BPV code, SecVIII, Div 1 – Rules and regulation of pressure vessel.

❖ASME BPV code, Section IX – Welding and Brazing qualification

❖Indian Boiler regulations (IBR) and any other specified.

2. *Material Specification Processing*

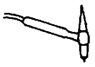
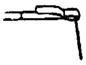
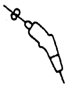
❖Carbon Steel: After welding operation, carbon steel welded joints are to be stress relieved, in accordance with Table 5.3. By using local stress relief, the welded joint temperature is heated to 600 ̊C and not less than it. The range of temperature is kept between 600 to 650 ̊C, for one hour a weld of 25mm thickness is processed. Then weld area is kept for cooling in still air without any interruptions and temperature is maintained below 315 ̊C.

❖ Austenitic Stainless Steel: After welding operation, for welding joint of stainless steel there is no need of stress relief as the solution annealing is carried out. The specified conditions are fracture at elongation and reduction areas, notch toughness, fatigue strength, ageing of material and its non brittle nature at operation situation and availability.

3. *Welding Processes*

The following welding processes shall be used

Table 8 Arc Welding Processes

Welding Process	AWS Designation	Electrode	Shielding Gases	Remarks
Gas Tungsten Arc Welding	GTAW 	Non Consumable Tungsten Electrode	Argon And Helium Gas To Penetrate Weld	Clean Process
Shielded Metal Arc Welding	SMAW 	Consumable Stick Electrode	Some Shielding. Gas Produced From Welding Rod.	Common In The Field And In Small Shops. Produces Excessive Fumes.
Gas Metal Arc Welding	GMAW 	Consumable Wire Electrode	Argon, Co_2 And Ar / Co_2	From Electrode, Metal Flows To Workpiece
Flux Core Arc Welding	FCAW 	Consumable Electrode Wire With Core Flux	External Gas As Co_2 Or Gas Generated By Flux	Same As GMAW

4. *Preheating*

1. Preheating process of improving welding accuracy and prevention of cracks. The general requirements of PWHT also apply to preheating.

2. Preheating shall be used as per the recommendations of ASME BPV Code Section VIII Division 1. For equipment under the purview of IBR, the requirements of IBR shall govern. Table 9 gives the requirements of preheating for commonly used materials.

TABLE 9 Preheat Requirements

Sl. No.	Base Material	Nominal Wall Thickness mm	Minimum Tensile Strength MPa	Minimum Temp. °C
1.	Carbon steel	≤ 25	490	10
2.	Carbon steel	> 25	490	100

5. *Post weld Heat Treatment*

PWHT is a heat treatment process of improving the weld properties after the welding process. It follows the ASME BPVC Sec.VIII Div.1 codes. Table 10 summarizes the PWHT requirements for commonly used materials. For equipment in the range of IBR, PWHT is as per IBR.

TABLE 10 Post weld Heat Treatment Requirements
(For Commonly Used Steel Materials)

Sl. No	Base material	Nominal wall thickness mm	Metal temp. range ° c
1.	Carbon steel	≤ 32	None
2.	Carbon steel	> 32	600 to 650
3.	Austenitic stainless steels	All	-

6. *Efficiencies of Welded Joints*

The efficiency of weld joints subjected to tension depends upon the welding type and the test process. Double welded butt joint is a strong joint. Joint efficiency of weld joint is shown in table 11

Table 11 Efficiencies of Weld joint

Joint Type	Full Radiograph	Spot Radiograph	No Radiograph
1	1.0	0.85	0.7
2	0.9	0.8	0.65

7. *Construction Process*

General procedure for construction of a pressure vessel is explained in detail below along with the assembly of the parts to complete equipment. The construction of pressure vessel is according to ASME codes and standards.

❖Making of Shell: Selected raw material is formed into thin shell plates of required thickness and length by applying forging process. These shell plates sending to rolling operation for rolling the plate into cylindrical shell form as shown in fig 3. Now the shells after bending is joined to its ends by the process called longitudinal seam welding or L-seam welding. It is a butt weld with full penetration and the electrode used is E7018 which is a low alloy and high tensile steel electrode. The two ends are welded by welding operation. Uneven edges are removed during welding process. To specified requirement the cylindrical shell is manufactured.

❖Making of Dished Ends: Selected raw material is formed into thin sheets of required cross section thickness and radius. This flat material is loaded into the pressing machine. The machine’s piston rod of master cylinder moves up and down to drive the upper tool to press the raw sheet plat to become the required concave shape. This concave shape plate is load edging machine. The clamping frame as shown in fig 4 function as the dished end blank is fix and free rotation it makes, the pressure wheel make movements based on certain round arc and put force constantly to form dish ends on the end blank. The Edge trimmer cuts the dished end uneven edges. To the specified requirements the dished end is manufactured.

