Design & analysis of the pressure vessel manhole nozzle metallic Flangeguard as per ASME sec VIII div. 1, edition 2010

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***Abstract* - Manhole is used in pressure vessels, tanks etc for the frequent interaction between personnel inside the pressure vessel. In most industries maintenance work of the pressure vessels, tanks & piping elements is carried during the shut-off conditions of the plant; since during the service periods it is being not possible to do inspection, cleaning & regular maintenance operations. Standard size Manhole is used (24"NB /500NB), and Flange carries almost 20 numbers of holes & Stud-bolt & nuts assemblies. Safety Spray Shields are used to prevent injury to personnel or damage to equipment in the event of a leak or spray-out of acids, caustics, chlorine, and other dangerous liquids at piping connections; These Safety Shields are commonly referred to as flange guards. In this report the focus is to design a Metallic Flangeguard which will not only protect the personal but also will help us in recovery of the leaked fluid without any contamination.**

***Keywords* - Design by Analysis (DBA), Design by formulae (DBF) & Finite element analysis (FEA)**

I. INTRODUCTION

In this report the Main focus is on the Flangeguard designing & analyzing for a Pressure vessel which is handling Ethylene oxide. The various parameters are taken into a consideration as per ASME SEC VIII DIV. 1, EDITION 2010 guidelines.

Ethylene oxide, properly called oxirane by IUPAC (International Union of Pure and Applied Chemistry), is the organic compound with the formula C2H4O. It is cyclic ether also colorless flammable gas at room temperature. The Design pressure & temperature for the Pressure Vessel is 7.2 Kg/cm² & 55ºC. Pressure vessels used in industry are leak-tight pressure containers, usually cylindrical or spherical in shape, with different head configurations. They are usually made from carbon or stainless steel and assembled by welding. Early operation of pressure vessels and boilers resulted in numerous explosions, causing loss of life and considerable property damage. Some 80 years ago, the American Society of Mechanical Engineers (ASME) formed a committee for the purpose of establishing minimum safety rules of construction for boilers. In 1925 the committee issued a set of rules for the design and construction of unfired pressure vessels. Most states have laws mandating that these Code rules be met. Enforcement of these rules is accomplished via a third party employed by the state or the insurance company. These Codes are living documents in that they are constantly being revised and updated by committees composed of individuals knowledgeable on the subject. Keeping current requires that the revised Codes be published every three years with addenda's issued every year.

All the pressure vessels for use with compressed air and those subject to internal corrosion or having parts subject to erosion or mechanical abrasion, shall be provided with the suitable manhole, handhole or other inspection openings for examination and cleaning. These openings are opened & closed so many times during the inspection period & always needs to riveted again for the process to start. Sometimes during the testing also it is being observed that if the Flange joints are not properly sealed then the test fluid comes out & shows the point of leak.

Flanges, the most common trouble area, need to be sealed properly to prevent leakage and must also be catholically isolated to prevent stray currents which cause undo corrosion and eventual breakdown of the metal. Advance Products & Systems manufactures and maintains a supply of quality products and materials which help solve most flange sealing problems, therefore preventing subsequent corrosion and saving the integrity of the pipeline.

II. PROBLEM DEFINITION

1.1 Requirement of Flangeguard

The selection of the Material of construction, Design parameters are provided by the Process designers. But still the Vessels should be analyzed or tested for the Hydro test or Compressed Air or Gas. Maintenance of all process equipments, Storage tanks, Reactors etc is the routine job of every process, chemical, pharmaceuticals & petroleum industry. Since as the Volume of Storage & handling is quite on higher side the Vessels & tanks also having Large Diameters & heights.

During this phase internal inspections carried out. For which a person has to enter inside a Vessel or tank through a Manhole. It is being specially designed to suit the purpose & allow the entry & exit of the person with comfort inside vessel or tank. Due to frequent opening & closing the Manhole flange joints becomes loose.

There are few more reasons for the failure, such as loose tightening of Stud-bolts & nuts, ruptured Gasket etc; which may lead to a leakage across the joint. As it is fastened joint the spillage during normal hydro test or pneumatic test can be allowed. But we cannot remain so careless about the fact when the system is operating with actual process fluids such as; Flammable, Explosive, Toxic, Lethal & Corrosive etc. If the personal protection is being not taken into an account serious effect can be observed & that will create hazardous effect on system & surrounding.

Just face the fact if the Manhole flange joint is not properly sealed or riveted, also chances of Gasket leakage at the joint occurs; the effect of which will bring out all process fluid out of the sealed joint. The fluids which we are handling are having different properties such as Corrosive, Flammable, Acidic etc. The vessel during the operating condition by chance leaks at any joint then it may cause a disaster for the surroundings and the personal life. Also there is no control on amount of spillage across the joints along with no recovery of the fluid which spills or vented out.

