MAJOR PROJECT

ON

DESIGNING OF OIL - GAS SEPARATORS

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DESIGNING OF OIL – GAS SEPARATORS

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CERTIFICATE

This is to certify that the work contained in this thesis titled “Designing of Oil–Gas Separators”has been carried out by Kunal Pant, Mani Tyagi, Sagar Chauhan and Prashant Baral under my supervision and has not been submitted elsewhere for a degree.

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ABSTRACT

The American Petroleum Index (API) separator was first developed by the API and the Rex Chain Belt Company which is now called USFilter Envirex Products. The very first API separator was put to work in 1933 at the Atlantic Refining Company (ARCO) refinery in PHILADELPHIA. From that time till now literally all of the refineries worldwide have installed the API separators in their wastewater treatment plants and other places.Mainly those refineries installed the API separator using the very original design which was based based on the specific gravity (S.G.) difference between the oil and water. Even though many refineries now use the plastic parallel plate packing which is used to enhance the gravity separation.

The API separator is a gravity separation equipment which was designed by using Stokes Law which defines the rise velocity of oil droplets based on it's density and it's size.The design of the separator is mainly based on the difference between the oil and the water because the difference too small than the specific gravity (sg) difference between the suspended solids and the water. Based on the design criteria.Most of the suspended solids would settle below the separator as a sediment layer the oil will rise to upper side of the separator and the water will be the middle layer and between the oil on upper side and the solids below.

Mostly the oil layer is removed and again re-processed or removed off and the bottom sediment layer is removed by a chain and flight scraper and the sludge pump.The water layer is subsequently sent to further treatment consisting of usually of a Dissolved Air Flotation unit for more removal of any remaining residual oil and then to some type of biological treatment unit for removal of unwanted dissolved chemical compounds.

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Aim

The aim of this project is:-

1. To know about the various separation processes going on in the industry.
2. To know about working of Oil-Gas Separator
3. To design the Oil-Gas Separator(Vertical and Horizontal)

Methodology

This report is organised in Seven chapters.

Chapter1 Will give the introduction

Chapter2 Will give an overview of Separation Processes. The types of Separation and the Equipment used for the given separations

Chapter3 Will focus on the project work of Oil-Gas separators their Functions, Methods used and problems.

Chapter4 Willbe dealing with the designing prospects of oil-gas separators.

Chapter5 Will have the case study problems.

Chapter6 Will have the numerical related to designing of the separators.

Chapter7 Will have the conclusions and recommendations of this study.

INTRODUCTION

Practically in every process requires the separation of entrained material or two non-mixing phases in a process. That may be either as a step in the purification of One stream. These separations may be:

1. Liquid Particles from vapour or gas.
2. Liquid Particles from Non Mixing Liquid.
3. Dust from vapour or gas.
4. Solid particles from liquid.
5. Solid particles from other solid.

These types of operations may sometimes be well known as mist entrainment, decantation, dust collection, filtration, centrifugation, sedimentation, screening, classification, scrubbing and many more. They mostly involve handling relatively huge quantities of 1 phase in order to gather or separate the other one. Therefore the size of equipment will become very large. For the prevention of space and money constraints it is very important that the vessel be specified and rated to operate. This topic will be limited to the removal and separation of the liquid or the solid particle from vapour or gas carrying stream (or) separation of solid particle from a liquid one . Many other specific separation technique such as pressure - leaf filtration, centrifugation , rotatory drum filtration and others that require technology exactly to the vessel and cannot be grouped in many instances.

Particle Size

The particle sizes of the liquid and the solid dispersions will change marked depending upon the origination and nature of the operation generating the particular particles. For the design of the equipment to reduce and eliminate the particles from a fluid stream, it *is* important to either know from a data with range and a distribution of the particle sizes, or in a position to estimate the normal and the extreme expectancies. The significant laws ruling Particle performance in each of the ranges is also shown. Particle size is measured in microns. A micron is 1/1000 millimetre (or) 1/25,400 inch. Amill micron is 1/1000 of a micron (or) 1/1,000,000 millimetre. Usually the particle size is given as an average of diameter in Microns although some literature report particle radius. Particle concentration is mainly expressed as (grains/cubic feet of gas volume) . One grain is 1/7000 of a pound. The mechanism of formation has a controlling influence over the uniformity of particle size and the magnitude of the dimensions. Thus the sprays exhibit a hug particle size distribution, whereas condensed particles such as fumes, mists and fogs are particularly uniform in size. Table P.1 gives the approximate the average particle sizes for dusts which can be generated around the process plants. Table P.2 gives the size ranges for some aerosols, dusts and fumes. Table P.2 gives typical analysis for a few dusts and Table P.3 gives screen and particle size relationships. Table P.4 gives the mean particle size for water spray from a nozzle.

Table P.2
Typical Dust Size Analysis

	DUST			
	Rock	Cement Kiln Exhaust	Foundry Sand	Limestone
Sp. Gravity	2.63	2.76	2.243	2.64
Apparent Wt., lbs./cu.ft.	61.3	52.0	45.9	72.0
Screen Analysis (Percent passed)				
100 Mesh	98.8	99.6	91.2	85.6
200 Mesh	92.8	92.2	78.4	76.4
325 Mesh	79.6	80.8	67.6	66.4
400 Mesh	70.8	73.2	64.4	63.2
Elutriation Analysis: Percent Under Terminal Velocity				
320 In./min. .	75.8	78.0	64.2	70.5
80 In./min. ..	37.0	61.0	53.9	52.0
20 In./min. ..	17.5	40.8	42.0	33.0
5 In./min. ..	8.9	23.0	32.0	18.0

Table 1 Particle Size

Table P.1

Sizes of Common Dusts and Mists

Dust or Mist	Average Particle Diameter, Microns
Human Hair (for comparison)	50-200
Limit of visibility with naked eye	10-40
Dusts	
Atmospheric dust	0.5
Aluminum	2.2
Anthracite Coal Mining	
Breaker air	1.0
Mine Air	0.9
Coal Drilling	1.0
Coal loading	0.8
Rock drilling	1.0
Alkali fume	1-5
Ammonium Chloride fume	0.05-0.1-1
Catalyst (reformer)	0.5-50
Cement	0.5-40-55
Coal	5-10
Ferro-manganese, or silicon	0.1-1
Foundry air	1.2
Flour-mill	15
Fly Ash (Boiler Flue gas)	0.1-3
Iron (Gray Iron Cupola)	0.1-10
Iron oxide (steel open hearth)	0.5-2
Lime (Lime Kiln)	1-50
Marble cutting	1.5
Pigments	0.2-2
Sandblasting	1.4
Silica	1-10
Smelter	0.1-100
Taconite Iron ore (Crushing & Screening)	0.5-100
Talc	10
Talc Milling	1.5
Tobacco smoke	0.2
Zinc oxide fume	0.05
Zinc (sprayed)	15
Zinc (condensed)	2
Mists	
Atmospheric fog	2-15
Sulfuric acid	0.5-15

Table P.3

Dry Particle Screen Sizes

W. S. Tyler Screen Scale	Micron (approximate)
80	174
100	146
115	123
150	104
170	89
200	74
250	61
270	53
325	43

Table P.4

Approximate Particle Sizes From Liquid Full Cone Spray Nozzles

Liquid: Water

Nozzle Size, In.	Operating Pressure, Psig	Approx. Mean Particle Size, Microns
½	15	1200
	60	750
¾	10	1600
	40	1000
1	15	1750
	40	1250
1½	15	2300
	60	1800
3	10	5300
	30	4300

Table 1 Particle Size

Terminal Velocity:

When a particle falls under the effect of gravity it will speed up until the frictional drag in the fluid balances the gravitational forces. At that point it will continue to fall at a constant velocity. This is the terminal velocity (or) free-settling velocity. The general formula for any shape particle are :

$$U_t = \sqrt{(2 * g_L * m_P * (\rho_s - \rho) / \rho\, \rho_s A_p\, C)}$$

For Sphere:

$$U_t = \sqrt{(4 * g_L * D_P * (\rho_s - \rho) / 3 * \rho * C)}$$

SEPARATION PROCESSES

1. SOLID – SOLID SEPARATION:

Processes and vessels is required to extract valuable solids from discarded material and for size grading solid raw material and product. The vessel used for solid-solid separation process is developed mainly for the minerals processing and metallurgical industry for the upgrading of ores. The techniques used depends on difference in physical, rather than chemical, properties, through chemical additives that may be used to enhance the separation .These techniques can be used to select the types of processes likely to be suitable for a particular material and size range. Sorting of material by the appearance by hand, are now rarely used due to high cost of labour.

a) Screening (Sieving):

Screens separate the particles on the basis of particle size. It's main application is the in grading of raw materials and products into the size ranges but they are also used for the removal of the over and undersized contaminants and for removing water. Industrial screening equipment's are used over a wide range of particle size from fine powder to large rocks. For the small particles woven cloth (or) wire screens are widely used and for the larger sizes perforated metal plates or grids are used . Screen sizes are given in two ways 1) by a mesh size number for small sizes and by 2)The actual size of the opening in the screen for large sizes. There are several different standards in use for the mesh size, and it is very important to quote the standard used when specifying the particle size ranges by the mesh size. In the United States the appropriate ASTM Standards are used.

b) Liquid-Solid Cyclones :

Cyclones are used for the classification of the solids as well as for the liquid-solid and the liquid-liquid separation. Liquid cyclones are used for the classification of solid particles over the size range of 5 to 100 mm. Commercial units are also available in the wide range of materials of the construction and sizes as small as 10mm and to up to 30m in diameter. The separating efficiencies of the liquid cyclone depend on the particle size and density and the density and viscosity of the liquid medium.

c) Hydro separators and Sizes :

Classifiers that depend on the difference in the settling rates of different size particles in the water is frequently used for separating of the fine particles in the 50 to 300mm range.

