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Design and Analysis of Three Phase Production Separator

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ABSTRACT:we are basically concerned with the design and analysis of a separator. We are looking forward to design this separator in such a way that it optimizes the process of separation, increases efficiency i.e. more output with same initial investment. We will carry out the design analysis by various empirical methods and will compare with standard data to check for the errors.

The separator taken into consideration is right now having capacity of 2 million gallons of crude oil purification per day and we are focussing on increasing its output to about 125%-130% more with simple modification in design. This will increase the production eventually and is a profitable step for the company. Thus, givingbest return on investment.

In this design, we followed ASME code. We used software like PVElite® and AutoCADfor vessel designing and drafting respectively.

KEYWORDS:Three Phase Production Separator, Oil Water and Gas Separation, Vessel Design, Vessel Analysis, Oil Production and Separation.

I. INTRODUCTION

Separators are used in oil and petro-fields. Separators are a type of pressure vessels and their main function is to separate the different components from crude oil. Separators can be either two phase or three phase. A three phase separator is designed in such a way that it separates oil, water and gas from crude oil or well fluid.

If the input in the separator vessel is high the pressure and eventually the stress on the dish end would be proportionally high. Hence, it wouldn't be able to sustain the high pressure. To overcome this problem, we need to redesign the separator.

In thin-walled cylinders which are subjected to internal pressure, maximum stress occur at the inside portion of the radius of cylinder. Stress depends upon:-P = internal pressure in cylinder, D = internal diameter of cylinder, T = wall thickness

Hence, with increase in pressure the stress also increases.

Production separator can be of many types but the most widely used separator is Gravity type Separator**.**

COMPONENTS OF SEPRATOR

- INLET DEFLECTOR : It separates the gas stream from the bulk fluid
- WAVE BREAKER : It is used to limit the wave propagation
- DEFORMING PLATE : It reduces the foaming at the gas liquid interface
- VORTEX BREAKER : It decreases the vortex flow when the liquid control valve is open.
- MIST EXTRATOR : It is primarily used to eliminate the mist or smog from the gases.

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- WEIR : It maintains the oil level in the vessel.
- INTERFACE CONTROLLER : It controls the water level, and it gives the signal to the water dump valve, which further releases the water and maintains the required level of water.
- PERSSURE CONTROL VALVE : It maintains the pressure in the vessel.

Selection of separator depends primarily on the:

- Gas handling requirement and
- Space availability

1. GRAVITY SETTLING ZONE: **It occupy large vessel volume, it** mainly consist of DROPLET COALSELING AND MIST SEPRATOR ZONE.

II. AIMS AND OBJECTIVE

A. To increase the efficiency of the three phase production separator.
B. To design a Three Phase Production Separator with least number of modifications.
C. To design the Production Separator following ASME Section VIII and ASME Section II.
D. To analyse parts, internal and external components for design failure.
E. To carry out mathematical analysis by various empirical methods.
F. To fix and eliminate errors in the mathematical calculations and in designing process.
G. To modify the design which increase the output without any capital investment.

III.SEPRATION PROCESS

Well Heads:-Well Heads are placed on top of the reservoirs of oil or gas. A well head can also work as an injection well. It can inject water or gas back into their reservoirs. This maintains levels of pressure and eventually maximizes production.

Manifolds and Gatherings

Onshore:-In onshore facility, the well streams are brought to the main facility of production over a connection pipeline systems and manifolds.

This pipeline allows setting up of “well sets” of production so that for a coming production level, most efficient and effective utilisation of composition of reservoir well flow (gas, oil, water, etc.) is selected from the wells.

Offshore:-The fluid stream is fed directly in to the production manifolds from the dry completion wells. Risers are also used in this. Risers are those which allow a pipeline to rise up to the top structure.

The well often produces a combination of water, oil and gas with various hydrocarbons and contaminants which must be separated and processed.

Production separator can be of many types but the most widely used separator is Gravity type Separator.

Gravity Separator

In gravity separation, a horizontal vessel is present in which the well flow is fed. The retention period is about five minutes. After the inlet is fed, gas is allowed to bubble out, water is settled at the bottom and oil settles in the middle section. Often, the pressure is reduced in several stages (HP Separator, LP Separator, etc.) which allow controlled separation of volatile components.

A baffle slug catcher is placed just after the entrance from which the crude or fluid stream passes. It reduces the effect of slugs. Slugs are large gas bubbles or liquid plugs.

Fluid outlets i.e. Water and Oil Outlets from the separator are generally equipped with vortex breakers.

Vortex Breakers reduces disturbance on the liquid table inside. Vortex is basically a whirling mass of fluid or air. Vortex Breaker is used to eliminate vortexes that are formed when the fluid passes from the outlet due to mixing of water and gas. It makes sure that only the liquid which is separated is passing from the outlets.

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The gas outlets contain Demisters and it removes liquid droplets from the gas.

Other types of separators are vertical separator and cyclone (centrifugal separator). Vertical Separators are used to save weight and space. Cyclone separators are used to improve separation.

