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Analysis of Effect of Pressure on Separator Pressure Vessel Design using PV Elite Software

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Abstract - *Petroleum reservoir fluids are generally recovered from subsurface as a multiphase system. It is separated at surface into different phases for safe and reliable transport to refining facilities where there are further separated into different products. Separators play a vital role in hydrocarbon phase separation. They are pressure vessels and their outer shell is designed based on this fundamental. The safety factor of a pressure vessel is related to both the tensile stress and yield strength after incorporating material allowance. ASME Code Section VIII has fully covered these two parameters in the construction code for pressure vessel. This code section addressed mandatory requirement, specific prohibition, and non-mandatory guidance for pressure vessel materials, design, fabrication, examination, inspection, testing, certification, and pressure relief. In this study, mechanical design of a horizontal pressure vessel for three phase separator conforming to ASME code section VIII is analyzed for different design pressures.*

Key Words: Pressure, Separator analysis, Pressure Vessel, PV Elite, Separator design

1. INTRODUCTION

Petroleum reservoir fluids consists mainly of hydrocarbons and small amounts of inorganic chemicals, among which water, carbon dioxide (CO2), nitrogen (N2), hydrogen sulphide (H2S) are the most common (Pedersen & Christensen, 2007). Petroleum reservoirs are formed after a long period of time (millions of years) and generally at a burial depth between 760m and 4900m, where kerogen transformation into oil and gas. This leads to high pressures in the reservoir. Which can lead to part of the gas getting dissolved in petroleum fluids (Tabak, 2009).

A typical production system consists of many activities that must be carried out to safely extract and process hydrocarbons. Oil and gas reservoirs are exploited through wells and their fluid throughout is metered, measured, and broadly separated into oil, water, and gas phase before being sent to various gathering stations. At the gathering stations the input fluid is cleaned from impurity and refined to market specifications for transport and sale, or in case of gas and water, also to be reinjected into the reservoir.

1.1 Typical Petroleum production system

A typical production system consists of many components to carryout operations mentioned above safely and reliably. Some of the components of a petroleum production system are:

1. Wellheads: Ignoring the subsurface components, the production system begins at the wellhead, which includes a minimum of one choke, unless the well is on artificial lift. Typically, multiple chokes are required on high-pressure wells. Finally, an automatic Surface Safety Valve (SSV) is installed on high-risk installations to maintain safety and comply with the local laws.

2. Manifold: Manifolds are collection of valves to gather and control the flow from different wells at a location. They are required whenever two or more wells are commingled in a central facility. They allow flow from one well to be produced into any of the bulk or test systems. Isolation block valves in the manifold allow maintenance of the system without having to shut-in the well.

3. Separators: The target of the separation of reservoir fluids from the wells is to produce a gas stream as much free as possible of C3+ hydrocarbons and a crude oil stable at storage conditions. This is done to ensure that the crude oil does not undergo any vaporization when delivered into the storage tank or liquid does not drop out in gas pipeline in the event of small variations of storage pressure and/or temperature.

4. Pumps: Pumps are normally needed to move oil through the production facilities and deliver oil to a pipeline downstream of the facilities. Pumps are sometimes used in water-treating and disposal processes. Small pumps may be required to pump skimmed oil to higher-pressure vessels for treating glycol heat medium, cooling water service, firefighting, and so forth. (Arnold & Stewart, 2008).

5. Compressors: A type of pump that increases the pressure of gas. Compressors increase the pressure of the gas separated from the stage separators. (Arnold & Stewart, 2008). Compressors work on compressible fluid, so it uses a reciprocating design and not a centrifugal or screw pump design.

6. Heater Treaters: A vessel that uses heat to break oil-water emulsions so the oil can be accepted by the pipeline or transport. There are vertical and horizontal treaters. The main difference between them is the residence time, which is shorter in the vertical configuration compared with the horizontal one. (Oil Field Glossary, Schlumberger 2020).