The principal ones used in the chemical process industries are as follows:

Thickeners: They are primarily used for the liquid-solid separation. When they are used for classification, the feed rate is kept such that the overflow rate is always greater than the settling rate of the slurry, and the finer particles remain in the overflow stream.

Rake classifiers: Are inclined shallow rectangular troughs, fitted with mechanical Rakes at the bottom to rake the deposited solids to the top of the incline. Several rake classifiers can be used in series to separate the feed into different size ranges.

Bowl classifiers: Are shallow bowls with concave bottoms fitted with rakes. Their Operation is similar to that of thickeners.

d) Hydraulic Jigs :

Jigs separate solids by difference in density and size. The material is immersed in water, supported on a screen. Pulses of water are forced through the bed of material either by moving the screen or by pulsating the water level. The flow of water fluidizes the bed and causes the solids to stratify with the lighter. Material at the top and the heavier at the bottom.

e) Electrostatic Separators :

Electrostatic separation depends on differences in the electrical properties (conductivity) of the materials to be treated. In a typical process the material particles pass through a high-voltage electric field as it is fed on to a revolving drum which is at earth potential. Those particles that acquire a charge adhere to the drum surface and are carried further around the drum before being discharged.

2. LIQUID-SOLID (SOLID-LIQUID) SEPARATORS :

The need to separate solid and liquid phases is probably the most common phase separation requirement in the process industries, and various techniques are used. Separation is effected by either the difference in density between the liquid or solids using either gravity or centrifugal force or for filtration depends on the particle size and shape. The most suitable technique to use will depend on the solids concentration and feed rate as well as the size and nature of the solid particles. The choice of equipment will also depend on whether the prime objective is to obtain a clear liquid or a solid product and on the degree of dryness of the solid required.

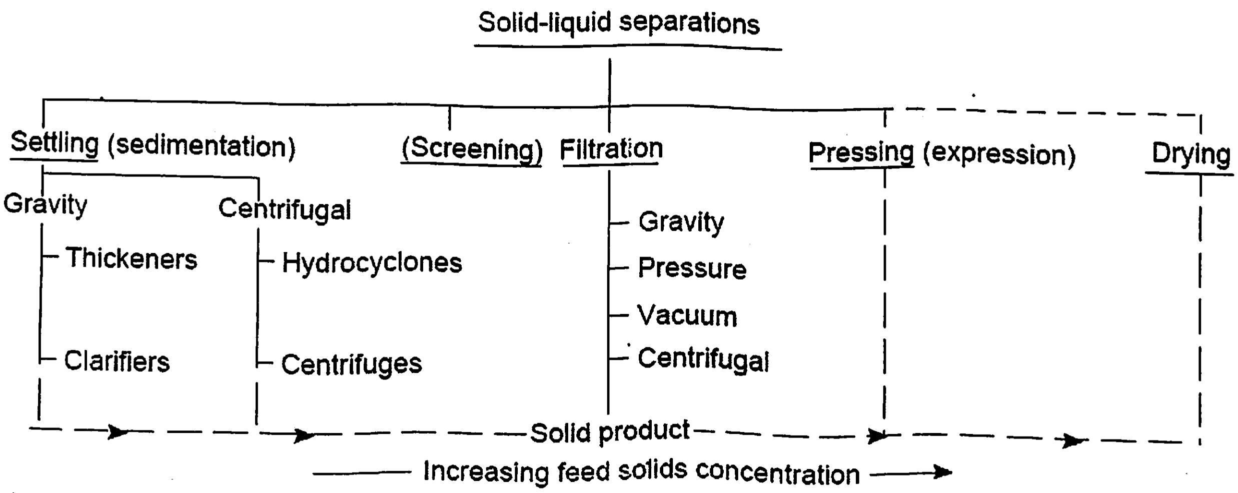


Table2: Solid – Liquid Separations

a) Thickeners and Clarifiers :

Thickening and clarification are sedimentation processes and the equipment used for the two techniques are similar. The primary purpose of thickening is to increase the concentration of a relatively large quantity of suspended solids where that of clarifying as the name implies, is to remove a small quantity of fine solids to produce a clear liquid effluent. Thickening and clarification are relatively cheap processes when used for the treatment of large volumes of liquid. A thickener or clarifier consists essentially of a large circular tank with a rotating rake at the base. Rectangular tanks are also used but the circular design is preferred. They can be classified according to the way the rake is supported and driven. Various designs of rake are used depending on the nature of the solids. Flocculating agents are often added to promote the separating performance of thickeners.

b) Filtration :

In filtration processes the solids are separated from the liquid by passing the slurry through some form of porous filter medium. Filtration is a widely used separation process in the chemical and other process industries. Many types of equipment and filter media are used designed to meet the needs of particular applications. The most commonly used filter medium is woven cloth but a great variety of other media is also used. Filter aids are often used to increase the rate of filtration of difficult slurries. They are either applied as a recoat to the filter cloth or added to the slurry and deposited with the solids assisting in the formation of a porous cake. Industrial filters use vacuum, pressure or centrifugal force to drive the liquid through the deposited cake of solids. Filtration is essentially a discontinuous process. With batch filters such as plate and frame presses, the equipment has to be shut down to discharge the cake and even with those filters designed for continuous operation, such as rotating-drum filters periodic stoppages are necessary to change the filter cloths. Batch filters can be coupled to continuous plants by using several units in parallel or by providing buffer storage capacity for the feed and product. The principal factors to be considered when selecting filtration equipment are:-

1. The nature of the slurry and the cake formed.
2. The solids concentration in the feed.
3. The throughput required.
4. The nature and physical properties of the liquid: viscosity, flammability, toxicity, Corrosiveness.
5. Whether cake washing is required.
6. The cake dryness required.
7. Whether contamination of the solid by a filter aid is acceptable.
8. Whether the valuable product is the solid or the liquid or both.

c) <u>Centrifuges</u> :

Centrifuges are classified according to the mechanism used for solids separation:

a. Sedimentation centrifuges: in which the separation is dependent on a difference in density between the solid and liquid phases.

b. Filtration centrifuges: which separate the phases by filtration? The walls of the centrifuge basket are porous, and the liquid filters through the deposited cake of solids and is removed.

d) Solids Drying :

Removal of water is called drying or other volatile liquids by evaporation. Most solid materials require drying at some stage in their production. The choice of suitable drying equipment cannot be separated from the selection of the upstream equipment feeding the drying stage. The overriding consideration in the selection of drying equipment is the nature and concentration of the feed. Drying is an energy-intensive process and the removal of liquid by thermal drying will be more costly than by mechanical separation techniques. Drying equipment can be classified according to the following design and operating features:-

1. Batch or continuous.
2. Physical state of the feed: liquid, slurry, wet solid.
3. Method of conveyance of the solid: belt, rotary, fluidized.
4. Heating system: conduction, convection, radiation.

3) LIQUID-LIQUID SEPARATION :

Separation of two liquid phases' immiscible or partially miscible liquids is a common requirement in the process industries. For example in the unit operation of liquid - liquid extraction the liquid-contacting step must be followed by a separation stage.

a) Decanters :

Decanters are used to separate liquids where there is a sufficient difference in density between the liquids for the droplets to settle readily. Decanters are essentially tanks that give sufficient residence time for the droplets of the dispersed phase to rise to the interface between the phases and coalesce. In an operating decanter there will be three distinct zones or bands: clear heavy liquid separating dispersed liquid and clear light liquid. Decanters are normally designed for continuous operation but the same design principles will apply to batch-operated units. Variousvessel shapes are used for decanters but for most applications a cylindrical vessel will be suitable and will be the cheapest shape. The position of the interface can be controlled with or without the use of instruments by use of a siphon take-off for the heavy liquid. The height of the take-off can be determined by making a pressure balance. Neglecting friction loss in the pipes the pressure exerted by the combined height of the heavy and light liquid in the vessel must be balanced by the height of the heavy liquid in the take-off leg.

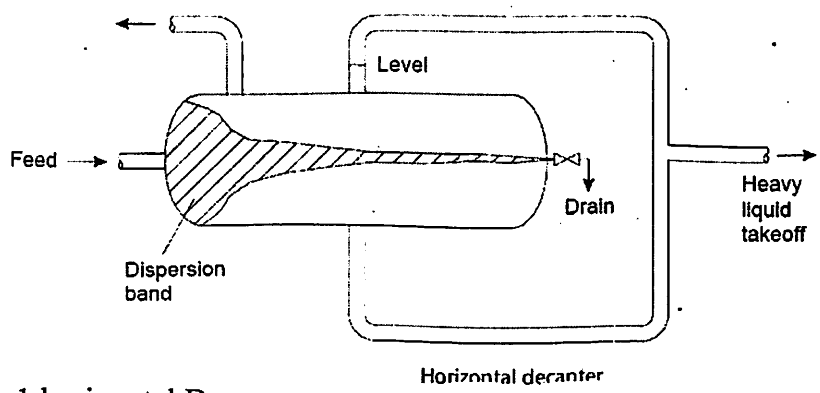


Fig.1 horizontal Decanter

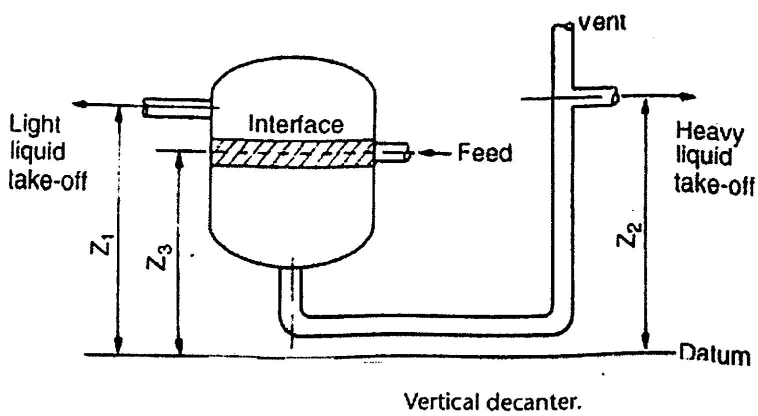


Fig.2 vertical decanter

b) <u>Coalesces</u>:

Proprietary equipment in which the dispersion is forced through some form of coalescing medium is often used for the coalescence and separation of finely dispersed droplets. A medium is chosen that is preferentially wetted by the dispersed phase knitted wire or plastic mesh beds of fibrous material or special membranes are used. The coalescing medium works by holding up the dispersed droplets long enough for them to form globules of sufficient size to settle. Coalescing filters are suitable for separating small quantities of dispersed liquids from large throughputs. Electrical coalesces in which a high voltage field is used to break down the stabilizing film surrounding the suspended droplets are used for desalting crude oils and for similar applications.

