STIFFENING RING DESIGN ON PV ELITE FOR EXTERNAL PRESSURE ACTING ON THIN WALLED CYLINDRICAL MOUNDED VESSEL

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Abstract – *Thin wall pressure vessels (TWPV) are widely used in Oil & Gas industry for storage and transportation of liquids and gases when configured as tanks. Many a times Mounded cylindrical pressure vessels are used for storage of LPG or Propane and are much safer. For Mounded tanks along with internal pressure from petrochemicals external pressure acts as well. External pressure is compensated with increased thickness, which becomes a costly affair to a much greater extent if the storage tank is of high capacity. Therefore, a stiffening ring design is done to compensate the pressure without expenditure of extra money making it highly efficient.*

Key Words: Mounded cylindrical pressure vessels, external pressure, thickness, petrochemicals, stiffening ring.

1. INTRODUCTION

Used for storage of Liquefied gases (Mainly LPG and Propane) at ambient temperature. Since the vessels are installed above the highest ground water table, the soil cover usually protrudes above grade as an earth mound, hence the term "MOUNDED STORAGE". Continuous efforts towards improvement of safety standards led to the design of these types of storage vessels. These are horizontal bullets installed for bulk storage of liquefied petroleum gas (LPG). Offering a safer method for storing highly inflammable LPG; mounded LPG bullets are large, buried, horizontal cylindrical steel tanks with dished ends. Several vessels can be located side by side in one mound. Vessels are completely covered with soil and only manhole/dome and other nozzles protrude outside. Vessels have a slope of 1:200 min. for drainage purpose.

2. ADVANTAGES OF MOUNDED BULLETS

Mounded bullets have a sand cover, which can take impact of external missile bodies. Scenario of BLEVE (boiling liquid expanding vapour explosion) is eliminated, since no fire possible below the bullets. Reduced fire case PSV loads as compared to spheres. Reduced firewater requirement for firefighting. Difficult for external agencies to identify the mound as a storage facility. Mound cover protects the vessels against Heat radiation from nearby fire, Pressure wave originating from an explosion, Impact by flying objects, Sabotage, etc. It reduces site area due to less stringent inter spacing requirements. Mounded bullet installation is more space efficient than spheres. This is because of the smaller vessel-to-vessel spacing and due to the smaller safety distance requirement between the mounded storage vessels and items such as control rooms, buildings, roads etc. Mounded bullets offer the possibility of partial or total off-site construction. Mounded bullets are installed on sand bed foundations, which allow the load to be transferred uniformly to the underlying sand. This requires no heavy foundation work and offers uncomplicated, low cost installation. The preferred type of foundation for a mounded storage vessel is a continuous sand bed, supporting the vessel over its entire length. The use of the sand foundations allows the vessels to be installed early in the project and also allows vessel loadings to be predicted more accurately for vessel design. Usually the foundation will be constructed with a slope of at least 1:200 to facilitate draining of the vessel and the sand beneath the vessel must have adequate elevation not less than 0.76 m to facilitate drainage. Normally mound is provided with either earth, sand or concombustible materials like perlite, vermiculate, etc. for at least 700 mm thickness. As there are possibilities for foundation settlement, the surrounding of bottom nozzle should be filled with such material that can absorb settlement. Provisions are provided for monitoring the settlement of vessel in mounded storage facility. Bullets must be coated with special corrosion inhibiting layers such as epoxy layers and cathodic protection is critical to prevent corrosion.

3. DESIGN PARAMETERS FOR PRESSURE VESSEL

American Society of Mechanical Engineer's (ASME) Boiler and Pressure Vessel Code (BPVC) Section VIII, Division 2 has been employed for the design of bullet. The parameters considered for the design are shown in Table I.

Table -1: Design Parameters

Design Pressure (Internal)	14.5 kg/cm^2
Design Pressure (External)	2 kg/cm^2
Design Temperature	-6 ^{0}C to +55 ^{0}C
Max. Working Pressure	15.4 kg/cm^2
Operating Temperature	40 ^{0}C
Capacity	85 m^3
Length	10 m
Diameter	3.5 m
Density of LPG	490 kg/m^3

Design code	ASME Section VIII Division 2
Wind design code	IS-875
Seismic design code	IS-1893 RSM

The assemblage of different components such as shells, heads, nozzles and stiffener rings usually constructs pressure vessels.