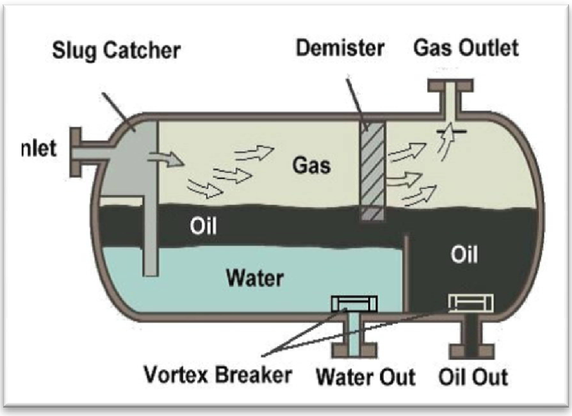

Fig.1. Separation process flow in horizontal gravity Separator

Unit Conversions

Oil Output is measured in number of barrels of oil produced per day.

1 Barrel/day = 42 Gallons (US)/day

1 Barrel/day = 1.84 x $10^{-6}m^3/s$

1 Barrel/day = 1.84 x 10^{-3} litres/s

1 Barrel = 159 litres

1 Gallon = 3.78 Litres

1 Gallon = 3.7 x 10^{-3} m^3/s

Reinforcement

Reinforcement is a process of adding an additional material in the opening region of the nozzle by thickening the shell or by adding an actual pad material. Reinforcement can be inside or outside. From Reinforcement calculations following parameters can be obtained:-

1. Required thickness of nozzle for shell and nozzle
2. Area of reinforcement required
3. Area of reinforcement available
4. Cross-sectional area of various welds available for nozzle
5. Cross- sectional area of various welds available as reinforcement
6. Total area available
7. Size of reinforcing pad if required

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Vessel and Component Specifications

SEPARATOR SPECIFICATIONS	
Design Internal Pressure (for Hydro test)	138.00 bars
Design Internal Temperature	140 °C
Hydro test type	Not given
Position of Hydro test	Horizontal
Nozzle Projection from Top of Vessel	0.0 mm.
Nozzle Projection from Bottom of Vessel	0.0 mm.
MDMT (Minimum Design Metal Temp.)	-50 °C
Construction	Welded
Special Service	None
Radiography Degree	RT 1
Miscellaneous Weight (%)	0.0
Is this a Heat Exchanger	No
User Defined Hydro test Pressure	0.0000 bars
User defined Maximum Allowable Working Pressure	138.04 bars
User defined Maximum Allowable Pressure New & Cold	0.0000 bars

Table.1. Specification of vessel components

Self-Reinforced Nozzle

Self-Reinforced nozzle is a type of nozzle neck which provides sufficient reinforcing in the nozzle welds and nozzle neck without any need of additional area. It uses excess thickness available in the shell.

Why Nozzle is required?

Openings in the pressure vessels in the region of heads or shells are required for following purpose:-

1. Man ways for letting people in and out of the vessel so that maintenance, repair and checking can be done.
2. Holes to drain and clean the vessel
3. Hand hole openings for inspecting the nozzle from outside.

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IV.DESIGN PROCEDURE

EVALUATION OF MATERIAL

Material	Yield strength h (S_{yt}) (N/mm^2)	$\sigma t = \frac{Syt}{F.O.S}$(N/mm2)	Elliptical head t_s (mm)
IS 2002-1962 1	200	133.33	141.188
IS 2002-1962 2	205	136.66	137.714
IS 2002-1962 2B	255	170	110.485
IS 2041-1962 20M0	275	183.33	102.39
IS 1570-1961ISCr90M055	290	193.33	97.056
A242(Cr-Si-Cu-Ni-P type)	289.57	193.04	97.20
A588(Mn-Cr-Cu-V type)	317.15	211.43	88.693
SA-240(Cr-Ni-Si type)	**374.2**	**249.5**	**75.084**

Table.2. Evaluation of material

Evaluated material:-

We have selected SA-240 because it has highest yield strength and due to this the thickness comes out to minimum.

DESIGN PRESSURE CALCULATION

MAXIMUM ALLOWABLE WORKING PRESSURE	Pi	Mpa g	13.9
T.L. TO T.L LENGTH	Ls	Mm	5400
MAXIMUM LIQUID LEVEL	H		1875
SPECIFIC GRAVITY OF CONTENT			0.972
TYPE OF DISH ENDS			2:1 Ellipsoidal
Internal Design Pressure Including Static Head			
FOR SHELL = Pi + H * ρ *9.80665/1000000	**13.91787 MPa g**		
FOR DISHED END = Pi + H * ρ * 9.80665/1000000	**13.9 Mpa g**		

Table.3. Design pressure calculation

CONCLUSION:-

Internal Design Pressure for Shell = 13.91787 Mpa g
Internal Design Pressure for Dished End = 13.9 Mpa g
These values are used for further calculations.