4) GAS-SOLID SEPARATIONS :

The primary need for gas-solid separation processes is for gas cleaning—the removal of dispersed finely divided solids and liquid mists from gas streams. Process gas streams must often be cleaned up to prevent contamination of catalysts or products and to avoid damage to equipment such as compressors. Also effluent gas streams must be cleaned to comply with air-pollution regulations and for reasons of hygiene to remove toxic and other hazardous materials .There is also often a need for clean filtered air for processes using air as a raw material and where clean working atmospheres are needed for instance in the pharmaceutical and electronics industries. The particles to be removed may range in size from large molecules measuring a few hundredths of a micrometre, to the coarse dusts arising from the attrition of catalysts or the fly ash from the combustion of pulverized fuels. A variety of equipment has been developed for gas cleaning. It can be used to make a preliminary selection of the type of equipment likely to be suitable for a particular application.

Gas-Cleaning Equipment

Type of Equipment	Minimum Particle Size (μm)	Minimum Loading (mg/m^3)	Approx. Efficiency (%)	Typical Gas Velocity (m/s)	Maximum Capacity (m^3/s)	Gas Pressure Drop (mm H_2O)	Liquid Rate ($m^3/10^3$ m^3 gas)	Space Required (relative)
Dry collectors								
Settling chamber	50	12,000	50	1.5–3	none	5	—	Large
Baffle chamber	50	12,000	50	5–10	none	3–12	—	Medium
Louver	20	2500	80	10–20	15	10–50	—	Small
Cyclone	10	2500	85	10–20	25	10–70	—	Medium
Multiple cyclone	5	2500	95	10–20	100	50–150	—	Small
Impingement	10	2500	90	15–30	none	25–50	—	Small
Wet scrubbers								
Gravity spray	10	2500	70	0.5–1	50	25	0.05–0.3	Medium
Centrifugal	5	2500	90	10–20	50	50–150	0.1–1.0	Medium
Impingement	5	2500	95	15–30	50	50–200	0.1–0.7	Medium
Packed	5	250	90	0.5–1	25	25–250	0.7–2.0	Medium
Jet	0.5 to 5 (range)	250	90	10–100	50	none	7–14	Small
Venturi	0.5	250	99	50–200	50	250–750	0.4–1.4	Small
Others								
Fabric filters	0.2	250	99	0.01–0.1	100	50–150	—	Large
Electrostatic precipitators	2	250	99	5–30	1000	5–25	—	Large

Table 3 Gas cleaning Equipment

a) Gravity Settlers :

Settling chambers are the simplest form of industrial gas-cleaning equipment but have only a limited use they are suitable for coarse dusts particles larger than 50 mm. They are essentially long horizontal rectangular chambers through which the gas flows. The solids settle under gravity and are removed from the bottom of the chamber. Horizontal plates or vertical baffles are used in some designs to improve the separation. Settling chambers offer little resistance to the gas flow and can be designed for operation at high temperature and high pressure and for use in corrosive atmospheres. The length of chamber required to settle a given particle size can be estimated from the settling velocity and the gas velocity.

b) Impingement Separators :

Impingement separators employ baffles to achieve the separation. The gas stream flows easily around the baffles whereas the solid particles due to their higher momentum tend to continue in their line of flight strike the baffles and are collected. Various baffle designs are used in commercial equipment. Impingement separators cause a higher pressure drop than settling chambers but are capable of separating smaller particle sizes 10–20 mm.

c) Centrifugal Separators (Cyclones) :

Cyclones are the principal type of gas-solids separator employing centrifugal force and are widely used. They are basically simple constructions can be made from a wide range of materials and can be designed for high temperature and pressure operation. Cyclones are suitable for separating particles above about 5 mm diameter smaller particles down to about 0.5 mm can be separated where agglomeration occurs. The most commonly used design is the reverse-flow cyclone other configurations are used for special purposes. In a reverse-flow cyclone the gas enters the top chamber tangentially and spirals down to the apex of the conical section it then moves upward in a second smaller-diameter spiral and exits at the top through a central vertical pipe. The solids move radially to the walls slide down the walls and are collected at the bottom.

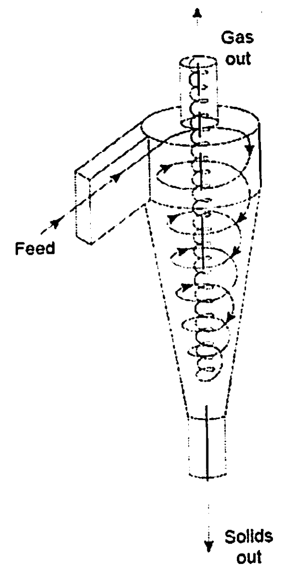


Fig.3 Cyclone

d) Filters :

The filters used for gas cleaning separate the solid particles by a combination of impingement and filtration the pore sizes in the filter media used are too large simply to filter out the particles. The separating action relies on the recoating of the filter medium by the first particles separated which are separated by impingement on the filter medium fibres. Woven or felted cloths of cotton and various synthetic fibres are commonly used as the filter media. Glass-fibre mats and paper filter elements are also used.

e) Electrostatic Precipitators:

Electrostatic precipitators are capable of collecting very fine particles <2 mm at high efficiencies. Their capital and operating costs are high and electrostatic precipitation should only be considered in place of alternative processes such as filtration where the gases are hot or corrosive. Electrostatic precipitators are used extensively in the metallurgical, cement, and electrical power industries. Their main application is probably in the removal of the fine fly ash formed in the combustion of pulverized coal in power station boilers. The basic principle of operation is simple. The gas is ionized in passing between a high-voltage electrode and grounded electrode; the dust particles become charged and are attractedto the earthed electrode. The precipitated dust is removed from the electrodes mechanically, usually by vibration, or by washing. Wires are normally used for the high voltage electrode, and plates or tubes for the earthed electrode.

5) GAS-LIQUID SEPARATORS :

The separations of the liquid droplets and mist from the gas (or) vapour streams are important to the separation of solid particles and with the possible exception of the filtration the same techniques and vessels are used. Where the carryover of some of the fine droplets can be accepted it is also often sufficient to rely on the gravity settling in the vertical (or) horizontal knockout pot. Knitted mesh and demisting pads are mostly used for the betterment of the performance of separating equipment's where the drops are likely to be diminished upto to 1 mm and where high separating efficiency is required. Proprietary demister pads are also available in a more wide range of materials metals and plastics thickness and pad density. For the liquid separators stainless steel pads around the size of 100 mm thick and with a nominal density of 150 kg/m3 are mostly used. The use of a demister pad also allows a smaller vessel to be used. Separating efficiency above the value of 99% can be obtained with a low pressure drop. Cyclone separators can also be used for the gas-liquid separation. It can be designed from the same methods for the gas-solids cyclones. The inlet velocity can be kept below 30 m/s to the avoid pickup of the liquid from the cyclone surfaces.

Settling Velocity:

$$u_t = 0.07[(\rho_L - \rho_v)/\rho_v]^{1/2}$$

where

u_t = settling velocity, m/s;
ρ_L = liquid density, kg/m^3;
ρ_v = vapor density, kg/m^3.

a) Vertical Separators:

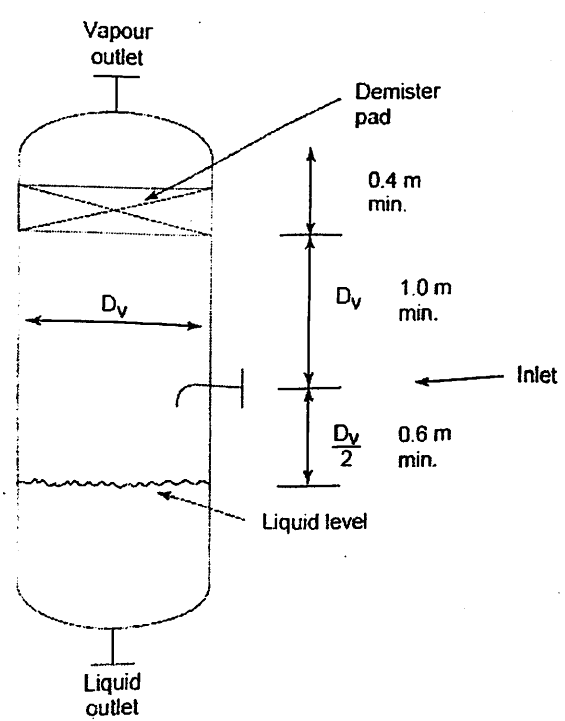
The layout and the typical proportions of the vertical liquid-gas separator is shown in the figure below . The diameter of vessel must be big enough to slow the gas below the velocity at which the droplets will tend to settle out. So the minimum allowable diameter will be given by:

$$D_v = \sqrt{\left(\frac{4V_v}{\pi u_s}\right)}$$

where

D_v= minimum vessel diameter, m;
V_v = gas, or vapor volumetric flow rate, m^3/s;
u_s = u_t, if a demister pad is used, and 0.15 u_t for a separator without a demister pad

U_t can be got from the terminal velocity equation.