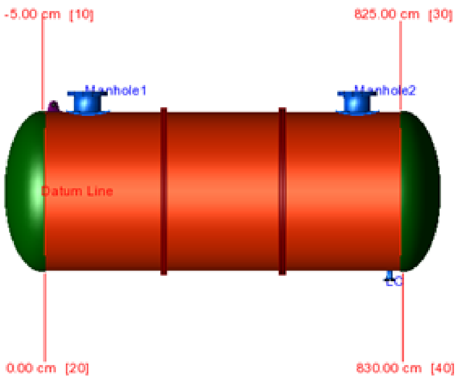

Fig:-1 Mounded pressure vessel with stiffening rings

3.1 Shell

Shells are the primary components that store liquids. Cylindrical shells are widely employed as they are having maximum section modulus and minimum induced stress for a given diameter. Pressure vessel shells are welded together to form a structure that has a common rotational axis. Spherical and conical shells are also in use.

3.2 Heads

A variety of heads are used for closing the ends of pressure vessel shells. These include hemispherical, elliptical, torispherical, conical and flat shaped heads. Curved configurations are stronger and allow the heads to be lighter, thinner and less expensive than flat heads. Heads are usually categorized by their shapes. Ellipsoidal, hemispherical, torispherical, conical, tori-conical and flat are the common types of heads.

3.3 Nozzle

Nozzles are necessary components of pressure vessel for the process industries. Nozzle is a component that is welded to the shell or heads of a pressure vessel for connecting the vessel to inlet and outlet pipes to convey working fluid in and out of the vessel. In order to minimize stress concentrations, preferred shape of nozzles are circular. Usually the nozzle ends are flanged to allow for the connections and to permit easy disassembly for maintenance or access.

3.4 Stiffener Rings

Stiffener rings are used all around the periphery of the vessel to increase the moment of inertia at local positions, thus increasing the resistance or strength and reducing the thickness requirements. The material used for stiffener rings is of comparatively low cost and it allows economically favorable manufacturing of pressure vessels.

3.5 Loads on Mounded Bullet

The analysis of mounded bullet is carried out by considering different loads mentioned in EEMUA Publication190:2005. Dead weight of the bullet, internal design pressure, weight of the maximum volume of liquid allocated to one stiffener, the pressure exerted by the mound on top of the cylinder and domed ends, axial loads due to changes in vessel length which are caused by variations in pressure and temperature, pressure exerted by the foundation and earthquake loads are considered in the analysis.

3.6 Load Combinations

There are three load combinations considered in the analysis for two support conditions, middle soft case and middle hard case, as mentioned in clause A.4.2.10 of EEMUA190: 2005.

Service (Filled with LPG in corroded condition)

Internal Design Pressure + Liquid Head + Design Temperature + Weight of Mound.

Hydro test (Filled with water and in un-corroded (new condition)

Hydro test pressure + Liquid Head + Weight of mound

Service (Filled with LPG in corroded condition)

Internal Design Pressure + Liquid Head + DesignTemperature + Weight of mound + Seismic loads

The material used for the construction of different parts of the bullet along with their tensile strength and yield stress values are listed in Table II

Table II Material Specification

Description	Material	Type of Steel	Tensile Stres (MPa)	Yield Stress (Mpa)
Shells	SA-516 70	Carbon Steel	485	260
Dished Ends	SA-516 70	Carbon Steel	485	260
Rings	SA-516 70	Carbon Steel	485	60
Nozzles	SA-350 LF2	Carbon Steel	485	248.22

4. DESIGN CALCULATIONS FOR SHELL THICKNESS WITHOUT STIFFENING RING

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd kgf/cm^2	Nominal Thickness mm	Total Corr Allowance mm	Element Diameter mm	Allowable Stress(SE) kgf/cm^2
10	20	14.500	18.000	1.5000	3500.0	1713.4
20	30	14.500	18.000	1.5000	3465.0	1713.4
30	40	14.500	18.000	1.5000	3500.0	1713.4

Element Required Thickness and MAWP :

From	To	Design Pressure kgf/cm^2	M.A.W.P. Corroded kgf/cm^2	M.A.P. New & Cold kgf/cm^2	Minimum Thickness mm	Required Thickness mm
10	20	14.5000	15.7305	18.0246	16.0000	14.8634
20	30	14.5000	15.7375	17.8777	17.5000	16.2367
30	40	14.5000	15.7305	18.0242	16.0000	14.8633
Minimum			15.730	17.878		