1.2 Purposed Methodology

To resolve the problems which is observed above the critical systems, the systems where the working pressure is large. The precautions must be taken care of at the design stages only, the latest software are available for pressure vessel designs are used (for E.g. PV-lite). In order to handle any analysis software, number of variables (Load cases) is to be considered. Manual methods of analysis may lead to various types of errors & difficult to debug. In this case the one cannot predict the chances of leakage or spillage from vessel near Manhole or any other nozzle. But we are simply focused on the Manhole where there are frequent openings took place. Safety spray shield can only protect personal but cannot hold the leakage, nor can fluid be recovered completely.

Flangeguard is the solution only to protect the personal and recovery of process fluid at the time of leakage. Also there is no preliminary signal or intimation at the time of leakage. Sometimes the fluids are colorless or odorless which is difficult to notice in case they leak. Also in big plants or areas it is difficult to monitor these sorts of minute leakages. Here in this report the safety aspect is limited only up to the Manhole. The design of Flangeguard is done considering it is as a Pressure vessel and has to be designed as per ASME SEC VIII DIV. 1, EDITION 2010 guidelines.

Below Figure shows the Process flow Diagram for the Metallic Flangeguard, designed as per ASME norms. From the figure it can be understood that the Flangeguard is nothing else but a small pressure vessel which can hold the fluid on leakage for a time been & also can send the signal to the Control panel, as it is provided with a pressure transmitter. It has to be installed before placing the Manhole flange, as it is welded at bottom to the Manhole neck. There is also a recovery tank present in the system as it will give temporary storage to the Leaked fluid. The line is provided with a Pressure safety valve which will be set for more pressure than operating pressure. At the time of testing of this Metallic Flangeguard the Vent is provided at top, as it has to be treated like a small vessel & designed as per Parent Vessel but considering the fact of safety, it is designed for more pressure.

Purposed Layout

Fig. 1. Shows New System Layout using Flangeguard, Leak detection & recovery.

III. DESIGN & CALCULATIONS

3.1 Procedure

Detailing of complete procedure of problem which has to be sorted out, let us take a case study of Ethylene oxide storage vessel, with a complete design & drawing based on the same being discussed below. The materials to be used in pressure vessels must be selected from Code-approved material specifications.

This requirement is normally not a problem since a large catalogue of tables listing acceptable materials is available. Factors that need to be considered in picking a suitable table are:

- Cost
- Fabricability
- Service condition (wear, corrosion, and operating temperature),
- Availability Strength requirements

Several typical pressure vessel materials for a noncorrosive environment and for service temperatures between ¡50±F and 1000±F

3.2 Design parameters & Materials

1. Design code : ASME SEC VIII DIV.1 ,Edition 2010, Addenda-2011 & SMPV(U) Rule-1981
2. Service : Ethylene Oxide
3. Type of vessel: Horizontal, limpetted
4. Inside Dia: 955 mm Shell Length: 250 mm
5. End closures type: 2:1 Ellipsoidal Dished Ends
6. Design pressure: [Vessel Side : 7.0 + 0.0955(Static Head) Kg/cm2 (g) Incl. Static Head] [Limpet Side: 10 Kg/Sq.cm(g)]
7. Design Temperature: 6 to +55 Deg.C
8. Operating Pressure: 3.500 Kg/cm2 (g)
9. Operating Temperature: 35 Deg.C
10. Gross Geometric Vol.: 0.41 m^3
11. Filling Percentage: 90%
12. Radiography: Shell: Full & Ends: Full
13. Joint Efficiency: Shell: 1 & Ends: 1
14. Corrosion Allowance: 0.0 mm
15. Material of construction shell: [Vessel Side: SA 240 Gr. 304L] & [Limpet Side: SA 312 TP 304-Limpet Coil]
16. Dished Ends: SA 240 Gr. 304L
17. Stiffeners: SA 240 Gr. 304L
18. Nozzle flanges: SA 182 F304L
19. Nozzle necks: SA 312 TP 304L
20. R.F Pad Plates: SA 516 Gr. 70
21. Lifting Lugs: SA 283 Gr.C or IS:2062 Gr.A
22. Pressure Bolting: SA 193 Gr.B8/SA 194 Gr.8,
23. Gaskets: SS-304 , Spiral wound.
24. Saddles: SA 283 Gr.C or IS:2062 Gr.A
25. Foundation Bolting: SA 307 Gr B / SA 563 Gr.A