Vertical liquid-vapor separator.

Fig 4 Vertical liquid – Vapour Separator

b) Horizontal Separators:

A horizontal separator is selected when there is a long liquid holdup time is required. In the design of the horizontal separator, the vessel diameter will not be determined independently of the length unlike for the vertical separator. The diameter and the length and level of the liquid must be chosen such as to give sufficient vapour residence time for liquid droplets to spill out and for the required liquid holdup time to be met. The most economical length to diameter ratio will depend on the operating pressure.

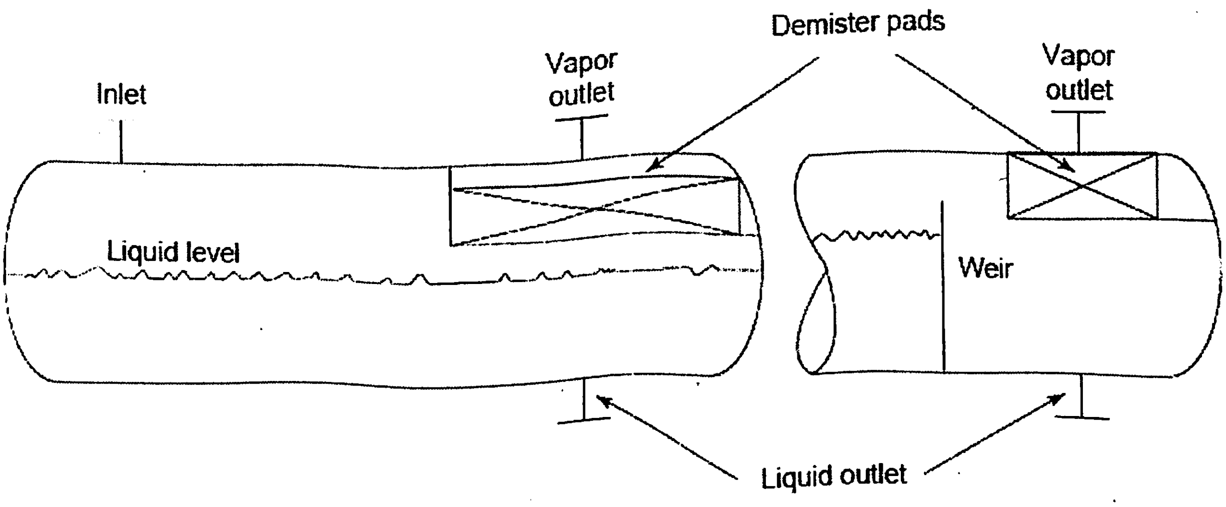
As a general guide, the following values can be used:

Operating Pressure, bar	Length: Diameter, L_v/D_v
0–20	3
20–35	4
>35	5

The relationship between the area for vapour flow and the height above theliquid level has been found from tables giving the dimensions of the segments of circles . For preliminary designs set the liquid height at half the vessel diameter

$h_v = D_v/2$ and $f_v = 0.5$,

Wheref_v is fraction of the total cross-sectional area occupied by the vapour.



Horizontal liquid-vapor separator.

Fig 5 Horizontal Liquid Vapour separator

PROJECT WORK

OIL – GAS SEPARATORS:

The term "oil and gas separator" in oilfield meaning tells about a pressure vessel which is used for separating well fluids got from oil and gas wells into gaseous and liquid components.

A separating vessel may be said to in the following ways:

1, Oil and gas separator.

2. Separator.

3. Stage separator.

4. Trap.

5. Knockout vessel, knockout drum. Knock out trap water knockout, or liquid knockout.

6. Flash chamber, flash vessel, or flash trap

7. Expansion separator or expansion vessel.

8. Scrubber (gas scrubber). dry or wet type.

9. Filter either dry or wet type.

10. Filter Separator.

<u>An oil and gas separator may generally include the below essential components and features</u>:

1). A vessel that includes

(a) Primary separation device.

(b) Secondary gravity separation section.

(c) Mist extractor to free liquid particles from the gas.

(d) Gas outlet.

(e) Liquid settling section to remove gas and vapour from oil.

(f) Oil outlet.

(g) Water outlet in case of three-phase unit.

2). Enough volumetric liquid capacity to handle liquid slug from the wells or the flow lines.

3). Have an enough vessel diameter and height (or) length to allow most of the liquid to separate from the gas.

4). A means of controlling an oil level in the separator, which usually includes a liquid-level controller and a diaphragm motor valve on the oil outlet. For three-phase operation, the separator must include an oil/water interface liquid-level controller and a water-discharge control valve.

5. A backpressure valve on the gas outlet to maintain a steady pressure in the vessel.

6. Pressure relief devices.

Primary functions of Oil – gas separator :

1. Removal of oil from gas:

Difference in density of the liquid and gaseous hydrocarbons may help in separation in an oil and gas separator. However in some circumstances it is important to use mechanical devices commonly referred to as mist extractors to remove the liquid mist from the gas before it can be discharged from the separator. Also it may be useful to use some means to remove non-solution gas from the oil before the oil is removed from the separator.

2. Removal of gas from oil :

The physical and chemical characteristics of the oil and its conditions of pressure and temperature will determine the amount of gas it will contain in the solution. The amount at which the gas is liberated from a given oil is a function of change in pressure and temperature. The volume of gas that an oil and gas separator will ought to remove from crude oil depends on :

(1) Physical and chemical characteristics of the crude

(2) Operating pressure

(3) Operating temperature

(4) Rate of throughput

(5) Size and configuration of the separator

3. Separation of water from oil :

In some cases it is useful to separate and to remove water from the well before it flows through the pressure reductions such as those caused by chokes and valves. Water removal can prevent difficulties that could be caused downstream by the water such as corrosion, hydrate formation, and formation of tight emulsion that may be difficult to resolve into oil and water.

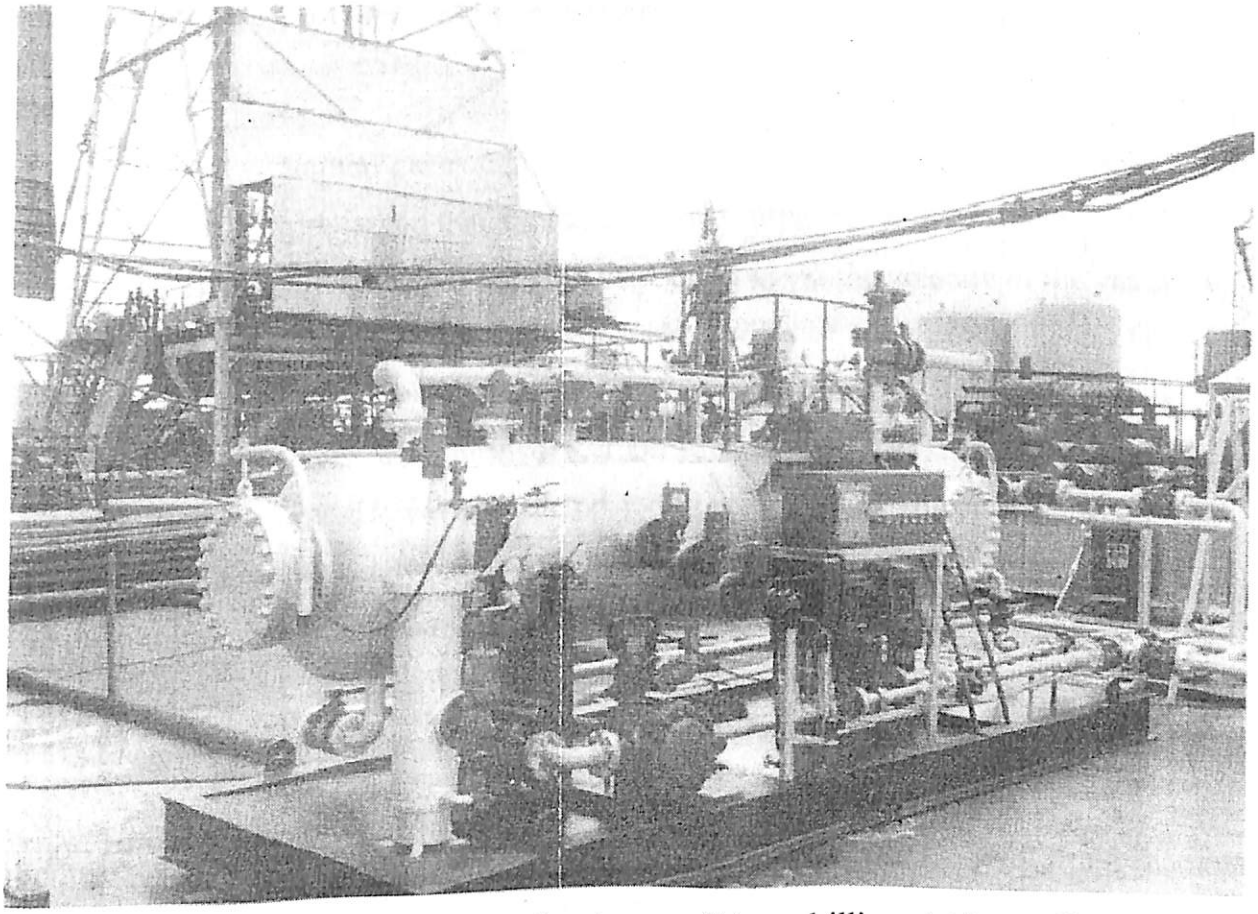


Fig6. Horizontal skid-mounted three-phase well tester on offshore drilling platform off coast of Brazil