Fig:-2 Internal Pressure calculations

External Pressure Calculations

From	To	External Actual T. mm	External Required T. mm	External Des. Press. kgf/cm^2	External M.A.W.P. kgf/cm^2
10	20	18.0000	12.8452	2.00000	4.23031
20	30	17.5000 <<<	21.5518	2.00000 >>>	1.13005
30	40	18.0000	12.8452	2.00000	4.23031
Minimum					1.130

External Pressure Calculations

From	To	Actual Len. Bet. Stiff. cm	Allow. Len. Bet. Stiff. cm	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	893.333 >>>	520.810	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc

Fig:-3 External Pressure calculations

From the above two figures, we can note that the minimum thickness required for shell to compensate internal pressure is 17.14 mm i.e 18 mm nominal and the corresponding thickness against external pressure is 21.55 mm i.e 22 mm nominal. Therefore, extra 4mm thickness is required to compensate external pressure. This is avoided by the use of stiffening ring.

5. DESIGN CALCULATIONS FOR SHELL THICKNESS WITH STIFFENING RING

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd kgf/cm^2	Nominal Thickness mm	Total Corr Allowance mm	Element Diameter mm	Allowable Stress(SE) kgf/cm^2
10	20	14.500	18.000	1.5000	3500.0	1713.4
20	30	14.500	18.000	1.5000	3465.0	1713.4
30	40	14.500	18.000	1.5000	3500.0	1713.4

Element Required Thickness and MAWP :

From	To	Design Pressure kgf/cm^2	M.A.W.P. Corroded kgf/cm^2	M.A.P. New & Cold kgf/cm^2	Minimum Thickness mm	Required Thickness mm
10	20	14.5000	15.7305	18.0246	16.0000	14.8634
20	30	14.5000	15.7375	17.8777	17.5000	16.2367
30	40	14.5000	15.7305	18.0242	16.0000	14.8633
Minimum			15.730	17.878		

Fig:-4 Internal pressure calculations

External Pressure Calculations

From	To	External Actual T. mm	External Required T. mm	External Des. Press. kgf/cm^2	External M.A.W.P. kgf/cm^2
10	20	16.0000	12.8448	2.00000	3.26717
20	Ring	17.5000	14.2896	2.00000	3.52374
Ring	Ring	17.5000	13.6781	2.00000	3.98853
Ring	30	17.5000	14.2896	2.00000	3.52374
30	40	16.0000	12.8448	2.00000	3.26717
Minimum					3.267

External Pressure Calculations

From	To	Actual Len. Bet. Stiff. cm	Allow. Len. Bet. Stiff. cm	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	Ring	309.167	528.051	No Calc	No Calc
Ring	Ring	275.000	528.054	2974.10	3017.25
Ring	30	309.167	528.051	2974.10	3017.25
30	40	No Calc	No Calc	No Calc	No Calc

Fig:-5 External pressure calculations

After the application of stiffening ring, we can see that the external required thickness has reached below 15 mm, thereby making the internal pressure thickness governing. The stiffening ring cross section used in this case is as follows:

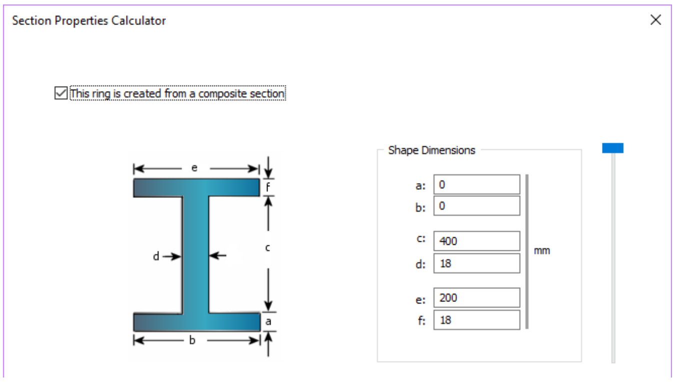

Fig:-5 External pressure calculations

6. RESULTS

Table III Steel Requirement

Description	Shell Thk (governing)	Steel Plate required (in Kgs)	Total Wt. saved (kg)
Without Stiffner	22mm	15666	
With Stiffner	18mm	12817	2849

In our case the weight of stiffenering ring each is 1000 Kg. Therefore with the use of 2 Stiffening rings we can manage to save upto 850 kg Steel. For heavy capacity mounded vessels, where the weight of mound is also quite significant, there could be high amount of steel that would be saved.

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