3.3 Volumetric, Static head & Hydro test Pressure Calculations for Flangeguard

Volumetric calculations:

Shell Inside diameter, d = 955mm

Shell Length (T.L to T.L) L = 250mm

1) Vol. of the cylindrical shell = 0.7854 x d^2 x L

= 0.179 m^3

Volume of 2 Nos. 2:1 Ellip. Dished Ends = 2 x 0.1309 x ID^3

= 0.228 m^3

Total water filled capacity V = 0.407 m^3

2) Overall length of the Vessel: TL to TL Length = 250mm

Dished End Outside Height = 248.8mm

Overall Tank length (Outside to Outside) = 250 + 2 x 248 = 748 mm

3) Calculation for static head :

Type of vessel = Horizontal, limpetted

Specific Gravity of Liquid = 1.0

I.D of vessel, D = Shell diameter = 955 mm.

Pressure due to static head, p = D x Density of Liquid x % Filling = 955 kg/m^2

= 0.096 kg/cm^2 (g)

Hence, pressure due to static head = 1.378 Psi

Total Design Pressure = Design Pressure + Static head = 99.56 psi (g) + 1.378 psi(g)

= 101.00 psi(g)

Total Design Pressure = 7.10 kg/cm^2 (g)

4) Hydro static test pressure calculation:

Hydro test pressure = (1.3 x Design pressure x Max. allowable stress in ambient conditions)/ Max. Allowable in design conditions

= (1.3 x 101.00 x 16700)/ 16700

= 131.30 psi (g)

= 9.23 kg/cm^2 (g)

3.4 Nozzle Neck Thickness Calculations

SELECTION OF FLANGE RATING VESSEL SIDE NOZZLE FLANGES

Material of construction

Flanges	:	SA 182 F304L
Material Group as per ASME B16.5	:	2.3
Pressure-Temperature Rating Table	:	2-2.3

Total design pressure considering liquid head : 101.00 Psi (g)

Standard Flange Rating Check as per ASME B 16.5

Design Temperature	:	55	°C	=
Design Pr. + Static Head	:	101.00	Psi (g)	
Rating of Flanges selected	:	150#		
Allowable Pressure (ASME B 16.5)	:	219.5	Psi (g)	

Allowable Pressure at Design Temp. > (Total Design Pressure Incl. Static Head) Hence selected flange rating (150 #) is safe.

(As per Clause UG-45 of ASME Sec-VIII Div-1)

NOZZLE MARK NO.: M1
NOZZLE SIZE (mm NB): 500
M.O.C OF NOZZLE NECKS: SA-240 Gr.304L
OUTSIDE RADIUS OF PIPE IN mm (Ro) = 254.00
DESIGN PRESSURE (internal) in (Pi) Psi = 102.40
DESIGN PRESSURE (External) in (Pe) Psi = 0.00
MAX. ALLOWABLE STRESS in (S) Psi = 16700
STD. WALL THK.AS PER ANSI B36.10 in mm = 9.52
MIN. STD WALL THK in mm = 8.33
CORROSION ALLOWANCE in mm = 0.00
(Min. neck thk. required for internal pressure using UG-27):

$$\mathbf{t} = \frac{P \times Ro}{SE + 0.4\,P} = 1.55\text{mm}$$

MIN. WALL THK. AS PER UG-45(a) = 8.33mm
tb1: REQUIRED THK. OF SHELL/DE UNDER INT.PRESSURE,
At E =1.00, + C.A, IN mm AS PER UG-45 = 6.00mm.
tb2: REQUIRED THK. OF SHELL/DE UNDER EXNT.PRESSURE,
At E =1.00, + C.A, IN mm AS PER UG-45 = 0.00mm
tb3 :(STD. WALL THK.(mm) x 0.875)+C.A
AS PER UG-45(b)(4) = 8.33mm
tb= MIN.(tb3,Max(tb1,tb2)) AS PER UG-45(b) = 6.00mm.
NOMINAL THK. REQD. in mm= 6.00mm
PROVIDED NOZZLE THK. : 8.00mm
As Provided nozzle neck thicknesses are greater than required thickness. Hence Safe.