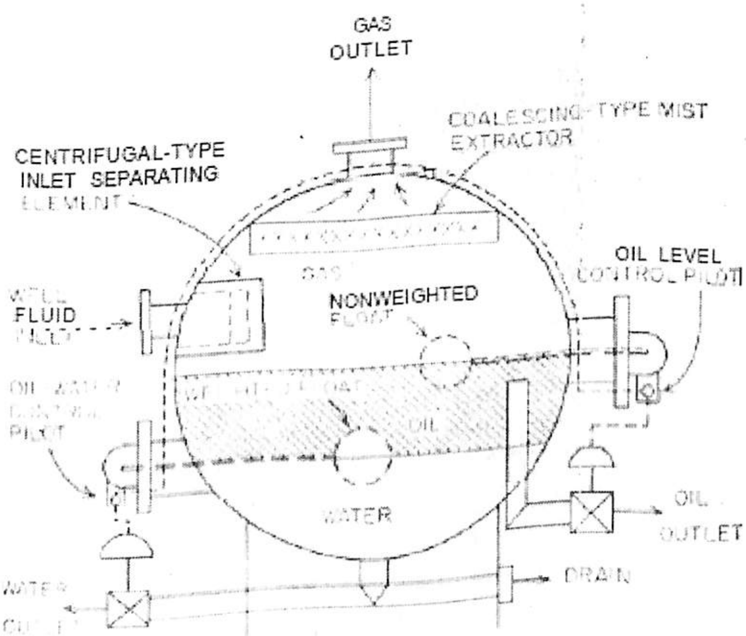


Fig7. Spherical 3 phase oil/gas/water separator

Methods Used to remove Oil from Gas in Separators:

1) Density Difference :

Natural gas is lighter than compared to liquid hydrocarbon. Small particles of liquid hydrocarbon that are for short time suspended in a stream of natural gas will by density difference get out of the stream of gas if the velocity of the gas is relatively slow. The bigger droplets of hydrocarbon will fast settle out of the gas but the smaller ones will take longer time. At standard condition of pressure and temperature, the droplets of liquid hydrocarbon can have a density of 400 to 1,600 times that of natural gas. However as the operating pressure and temperature increase the difference in density decreases. At an operating pressure of approximately 800 psig the liquid hydrocarbon shall be only 6 to 10 times as dense as that gas. Thus the operating pressure materially affects the size of the separator and the size and type of mist extractor required to separate properly the liquid and gas.

2) Impingement :

In a flowing stream of gas containing liquid mist is impinged on a surface the liquid mist might stick to and add up on the surface. After the mist adds up into bigger droplets the droplets will fall down to the liquid section of the vessel. If the liquid content of the gas is high (or) if the mist particles are very fine many successive impingement surfaces may be required to effect proper removal of the mist.

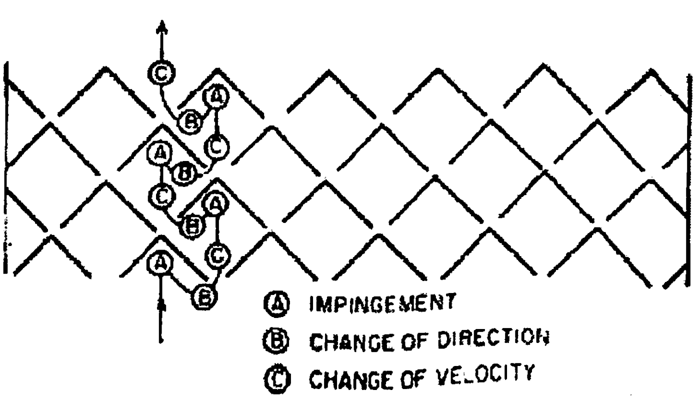


Fig8. Impingement

3) Change of Flow Direction :

When the direction of the flow of the gas stream having liquid mist is changed at an instant the inertia causes the liquid to continue in the original direction of flow. Separation of liquid mist from the gas therefore can be effected because the gas will more easily think the change of flow direction and will tend to flow away from the liquid mist particles. The liquid is thus removed and may coalesce on a surface (or) fall to the liquid section below.

4) Change of Flow Velocity :

Separation of liquid and gas can be greatly be effected with either a sudden increase or a sudden decrease in gas velocity. Both conditions use the difference in movement of gas and liquid. With a decrease in velocity, the higher inertia of the liquid mist carries it forward and away from the gas. The liquid may then coalesce on some surface and gravitate to the liquid section of the separator. With an increase in gas velocity, the higher inertia of the liquid causes the gas to move away from the liquid, and the liquid may fall to the liquid section of the vessel.

5) Centrifugal Force :

If at all a gas stream carrying liquid mist flows in a circular manner at very high velocity centrifugal force tends to throw the liquid mist outward against the walls of the container. Now the liquid adds on into progressively bigger droplets and finally settles to the liquid section. Centrifugal force is by far the best method of separating liquid mist from gas. Efficiency of this type of mist extractor increases as the velocity of the gas stream increases. Thus for a given rate of entrance a smaller centrifugal separator will be enough.

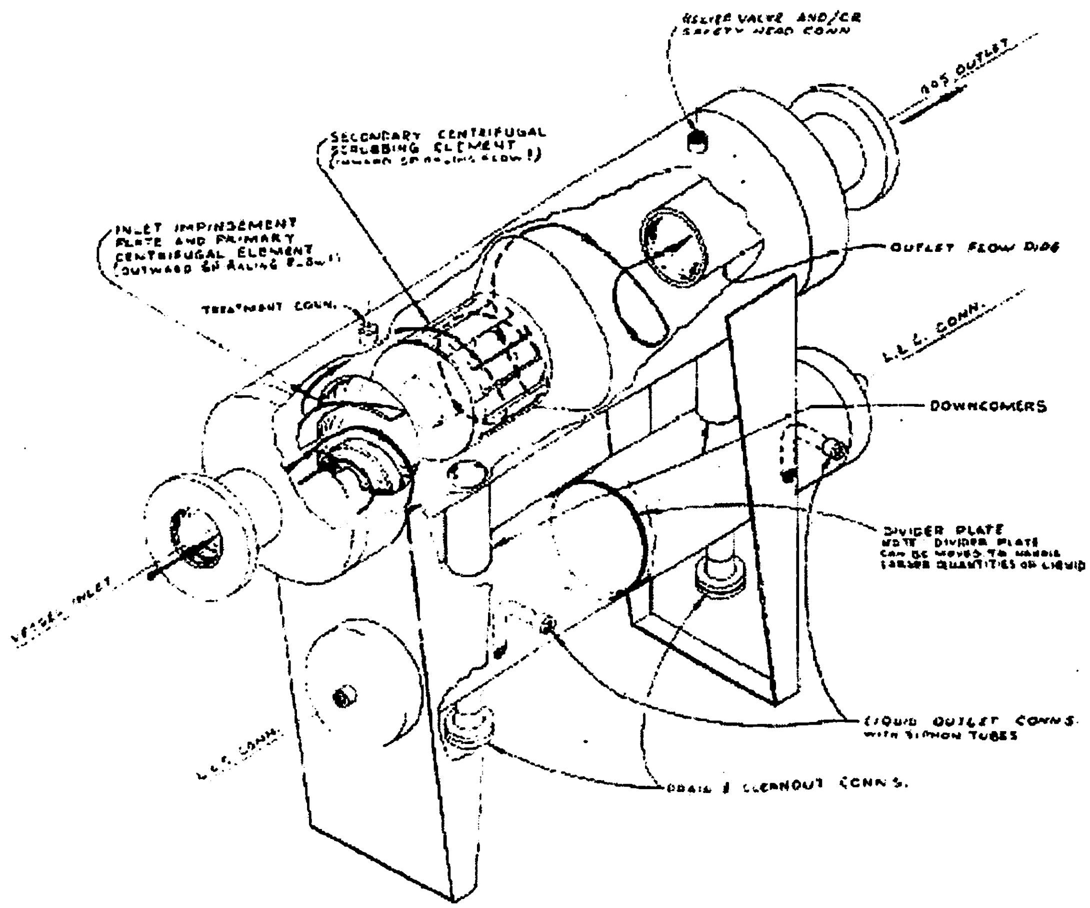


Fig9. Dual-Tube Horizontal two-phase Oil and Gas Separator with centrifugal Primary and Secondary Separating Elements.

6) Coalescence :

Coalescing packs have an effective means of separating and removing the liquid mist from the stream of natural gas. The most important use is the removal of liquid mist from the gas in transmission and distribution systems where the value of liquid in the gas is low.

7) Filtering :

Porous filters are very useful in removing the liquid mist from gas in certain applications. The porous material filters the liquid mist from the gas. The porous material uses the principles of impingement, the change of flow direction, and the change of velocity to help in separation of liquid mist from gas.