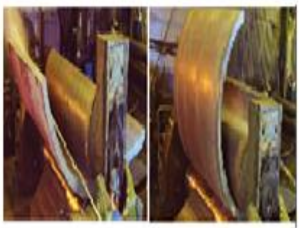



Fig 3 Shell Rolling   Fig 4 head pressing to concave

❖Making of Nozzles: selected raw material block is sending for forging operation. The raw material is heated up. The hot block is placed between die and compressive force is applied. After acquiring the required shapes, drilling process is carried to drill holes on the nozzles to fitting with the pressure vessel during process.

8. *Assembly of Pressure Vessel*

(1). Shell to Dish End Assembly

For joining the shell to dish ends, first the shell axis is too pointed and then the four circumferential points on dish end head are too pointed. The process of aligning is:

- To the end's straight face, consider outer circumference and locate the four centre points by dividing the perimeter to 4 parts.
- Placing the dish ends in reverse position on the Thick Leveled plates. By using two tri squares locate the opposite center-points. To have an idea of dish end top most point grace a mark with chalk. Repeat this at 90° with first point, which gives the centre of the dish end point.
- Connect the four centre-points representing 0º, 90º, 180º and 270º to the centre of the dish end.
- Use the same procedure to locate the nozzles or other attachments.

As per drawing, Proper assembly is only possible by having a dimension check of the diameter of shell and the circumference of the dished end, and then only assembly is done

(2). Fitting of Subassemblies

To the pressure vessels, fitting up the require attachments like nozzles, flanges, manholes, valves are marked and properly located at the same time to the pressure vessel setup. If any fouls with these attached elements exists with the welded seam or with them can be corrected and check. For checking, reference of the orientation plan or elevated view of horizontal pressure vessel is considered. By taking the reference of tangent line locate the nozzles with centre-point. All the schedule attachments are located to the pressure vessel.

B. *Quality Test for Pressure Vessel*

The pressure vessel after welded is sent for inspection. The constructed pressure vessel based on ASME codes will be inspected under inspection authority. An ASME BPV code provides the rules for the examination and inspection. The methods of examination used, Ultrasonic (UT), Radiographic (RT), Magnetic particle (MT) and Dye penetration (PT).

1. *Code Standards*

Levels of acceptance of defects in welds shall be based on ASME BPVC Sec.VIII Div.1. For equipment under the preview of IBR, the levels of acceptable defects shall be as per IBR. For the inspection and testing code specifications are:

- UG 90 – General
- UG 93 – Inspection of materials
- UG 97 – Inspection during fabrication
- UG 103 – Nondestructive testing

2. *Non Destructive Testing*

Non destructive testing methods is a way to evaluate the completeness of the vessel without negotiate. The NDT is based on the material and thickness. Visual inspection, dye penetration, magnetic particle testing examines the discontinuities and defects on the open surface or to near surface. Because of this reason they are known as surface examination methods. Whereas radiography, ultrasonic testing examines the defects within the component. So they are referred as volumetric methods.

Visual inspection is simplest and examines the cracks or defects on the surface. To determine the general condition of the equipment this method is very useful. Problems like corrosion, erosion and hydro blistering are detected with this test.

Dye penetrant test examines the welds surface flaws. It is a process of sending a special formulated liquid (penetrant) into the equipment to see for any interruption. Through a developing agent the entrapped liquids are detected. Fluoresce under black (ultraviolet) light is the penetrant used to detect the indications developed. The equipment must be opened, clean and undisturbed.

Magnetic Particle detection examines the weld surface flaws and subsurface defects. The magnetic flux detects the discontinuities in or near the surface with the ferro magnetic material. This magnetic flux is created by using electric current between region and contact prods. For carbon and low alloy steels, MT application is limited due to ferro magnetic material requirement. By sending ferromagnetic particles of dry powder or wet suspension into the magnetic lines, disturbances are observed and these particles are referred to fluoresce under black light.

Radiography testing is used to examine the subsurface cracks and defects and weld internal flaws. This testing uses same principle of X-ray testing in medical radiography. If any defects like holes, voids or discontinuities exist on the surface, it will reduce the depletion rays by creating greater exposure to film as dark area in the negative film. By using RT method, voids on open surface are easily detected than the cracks tightly closed.