7. Storage Tanks: A tank designed for storing volatile liquids such as gasoline and liquefied petroleum gases (LPG), which generate high internal pressures. A pressure storage tank is commonly spherical. Other types include spheroidal or hemispherical vessels. Some pressure storage tanks can support several hundred pounds per square inch of internal pressure. A pressure storage tank is also called a pressure-type tank. (Oil Field Glossary, Schlumberger 2020).

1.2 Separation

Separation, which is the first surface production step, refers to separation of these three fluid phases. After separation, the oil and gas phase are treated to market standards. Transfer of treated product to customers is done using very accurate measurement instruments. Separation is often accomplished in two or three stages, generally differentiated by the pressure of separation. This is especially done if production is from high-pressure wells. The initial Separation Pressure is an important parameter for consideration. Crude oil is generally costlier than natural gas, and so separation processes aim to increase the liquid content of the product. The multicomponent nature of the produced fluid dictates that more liquid component will be obtained from the separator for higher initial separation pressure. But this liquid might contain some light components that will vaporize in the stock tank downstream of the separator. So, the optimum pressure for separation should be kept such that:

- The pressure is low enough to ensure that light liquid components are not lost in the stock tank as gas phase.
- The pressure is high enough to ensure that maximum quantity of light components is stabilized in the liquid phase leading to increase liquid volume.

Generally, the high and intermediate stage separators are two-phase, while the low-pressure separator is three-phase. The low pressure three-phase separator is called a “free-water knockout” (FWKO) because it is designed to separate the free water from the oil and emulsion, as well as separate gas from liquid.

The choice of using two or three phase separator depends on the flowing characteristics of the wells:

- In case of high water cut from wells, it is possible to reduce the size of other separators by making the high-pressure separator three-phase
- If individual wells are flowing at different FTPs, then there is no benefit of making the high-pressure separator three phase.
- If all wells are flowing at same FTPs, it may be advantageous to remove the free water early in the separation using three phase high pressure separators.

Three-phase separator and free-water knockout are terms used to describe pressure vessels that are designed to separate and remove the free water from a mixture of crude oil and water. Since, flow normally enters these vessels directly from either a producing well or a separator operating at a higher pressure, the vessel must be designed to separate the gas that flashes from the liquid, as well as separate the oil and water. Between Three phase separator and FWKO, the term three-phase separator is normally used when there is a large amount of gas to be separated from the liquid.

2. Design Inputs

A three-phase separator is designed in PV Elite software using the following flow parameters:

Table -1: Fluid flow parameters

S. No.	Parameter	Summer	Winter
1	Temperature (°C)	67	59
2	Pressure (barg)	3.1	3.1
	Inlet Gas		
3	Flow rate (Am3/hr)	2755	6208
4	Density (kg/m3)	5.11	5.62
5	Viscosity (cP)	0.012	0.011
6	Molecular weight (kg/kg.mol)	34.23	36.50
7	Compressibility	0.974	0.9687
	Inlet Oil		
8	Flow rate (Am3/hr)	721	726
9	Density (kg/m3)	786.30	785.30
10	Viscosity (cP)	1.394	1.390
11	Surface tension (dyne/cm)	19.92	19.56
	Inlet Water		
12	Flow rate (Am3/hr)	74	75
13	Density (kg/m3)	974.90	981.20
14	Viscosity (cP)	0.418	0.470
15	Surface tension (dyne/cm)	64.68	66.10

The separator design parameters are:

Table -2: Separator design parameters

S. No.	Parameter	Unit	Value
1	Design Temperature	°C	85
2	Minimum temperature	°C	-20
3	Design Pressure	barg	FV/10
4	Test Pressure	barg	As per code
5	Internal Vacuum	mm Hg	Full Vaccum
6	Diameter of Shell	mm	6000
7	Tan. to Tan. Dimension	mm	18000
8	Corrosion allowance	-------	-------