Methods Used to remove Gas from Oil in Separators:

1) Settling :

Gas found in crude oil which is not in solution in the oil will usually tend to separate from the oil if it is allowed to settle for a sufficient length of time. An increase in hold up time for the given liquid output requires an increase in the size of the equipment (or) an increase in the liquid depth in the separator. Thus increasing the depth of oil in the separator may not get the increased emission of non-solution gas from the oil because "stacking up" of the oil may retaliate the gas from coming out. Exact removal of gas from oil is usually got when the body of oil in the separator is thin that is to say when the ratio of surface area to \ retained oil volume is high.

2) Agitation :

Agitation is useful in the removal of non-solution gas that may be mechanically locked in the oil by the phenomenon of surface tension and oil viscosity. Agitation will usually cause the gas bubbles to add up and to get away from the oil in less time than it would be required if the agitation was not used. Agitation can be obtained by properly designed and placed baffling.

3) Heat :

Heat helps in reducing the surface tension and viscosity and therefore helps in releasing gas that is hydraulically retained in the oil. The best method of heating crude oil is to pass it through a heated-water bath. A spreader plate which disperses the oil into small streams increases the effectiveness of the heated-water bath.

4) Chemicals :

Chemicals tend to reduce the surface tension of crude oil and help in freeing non-solution gas from the oil. Such chemicals will eventually reduce the foaming tendency of the oil and therefore upgrade the capacity of a separator when foaming oil is handled. Silicone is the most effective in reducing the foaming tendency of crude oil when it tends to be mixed with the oil in such a small quantity as parts per million (or) parts per billion.

5) Centrifugal Force :

Centrifugal force is the most effective in separating gas from oil. The heavier oil is easily thrown out against the wall of the vortex retainer and the gas occupies the inner portion of the vortex. With proper shape and size vortex will allow gasto g up while the liquid will flow downward to the bottom of the unit.

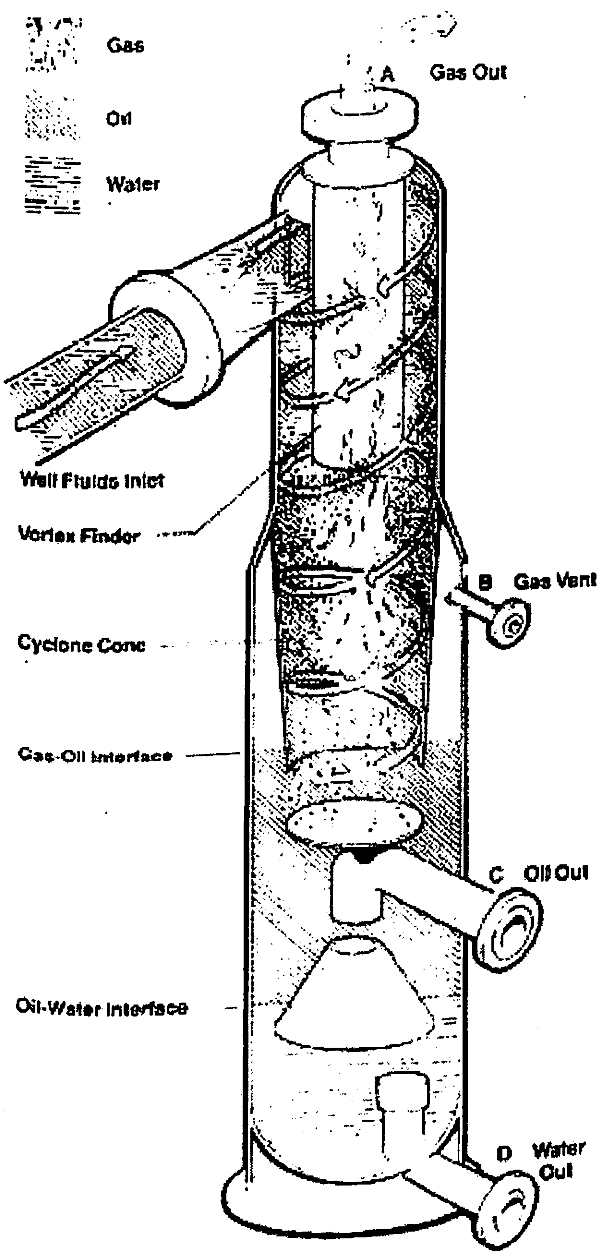


Fig10. Vertical three-phase separator with centrifugal force to obtain primary separation

Estimated Quality of Separated Fluids

1) Crude Oil :

ESTIMATED QUALITY OF SEPARATED CRUDE OIL

Approximate Oil Retention Time (minutes)	Estimated Free (Nonsolution) Gas Content of Effluent Oil (%)*		Estimated Range of Water Content of Effluent Oil			
			Minimum		Maximum	
	Minimum	Maximum	(ppm)	(%)**	(ppm)	(%)**
1 to 2	5.0	20.0	16,000	1.60	80,000	8.00
2 to 3	4.0	16.0	8,000	0.80	40,000	4.00
3 to 4	3.0	12.0	4,000	0.40	20,000	2.00
4 to 5	2.5	10.0	2,000	0.20	10,000	1.00
5 to 6	2.0	8.0	1,000	0.10	5,000	0.50
6 +	1.5	6.0	500	0.05	2,500	0.25

*Expressed as a percent of the total oil volume with the gas measured at standard pressure and temperature.
**Volume basis

Table 4. Estimated Quality of Separated crude Oil

2) Separated Water :

ESTIMATED QUALITY OF SEPARATED WATER

Water Retention Time (minutes)	Estimated Range of Oil Content of Effluent Water			
	Minimum		Maximum	
	(ppm)	(%)*	(ppm)	(%)*
1 to 2	4,000	0.40	20,000	2.00
2 to 3	2,000	0.20	10,000	1.00
3 to 4	1,000	0.10	5,000	0.50
4 to 5	500	0.05	2,500	0.25
5 to 6	200	0.02	1,000	0.10
6 +	40	0.004	200	0.02

*Volume basis.

Table5 . Estimated Quality of Separated Water

3) Gas :

ESTIMATED QUALITY OF SEPARATED GAS

Operating Pressure (psig)	Operating Temperature (°F)	Estimated Oil Content of Effluent Gas			
		Minimum		Maximum	
		(ppm)	(gal/MMscf)	(ppm)	(gal/MMscf)
0 to 3,000	60 to 130	0.01335	0.10*	0.1335	1.00**

*Equivalent to 14.129 L/NM^3 × 10^6
**Equivalent to 141.29 L/NM^3 × 10^6

Table6 . Estimated Quality of Gas

Comparison of Oil and Gas Separators

The table below is not intended as an absolute guide but affords a relative comparison of the various characteristics or features of the different separators over the range of types, sizes, and working pressures. We have to assume them to be mono tube vessels

COMPARISON OF ADVANTAGES AND DISADVANTAGES OF HORIZONTAL, VERTICAL, AND SPHERICAL OIL AND GAS SEPARATORS, TWO- AND THREE-PHASE

Considerations	Horizontal (Monotube)*	Vertical (Monotube)*	Spherical (One Compartment)*
Efficiency of separation	1	2	3
Stabilization of separated fluids	1	2	3
Adapatability to varying conditions	1	2	3
Flexibility of operation	2	1	3
Capacity (same diameter)	1	2	3
Cost per unit capacity	1	2	3
Ability to handle foreign material	3	1	2
Ability to handle foaming oil	1	2	3
Adaptability to portable use	1	3	2
Space required for installation			
Vertical plane	1	3	2
Horizontal plane	3	1	2
Ease of installation	2	3	1
Ease of inspection and maintenance	1	3	2

*Ratings: (1) most favorable; (2) intermediate; (3) least favorable.

Table7 . Comparison of vertical, horizontal and spherical separator

Special Problems in Oil and Gas Separation

1) Separating Foaming crude Oil :

When the pressure is drastically reduced to certain types of crude oil, tiny bubbles of gas are formed in a thin film of oil when the gas comes out of solution. This might result in froth being dispersed in the oil and thus creating what is known as foaming. In the other types of crude oil the viscosity and surface tension of the oil might mechanically lock gas in the oil causes an effect similar to foam. Oil foam is not stable unless a foaming agent is present in the oil. Foaming in crude oil may take place when

(1) The API gravity is less than 40° API

(2) The operating temperature is less than 160°F

(3) The crude oil is viscous having a viscosity greater than 5,000 SSU (about 53 cp).

Foaming to a very extent reduces the capacity of oil and gas separators because a longer retention time is required to separate properly a particular quantity of foaming crude oil. Foaming crude oil thus cannot be measured accurately with positive-displacement meters (or) with the help of conventional volumetric metering vessels. The problems combined with the potential loss of oil and gas because of improper separation emphasizes the need for special equipment and procedures in handling foaming crude oil.

2) Paraffin :

The Deposition of Paraffin in oil and gas separators reduces separator's efficiency and makes them capable of not working by partially filling the vessel (or) blocking the mist extractor and the fluid passages. Paraffin can be effectively removed from separators by use of steam or solvents. However the best way is to prevent the initial deposition in the vessel by heat (or) chemical treatment of the fluid. Another method useful in most instances which involves the coating of all the internal surfaces of the separator with plastic for which paraffin has very little or no affinity. The weight of the paraffin will cause it to remove off of the plastic-coated surface before it builds up to harmful thickness.

3) Sand, Silt, Salt etc. :

If sand and other solids are continuously produced in proper quantities with the well fluids they ought to be removed before the fluid enters the pipelines. Medium grained sand which is found in small quantities can be removed by settling it in oversized vertical equipment with a conical bottom and by time to time draining the residue from the vessel. Salt can be taken away by mixing water with the oil and after the salt has been dissolved the water can be separated from the oil and drained from the system.