Ultrasonic detection is used to examine the wall thickness during the operation and weld internal flaws. Ultrasonic testing for equipment is same as radar or scanning system. This method uses electromagnetic and acoustic waves to detect foreign particles. UT examines by sending the waves into material and the reflected waves gives the discontinuities during receive mode are defects. The defects information is sends through electronic recording signals.

3. *Inspection of Pressure Vessel*

The objective of inspection program for pressure vessel is to make sure the vessel is safely operated and maintained. The purpose of regular inspection of pressure vessels is:

- To improve the reliability
- To reduce operation and maintenance costs
- To reduce liability
- To minimize unscheduled outages
- To prevent damage to environment
- To improve facility, personal and public safety

4. *External Inspection for the Pressure Vessel*

The external inspection for pressure vessel is the overall inspection of pressure vessel. It provides information concerning:

- Vessel attachments: The structural attachments mounted on the pressure vessel are thoroughly checked if any expansion or contraction took place. Sufficient allowances are specified for slotted bolt holes, unopposed saddle foundation. These

ISSN: 2278-0181
Vol. 4 Issue 09, September-2015

attachments are thoroughly examined for any cracks or distortions at the welds.

- Connections to vessel: Vessel connections like nozzles, manholes, flanges, valves, reinforced plates are thoroughly checked for any cracks, defects or deformations. In bolts and nuts, for corrosion or for any defects should be examined. In case of reinforcing plates, the weep holes are to open for the visual inspection of leakages and to protect the vessel and reinforcing plates from the pressure build in. In flanges, the faces are tested for distortion and to certify the position of gasket with the surface.
- Insulation or Other Coverings: when the external covering like insulation, corrosion resistance is coated to the vessel, a small portion of covering is removed and investigated for the material condition and vessel condition.
- Various other conditions: The vessel surface is examined for erosions. Vessel dents are the deformation occurs through the surface contact with the blunt object resulting no damage to the metal. Some dents are mechanically fixed by pressing out the dents. If any deformity is seen, the whole vessel has to be examined. Cuts and grooves reduce wall thickness and create high stress concentrations. It is compulsory to repair the area by knowing the extension of defect and repair it by welding or by patching. Grinding method is used to eliminate few minor cuts or grooves.
- Inspection of surface: Vessel surfaces are to be checked to find out whether the surface got cracks, swelling, bulges and any other dislocations. The saddle supports should be examined along with the heads and shells.
- Welded Joint: The areas where welding occurred and the adjacent areas damaged due to heat are to be inspected for cracks and for other defects. For this purpose, magnetic particle and liquid penetrant exams are more useful.
- Leak Test: The vessel has to be thoroughly checked for any leakages of liquid, gas. If any leakage occurring following the insulation coverings of vessel supports, any previous leakage has to be thoroughly examined. If necessary the covering has to remove until the source is set.

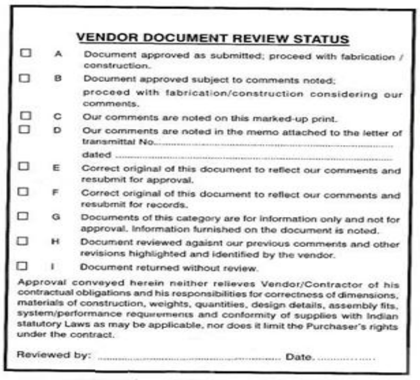
5. *Internal Inspection for the Pressure Vessel*

The internal inspection for the pressure vessel is carried only when the ultrasonic inspection testing data of wall thickness specify that there is some wall thin occurs or the equipments are not approved to indicate actual thickness of walls for shell and dished ends. All the parts are examined to cracks, corrosion, deterioration, lamination & hydrogen blistering.

- Vessel Connection: All external fittings and controls welded to any opening are to be inspected carefully for assuring free from obstacles. Thread connection are examined to check sufficient threads are provided.
- Vessel closure: For important closures of decontamination, fast opening closures are thoroughly examined for wear and sufficiency, which are used to operate the pressure vessel. Areas at high stress concentration are also examined for cracks.
- Corrosion: In a pressure vessel, few severe corrosion locations are there of liquid level, bottom area, shell area near to inlet nozzles are mostly affected for corrosion. Beside of these, the welded seam, nozzles and areas subjected to welds are regularly affected to increased corrosion levels. It would be helpful if data is collected for vessels of similar functioning to locate and analyze corrosion in the equipment for inspection.