9	Joint efficiency	-------	1
10	Head form	-------	2:1 (Semi-Ellipsoidal)
11	Seismic design (as per ADIBC and ASCE 7-05)	-------	-------
12	Wind design (i) as per BS 6399 – Part 2, (ii) as per ASCE 7 –05	m/sec	(i) 26, (ii)44.7
13	Sour Service	-------	Yes
14	Lining / Cladding	-------	3mm

3. Result and discussion

Separator pressure effects the requirement of metal thickness on the shell, left and right head. Chart 1 shows the effect of pressure on thickness. As expected, the required element thickness increases with the increase in design separator pressure. However, the increase in thickness requirement does not increase linearly with pressure as can be seen in the figure. The thickness of different elements is in the order, Left head thickness > Shell thickness > Right head thickness. The left head thickness requirement is highest because the left head has a manway in it along-with a 24-inch nozzle. This reduces the metal area leading to increase in the thickness requirement. The shell is generally made from multiple sheet metals which are welded together. The thickness requirement increases to provide the requisite thickness of the welded area.

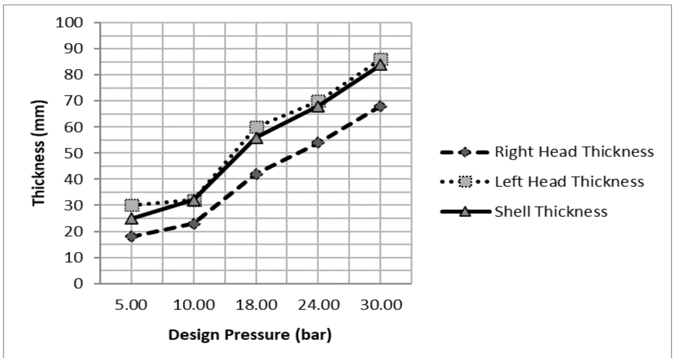

Chart -1: Effect of Pressure on element thickness

Chart 2 shows relationship between weight of separator for different pressures. As expected, the weight increases with pressure, due to increase in the thickness of metal used for construction. This is an important feature as it dictates the requirement for foundation strength and strength of structure on which the separator will be placed. This is especially important in offshore structures where any increase in weight might lead to massive increase in construction cost of the project. If, the weight cannot be supported by the structure, the material might be changed to comply with the weight restriction. As can be seen in figure 2, the volume inside the separator is unchanged. It is evidenced by the constant difference in weight of separator with and without liquid.

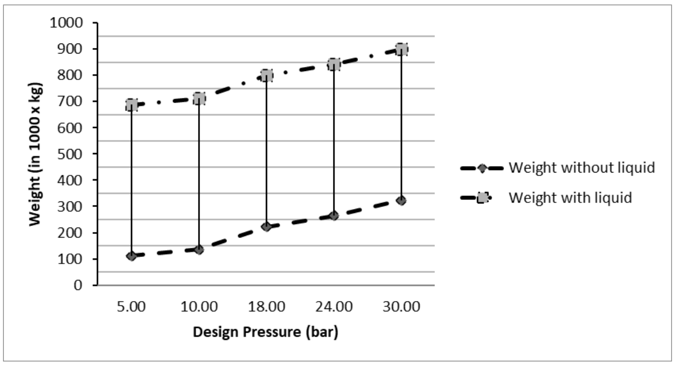

Chart-2: Weight of separator with or without liquid

Hydrostatic pressure test requirement for a separator as per ASME Code VIII UG 33 is 1.3 times the maximum allowable working pressure. This means that the hydrostatic pressure test of separators designed as per this code increases with the design pressure.

4. CONCLUSION

Separator design pressure effects the thickness of shell, left head and right head. It has been observed that the metal thickness increases with increase in design pressure. The difference in thickness between left head and right head is due to presence of manway and nozzles in the left head. The difference in thickness between heads and shell is due to presence of joints on the shell which need thicker sections to provide similar strength. The metal thickness used for manufacturing should be the maximum of all the calculated thickness.

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