4) Corrosion :

Produced well fluids tend to be very corrosive and are said to have caused early failure of equipment. The two very common corrosive elements are hydrogen sulphide and carbon dioxide. These two gases might be available in the well fluids in quantities that range from to 40 to 50% of the gas by volume.

DESIGNING

There are two major types of separation processes, component and phase separation. In component separation, the components are separated from a single phase by mass transfer. An example is gas absorption where one or more components are removed from a gas by dissolving in a solvent. In phase separation, two or more phases can be separated because force acting on one phase differs from force acting on another phase or because one of the phases impacts on solid barrier. The forces are usually gravity, centrifugal, and electromotive.

Examples are removal of solid from a liquid by impaction, gravity, centrifugal force, and the attraction of charged particles in an electrostatic precipitator. One exception to these mechanisms is drying by evaporating unbounded water from a solid. In this case, separation of liquid from solid occurs by mass transfer. For example, the water mixed with sand can be removed by evaporating the water. Because many component separations require contacting two phases, like liquid- liquid extraction, component separation is frequently followed by phase separation. Phase separators can be classified according to the phases in contact: liquid-gas, liquid-liquid, liquid-solid, solid-gas and solid-solid.

Vessel Designing:-

Most vessels in the process industries are thin-walled vessels, which have a wall thickness of less than about 5% of the inside diameter of a vessel. Internal pressure acting on walls of a cylindrical vessel produces a longitudinal and radial stress, also called hoop stress. For thin-wall vessels, it may be assumed that the radial stress is approximately uniform across the wall. Rase and Borrow for example, shows that the radial stress, produced by an internal pressure (P) is given by-

S=PD/4 ts

D- Diameter of vessel

The radial stress is larger than the longitudinal stress, and thus it must be used to calculate the wall thickness **ts**. If a cylindrical vessel fails, it will spilt longitudinally.

Vessels larger in diameter than about 30 in (0.672m) and above are fabricated from plates, which are formed into cylinders, called shells, and welded longitudinally. Shell smaller than 30 in (0.672m) may be extruded and thus will not contain a longitudinal weld. Shells may then be joined by welding circumferentially to form longer shells. After fabricating the shell, end caps, called heads are welded to the shell to form the vessel. Because the weld may have imperfections, the radial stress will be less than its maximum value. Thus, S is multiplied by a joint or weld efficiency E which depends on the type of x-ray inspection of the weld.

Thus,

ε s=PDM/4 ts

DM- Mean diameter is the average of the outside and inside.

Equations for Calculating Vessel Wall Thickness

P = 1.1P0' — or (1)

P = P0' + 25 psi — whichever is larger

For a shell

αs = p\2εs' s'-1.2P –(2)

For a tori spherical head:

αh = 1.104 P\2εh's'- 0.2 P (for torrisperical)

αh = P\2εh's'- 0.2 P (for ellipsoidal)- (3)

ts = αs D' + tc' –(4)

tH = αH D' + tc' – (5)

Variables

P, ts, tH, αs, αH

Calculation Procedure for Calculating Vessel Wall Thicness:-

- Calculate the design pressure, P from equation one where Po is the expected operating pressure.
- Select the shell and head weld efficiencies, epsilon s & epsilon h.
- Calculate shell factor in a hoop stress from eq-2.
- Calculate the head factor from 3.
- If P<150 psig select a torrispherical head & if P >150 select an ellipsoidal head.
- Calculate shell thickness from 4.
- Calculate head thickness from 5.
- Now select a standard thickness from a vessel manufacturer.

Vortex formation in vessels:-

Vortex formation in the separators must be prevented to reduce gas entrainment in the liquid which can result in the following major things:-

- Loss of valuable vapour.
- Pump damage.
- Loss of flow.
- Erroneous liquid level readings resulting in poor control.
- Vibration caused by unsteady 2phase flow.

Even the most common bathtub vortex is of scientific interest. Sibuklin describes experiments to determine the effect of earth's rotation on the rotation of bathtub vortex. The earth's rotation induces a small angular velocity when draining water the direction of rotation of bathtub vortex is usually accidental. Its mainly determined by residual motion caused by the method of filling the tub. Care is must taken to residual motions then the direction of vortex rotation will consistently be counterclockwise in the Northerm Hemisphere & clockwise in the Southerm Hemisphere.

Gas & Liquid Separator:-

Gas-Liquid or Vapor-Liquid separators are to recover valuable products, improve the product purity, reduce emissions & protect downstream equipments. Gas-Liquid are used after flashing a hot liquid across a valve. In this case separator is called a flash drum. The mixture which is to separate enters the separator about midway where a splash plate deflects the stream downward. It is separated by the principle of gravity and impaction. Liquid flows downward and the vapor flows upward in the separator. Due to gravity large drops settle down as the vapor arises. The separation of about 95% liquid from vapor is normal and if its greater than 95 percent then use a wire mesh mist eliminator installed near the vapor outlet. By the impaction using a wire mesh pad which s located at the top of the separator very small drops are separated. The mesh size is of 0.011in diameters wires interlocked by a knitting machine to form a pad from 4-6 in thick. The efficiency of separation of the pad is about 99.9% or greater. The main objective in sizing a gas-liquid separator is to lower the gas velocity sufficiently to reduce the number of liquid droplets from being entrained in the gas. That's why the separator dia. Is determined. The separator is also designed as an accumulator for the liquid portion of the stream. Thus the liquid height is calculated by allowing sufficient surge time to dampen flow-rate variations of the liquid stream as was discussed earlier for accumulators. This liquid height will also be sufficient to allow vapor bubbles to rise to the top of the liquid before being trapped in the outlet stream at the bottom of the vessel. This can be achieved by reducing the outlet liquid velocity by increasing the diameter of the outlet nozzle. In the separator there is not a single drop size but a distribution of drop sizes. To prevent all drops from being carried out by the gas stream would require an uneconomically large separator. Maximum gas velocity is specified so that all but the very small drops are recovered. An empirical expression for the maximum gas velocity is derived by considering the forces acting on a small drop suspended in a gas stream. These forces are gravity acting downward and the buoyant and drag forces acting upward.

Types of Gas-Liquid separator:-

- Vertical Separator.
- Horizontal Separator.
- Spherical Separator.
- Centrifugal Separator.
- Compact Separator.

Vertical Separator

There is several design procedures reported in the literature - not all of them are in agreement. Gas-liquid separators may be designed for horizontal or vertical operation but Younger found that for seven separators in use with L/D varying from 1.7 to 3.6 all were installed vertically. This is consistent with the rule given by Brenan that if L/D > 5 a horizontal separator should be used. Equations for sizing vertical gas-liquid separators are summarized and a calculation procedure is outlined. The volume of the dished heads is not included in the calculation procedure. As for sizing knockout drums first calculate the drum diameter. Next calculate the droplet settling length. This is the length from the center line of the inlet nozzle to the bottom of the mist eliminator. Schema recommends that the settling length should be to 0.75 D or a minimum of 12 in (0.305 m) whereas Gerund specifies a length equal to the diameter or a minimum of 3 ft (0.914 m). Also to prevent flooding the inlet nozzle Schema allows a minimum of 6 in (0.152 m) from the bottom of the nozzle to the liquid surface or a minimum of 12 in (0.305 m) from the center line of the nozzle to the liquid surface. Brenan recommends using 12 in (0.305 m) plus % of the inlet nozzle outside diameter or 18 in (0.4570 m) minimum. Gerund specifies a length equal to 0.5 D or 2 ft (0.610 m) minimum. Now calculate the liquid height. The separator is also sized as an accumulator to dampen variations in the liquid flow rate by allowing sufficient liquid residence time or surge time in the separator. Schema recommends a surge time in the range of 2 to 5 min whereas Younger recommends 3 to 5 min.

There is a minimum liquid height required to prevent a vortex from forming. The design of the separator will have to include a vortex breaker. The minimum liquid level should cover the vortex breaker plus an additional liquid height. Experiments conducted by Patterson showed that the lower liquid level varies slightly with the liquid velocity in the outlet nozzle. For a velocity of 7 ft/s (2.13 m/s) in the outlet piping of a tank with no vortex breaker, a vortex forms at a liquid level of about 5 in (0.127 m). The flow should be turbulent to break up any vortex. Thus, Gerund's recommendation allowing a 2 ft (0.610 m) minimum liquid level should suffice. To complete calculating the lengths of the separator specify the thickness of the mist eliminator, which must be thick enough to trap most of the liquid droplets rising with the vapor. The thickness of the eliminator is usually 6 in (0.152 m). An additional 12 in (0.305 m) above the eliminator is added to obtain uniform flow distribution across the eliminator. If the eliminator is too close to the outlet nozzle a large part of the flow will be directed to the center of the eliminator, reducing its efficiency. The total length of the separator can now be calculated by summing up the dimensions. According to Brenan L/D is greater than 5use a horizontal separator. Brenan states that if L/D < 3 increases L in order that L/D > 3 even if the liquid surge volume is increased. Increasing the surge volume is in the right direction.