6. *Inspection and Test Record*

The document is to verify that all the tests and inspections as required have been completed are to be attached to the reports of the inspection and tests. The document as shown in fig 4 is a compliance with the third party inspectors specific form. The document has to be signed with all the parties in inspection after the completion of process.



VENDOR DOCUMENT REVIEW STATUS

☐ A Document approved as submitted; proceed with fabrication / construction.
☐ B Document approved subject to comments noted; proceed with fabrication/construction considering our comments.
☐ C Our comments are noted on this marked-up print.
☐ D Our comments are noted in the memo attached to the letter of transmittal No.……………… dated ………………
☐ E Correct original of this document to reflect our comments and resubmit for approval.
☐ F Correct original of this document to reflect our comments and resubmit for records.
☐ G Documents of this category are for information only and not for approval. Information furnished on the document is noted.
☐ H Document reviewed agaisnt our previous comments and other revisions highlighted and identified by the vendor.
☐ I Document returned without review.

Approval conveyed herein neither relieves Vendor/Contractor of his contractual obligations and his responsibilities for correctness of dimensions, materials of construction, weights, quantities, design details, assembly fits, system/performance requirements and conformity of supplies with Indian statutory Laws as may be applicable, nor does it limit the Purchaser's rights under the contract.

Reviewed by: ……………… Date. ………………

Fig 4 Inspection Report

7. *Methyl Chloride Rundown Tank Installation*

The pressure vessel used for the purpose of storing methyl chloride in liquid stage is processed. The pressure vessel is designed and manufactured according to ASME codes. The pressure vessel completes all the tests based on the ASME code standards of quality testing. The vessel is certified for the process.

The pressure vessel is installed in the SRAAC Company plant of chloromethane as methyl chloride rundown tank for storing methyl chloride as shown in fig 5. The rundown tank is placed on a base foundation of height 4.5 meters.

Fig 5 Methyl chloride rundown tank

CONCLUSION

The designing of safe pressure vessel and its quality testing according to company requirements and ASME Code standards is been successfully completed. First for every pressure vessel safety is the primary aspect and it is acquired by following the design rules and procedures. PV Elite software is fast and produces accurate analysis within less time. Analysis of pressure vessel is much easier in PV Elite software. PV Elite performs calculations as the data is typed in and the results are easy to read and understand. In welding, the welding procedures and specified rules and regulations for the pressure vessel are to be followed strictly.

ACKNOWLEDGMENT

I gratefully acknowledge to department of Mechanical Engineering of G. Pulla Reddy Engineering College for technical support and providing the research facilities. I would also like to thank to SRAAC Company for their support and excellent co-operation in completing this project.

REFERENCES

[1]. Moss D.R, "Pressure Vessel Design Manual Third edition", Gulf Professional publishing Inc, Burlington, 2004.
[2]. Megyesy, Eugene F., "Pressure Vessel Handbook, Eleventh edition", Pressure Vessel Publishing Inc. Tulsa, Oklahoma. 2001
[3]. T.P Pastor & D.A Osage, "*Modernization of Pressure Vessel Design Codes ASME Section VIII, Division 2*", Journal of Pressure Vessel Technology, 2007, 129(4), 754-758.
[4]. B.S Thakkar & S.A Thakkar, "*Design of pressure vessel using ASME code, section VIII, division 1*", International Journal of Advanced Engineering Research and Studies, 2012, 1(2), 228-234.
[5]. S.R Gupta & C.P Vora, "*A Review Paper on Pressure Vessel Design and Analysis*", International Journal of Engineering Research and Technology, 2014, 3(3), 295-300, ESRSA Publications.
[6]. S.R Gupta & A. Desai, "*Design of Horizontal Pressure Vessel using PV Elite Software*", International Journal for Innovative Research in Science & Technology, 2014, 1(1), 58-63.
[7]. V. Vijay Kumar & P. Kumar, "*Mechanical Design of Pressure Vessel by using PV Elite Software*", International Journal of Scientific and Research Publications, 2014, 4(4), 1-4.
[8]. V. Kumar, N. Kumar, S. Angra, & P. Sharma, "*Design of Saddle Support for Horizontal Pressure Vessel*", International Journal of Mechanical, Aerospace, Industrial and Mechatronics Engineering, 2014, 8(12), 1919-1923.
[9]. M.A. Wahed & M. Farhan, "*An Investigation of Non Destructive Testing of Pressure Vessel*", International Journal of Emerging Technology and Advanced Engineering, 2013, 3(1), 243-248.
[10]. J.I Chang & C.C Lin, "A study of storage tank accidents", Journal of loss prevention in the process industries, 2006, 19(1), 51-59.