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V.CALCULATION

ORIGINAL DESIGN

Nozzle Diameter	= 8 inch = 203.2 mm
Nozzle Type	= Inlet Nozzle (Crude Oil)
Area A	= π/4 d*d$\frac{\pi}{4}d^2$= 32412.83 mm^2= 0.03241 m^2
Assume Velocity	= 0.5m/s
q1	= Area x Velocity= 0.03241 x 0.5= 0.016205 m^3/s
Volume of dish end = V_h	= π/4 d_i^3 = 2.576 m^3(di = 2700mm)
Volume of Shell	= π/4 d_i^2 x Ls (Ls = 5400 mm)= 30.917 m^3
Gross Volume	= 2Vh + Vs= 36.0698 m^3
Working Volume	= 0.75 x 36.0698= 27.052 m^3
Q_1	= Required Volume to be filled in the Vessel= q_1 x Time
Time	= Q_1/ q_1= 27.052 / 0.016205 = 27.83 min

This is the time taken to fill the vessel to its working volume.

- Gas Outlet = 60% of Q

Diameter	= 8 inch = 203.2 mm
Area A	=0.0324128 m^2
Q_1	= 0.01620 m^3/sec
But Q_1	= 0.3 x 27.052 = 16.23 m^3/sec
Q_1	= q_1 x Time
Time	= Q_1/q_1 = 16.69 min

This is time taken by Gas Outlet to discharge gas in one cycle.

Oil Outlet	= 30% of Q Diameter = 50.8 mm (2 inch)
Area, A	= 0.002055 m^2
q_2	= 0.0101275 m^3/sec
Q_2	= q_2 x Time
But Q_2	= 0.3 x Q1 = 5.41 m^3/sec
Time	= Q_2/q_2 = 133.5 min

This is the time taken by Oil Outlet to discharge pure oil in one cycle.

- Water Outlet

d	= 76.2 mm (3 inch)
Area, A	= 0.00455805 m^2
q_3	= 0.00279 m^3/sec
Q_3	= q_3 x Time

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But Q_3 = 0.1 x Q1 = 2.7052 m^3/sec

Time = Q_3/q_3 = 19.78 min

This is time taken by Water Outlet to discharge water in one cycle.

Water Outlet = 257.8/60 = 4.29 hour

Retention Period = t/60=238.2/60= 3.96 hour = 4 hour

AFTER MODIFICATION

Nozzle Diameter = 16 inch = 382.4 mm

Nozzle Type = Inlet Nozzle (Crude Oil)

Area A = π/4 d*d= 0.114790 m^2

Assume Velocity = 0.5m/s

q_1 = Area x Velocity= 0.0114790 x 0.5= 0.057395 m^3/s

NOW FOR,

Inlet Nozzle = 16 inch = 382.4 mm

Area, A = 0.114790 m^2

q_1 = 0.057395 m^3/sec

Q_1 = 27.052 m^3/sec

Time = Q_1/q_1 = 7.85 min

- Gas Outlet = 60% of Q

Diameter = 16 inch = 382.4 mm
Area A = 0.0324128 m^2
Q_1 = 0.01620 m^3/sec
But Q_1 = 0.3 x 27.052 = 16.23 m^3/sec
Q_1 = q_1 x Time
Time = Q_1/q_1 = 4.71 min
This is time taken by Gas Outlet to discharge gas in one cycle.

- Oil Outlet = 30% of Q

Diameter = 92.04 mm (4 inch)
Area, A = 0.006650 m^2
q_2 = 0.003325 m^3/sec
Q_2 = q_2 x Time
But Q_2 = 0.3 x Q1 = 8.11 m^3/sec
Time = Q_2/q_2 = 40.67 min
This is the time taken by Oil Outlet to discharge pure oil in one cycle.

- Water Outlet

d = 146.32 mm (6 inch)
Area, A = 0.016806 m^2
q_3 = 0.0084 m^3/sec

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Q_3 = q_3 x Time
But Q_3 = 0.1 x Q1 = 2.7052 m^3/sec
Time = Q_3/q_3 = 5.36 min
This is time taken by Water Outlet to discharge water in one cycle.

- **Retention Period = 118.645/60 = 2 hours/cycle**

So, in one day, no. of cycles = 24/2 = 12 cycles.

- For 12 inch nozzle

Area = 0.073024 m^2
q_1 = 0.0365 m^3/sec
Time taken by outlets:-

Crude oil, t = 12.35 min
Gas, t_1 = 7.41 min
Oil, t_2 = 59.35 min
Water, t_3 = 11.04 min
Retention Period = 150/60 = 2.50 hour
So, no. of cycles in a day = 24/2.5 = 9.6 cycles/day

VI. CONCLUSION

Percentage Savings in Time for Oil Outlet, Gas Outlet and Water Outlet is 69%, 71% and 72% respectively after the modification. Hence, there is considerable amount of cost saving.

On increasing Hub Thickness and Hub width, our required area was coming lesser than the provided area. Hence, for design to pass the test of required area Hub thickness and Hub Height could be increased within certain limits.

With the use of 8 inch nozzle there were 5.88 cycles/ day in the vessel. But with the use of 16 inch nozzle we are getting almost 12 cycles/ day. Hence, there is an increase of around 51% which can eventually save the time.

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