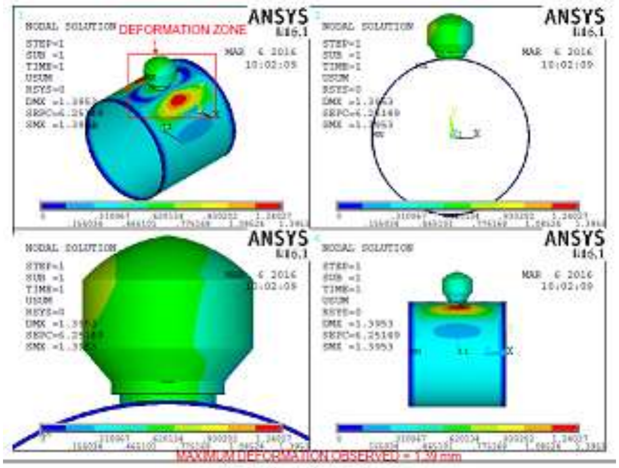
IV. FEA ANALYSIS

4.1 Procedure

The Old techniques of Design by formulae (DBF) methods were used to give design on safer side & thereby lead to more thick materials or rather more strong material selections. Because of which the overall cost of Vessels or Tanks etc., was too high & design used to be very Bulky & heavy. In any Process industry the Cost is more important & safety associated with the same.

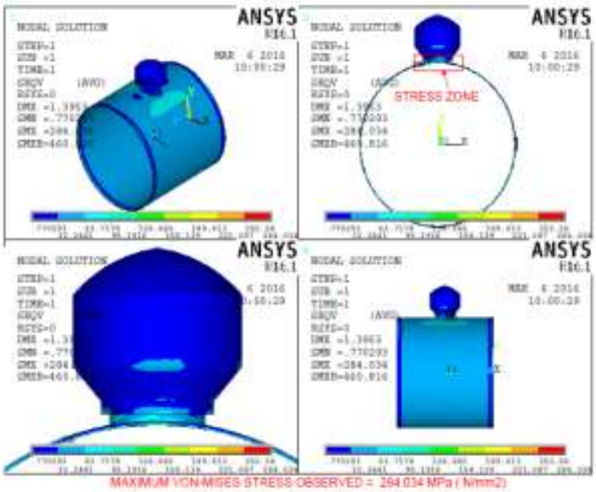
Here in this design the analysis are performed on ANSYS software & the Table given below shows how Flangeguard is safe as the selected parameters is justifying the overall safety of Vessel. Material used for the Flangeguard are having allowable stress value equal to that of the material in the Vessel wall, in case such material is unavailable lower strength material is used, provided with area or thickness of reinforcement is being increased. Additional Flangeguard on the parent Vessel credits extra stress value on the Vessel, It must be checked by Analysis, and also the results are plotted in the Table1.

4.2 Total Deformation

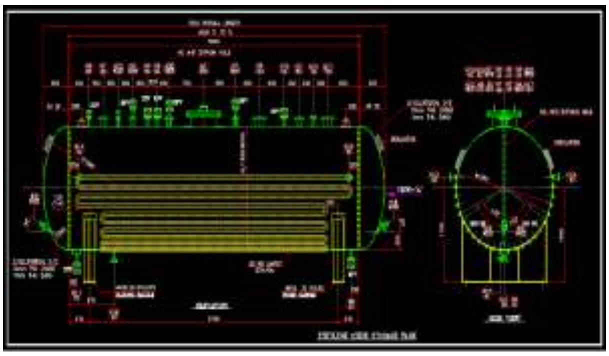


4.3 Factor of safety

4.4Equivalent (Von Mises) Stress



4.5 AutoCAD Drawing of the Vessel Tank.



4.6 Calculations

Calculation results of FEA Analysis

SR. NO.	TYPES OF FACTORS	VALUES IN UNITS
1	TOTAL DEFORMATION	Max 1.39 mm
2	FACTOR OF SAFETY	414 / 284~ 1.5
3	VON MISSES STRESS	Max 284 Mpa

V. *Conclusions*

The PV-Lite analysis results are giving the Standard dimensions for the Flangeguard. And also we can see from the Calculation results that the Design is more on safer side just like a Pressure vessel. Also we can see that we can recover fluid into some another vessel just in case the Holding time for the Flangeguard increased & more volume of the leaked fluid gets accumulated inside the Metallic Flangeguard. The concept of this Metallic Flangeguard is not yet applied in any Process industry. But once the analysis is being performed actual Metallic Flangeguard can be fabricated for all types of Pressure vessels. Commercially available Safety shields guard or Flange guard does not Hold the pressure & Fluid. It only controls the direction of leakage in the sense of personal protection. There are few Metallic Safety shields are also designed based on same concept. But pressure Holding ability is absent in most of the Guards. Use of this kind of Flangeguard may consume time of opening & closing of Manhole, but serves harmless surrounding in the Industry at a time of processing or testing.

VI. Acknowledgment

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The Codes & standards followed in all process & power indutries, as they gives a support to any design. During the design of the Flangeguard some papers from previous Journals are taken into the consideration.

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