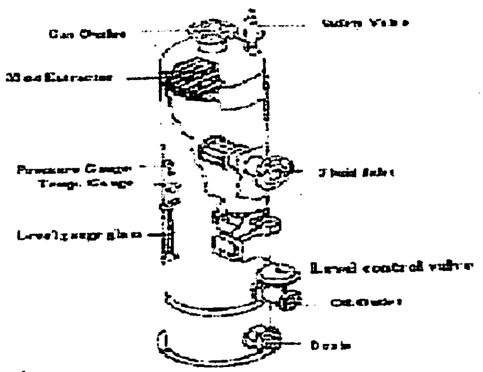


Fig 11 Vertical Separator

Summary of Equations for Sizing Vertical Gas-Liquid Separators

Vv'= vvA -(1)

$Vv = kv\ (\rho l' - \rho v'/\rho v')^{1\backslash 2}$ -(2)

kv = 0. 1 ft/s (0.03045 m/s) — with no mist eliminator -(3)

kv = 0.35 ft/s (0.0107 m/s) — with a mist eliminator

$A = \pi D^2/4$ -(4)

Ll A = VL' ts — where the minimum value of LL is 2 ft (0.610 m) -(5)

3 <ts< 5 min -(6)

L = LL+1.5D+1.5ft or -(7)

L = 8.5 ft (2.59 m) — whichever is larger

Variables

vv - A - kv - D - L - Ll – ts

Calculation Procedure for Sizing Vertical Gas-Liquid Separators

1. Select kv from Equation 3.

2. Calculate the maximum gas velocity Vv from Equation 2.

3. Calculate the cross-sectional area A from Equation 1.

4. Calculate D from Equation 6.9.4.

5. Round off D in 6 in (0.152 m) increments starting at 30 in (0.762 m). If D is Less than 30 in (0.762 m) use standard pipe.

6. Select a liquid-phase surge time ts from Equation 6.

7. Calculate the liquid-level height from Equation 5.

8. Calculate the total separator height from Equation 7. Round off L in 3 in (0.0762 m) increments.

9. If L/D < 3.0 then recalculate L so that L/D > 3.0 by letting L/D = 3.2. If L/D >5use a horizontal separator.

HORIZONTAL SEPARATORS

Like vertical gas-liquid separators there are several design procedures not all of them are in agreement. For horizontal separators, the calculation procedure for sizing is essentially the same as vertical separators except increase kv by 25 % . Also the minimum value of the cross-sectional area for gas flow should be at least 20 % of the total cross-sectional area of the separator. Use a 6 in (0.152 m) mist eliminator and a distance of 12 in (0.3048m) above the eliminator. According to Gerund the distance from the bottom of the mist eliminator to the liquid level should be at least 2 ft (0.610 m) and should not be below the center of the separator. Steinman recommends 6 in (0.152 m). Use an average of 1.25 ft. The main consideration is to prevent the mist eliminator from flooding because of a rising liquid level. We will design for a liquid level at the center of the separator. These rules result in a minimum diameter of 5.5 ft if the liquid level is at the center of the separator, as shown. This diameter might result in a short separator length if the liquid flow rate is small. If this occurs it may be necessary to increase the separator length or employ other designs for reducing the diameter as given by Silages and the calculation procedure for calculating L and D. As was the case for vertical gas-liquid separators if $L/D < 3$ increases L so that $L/D > 3$ even if the liquid surge volume is increased. Similarly if $L/D > 5$ increase D so that $L/D < 5$. Increasing D will reduce the gas velocity and increase the liquid surge volume which is in the right direction. The volume of the dished heads is not included in the design procedure.

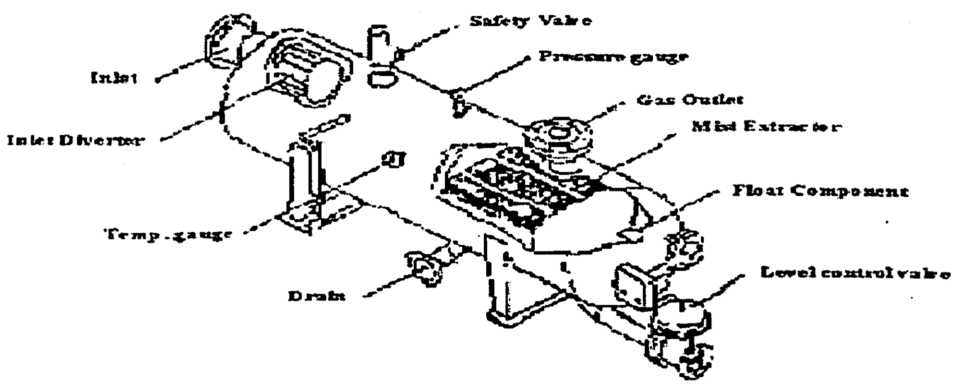


Fig 12 Horizontal Separator

Summary of Equations - Sizing Horizontal Gas-Liquid Separators

$Vv' = 0.5VvA$ -(1)

$Vv = 1.25\ kv\ (\rho l' - \rho v'/\rho v)^{1/2}$ -(2)

kv = 0.10 ft/s (0.0305 m/s) — with no mist eliminator -(3)

kv = 0.35 ft/s (0.107 m/s) — with a mist eliminator

$A = \pi D^2/4$ - Minimum D = 5.5ft(1.6m) -(4)

$0.5\ L\ A = Vl'\ ts$ (5)

$7.5 < ts < 10$ min (6)

Variables

Vv - A - kv - D - L – ts

Calculation Procedure for Sizing Horizontal Gas-Liquid Separators

1. Select kv from Equation 3.

2. Calculate the maximum vapor velocity Vv from Equation 2.

3. Calculate the cross-sectional area A from Equation 1.

4. Calculate D using Equation 6.11.4. Round off D in 6 in (0.152 m) intervals starting at 30 in (0.762 m). If D is less then 30 in (0.762) use standard pipe.

5. Select a liquid phase surge time ts from Equation 6.

6. Calculate the separator length from Equation 6.11.5. Round off L in 3 in (0.0762 m) intervals.

7. If $L/D < 3.0$ then recalculate L so that $L/D > 3.0$ by setting $L/D = 3.2$. If $L/D > 5.0$, then recalculate D so that $L/D < 5.0$ by setting $L/D = 4.8$.

CALCULATIONS

Q. The following is the given data for Vertical Separator. Estimate it's sizing for oil separator also.

Maximum Gas flow rate	50 MMscf/D
Specific gravity of gas	0.70
Maximum oil rate	30 B/D
Specific Gravity	0.934
Operating Temperature	115 ^{0}F
Operating pressure	185 psig
Design Pressure	250 psig
Oil Retention Time	2 min
Gas Compressibility Factor	0.97
Two – phase Operation	No Water

$F_{c0} = 0.167$, $M_g = 28.97 * 0.7 = 20.28$

Solution :

For the calculation of $\rho_g = p\, M_g / Z_g\, RT$

Where T is in ^{0}R

$\rho_g = (199.7)(20.28) / (0.97)(10.73)(575) = 0.68$ lbm/cu ft

Using the Equation

$A_g = q_g/86{,}400\ F_{c0}\ (1/Z_g)\ (P/P_b)\ (T_b/T)\ ((\rho_l - \rho_g/\rho_g))^{1/2}$

Substituting the values in the above equation

$= 50{,}000{,}000/ 86{,}400\ (0.167)\ (1/0.97)\ (199.7/14.7)\ (520/575)\ ((52.28 - 0.68 / 0.68))^{1/2}$

= 29.76 sqft for gas flow

$D = (29.76/0.7854)^{1/2}$

= 6.15 ft ID (or) 72 inch

Therefore,

A 72 inch ID vessel can be used if a volume of 50 MMscf/D includes a small safety margin. If separation was to handle 50 MMscf/d then a separator size of 78 in id may be required.

Now **Oil Sizing for the same Separator**

V_0 = Volume required in the separator for oil

= 30000/(1440/2)

= 233.98 cu ft

h_0 = Height of Oil in the Vertical Separator

= 233.98/28.27

= **8.28 ft** in 72 inch ID

h_0 for 78 inch id = 233.98/33.18

= **7.05 ft**

Therefore,

The Length Required for this Separator will be about 16 to 18 ft.

Q. The following is the given data for Horizontal Separator. Estimate it's sizing and same sizing for oil separator also.

Maximum gas flow Rate	100 MMscf/D
Specific Gravity of Gas	0.80
Maximum Oil Rate	50000 B/D
Specific Gravity of Oil	0.85
Operating Temperature	110 ^{0}F
Operating Pressure	800 psig
Design Pressure	1000 psig
Oil Retention Time	1.5min
Gas Compressibility Factor	0.834
Two – Phase Operation	No Water

$F_{c0} = 0.707$, $M_g = 28.97 * 0.80 = 23.18$

Solution.

For the calculation

$\rho_g = p\, M_g / Z_g\, RT$

$= (814.7)\,(23.18) / (0.834)\,(10.73)\,(570)$

$= 3.70$ lbm/cu ft

Using the Equation

$A_g = q_g / 86{,}400\, F_{c0}\, (1/Z_g)\, (P/P_b)\, (T_b/T)\, ((\rho_l - \rho_g/\rho_g))^{1/2}$

Substituting the Values in above equation

$= 100{,}000{,}000 / (86{,}400)\,(0.707)\,(1/0.834)\,(814.7/14.7)\,(520/570)\,((53.04 - 3.70 / 3.70))^{1/2}$

$= 7.40$ sqft for gas

Oil Sizing for the same Separator

V_0 = The volume required in the vessel

= (50,000 * 5.615 / 24*60) * 1.5

= 292.4 cu ft

Select a vessel length of 30 ft

A_0 = The Cross-Sectional area of oil

= 292.4 / 30

= 9.74 sqft

For Vessel Sizing,

Area of gas = 7.40 sqft

Area of Oil = 9.74 sqft

Dead Space = 2.00 sqft (About 25% of area of gas)

Total Area = 19.14sqft

Dead Space = Reserve space between oil and gas and is assumed to be about 10 – 30% of the gas space for reserve capacity

The Vessel will be = 9.74/19.14

= 51% full of liquid

Area of vessels ID = $(19.14 / 0.7854)^{1/2}$

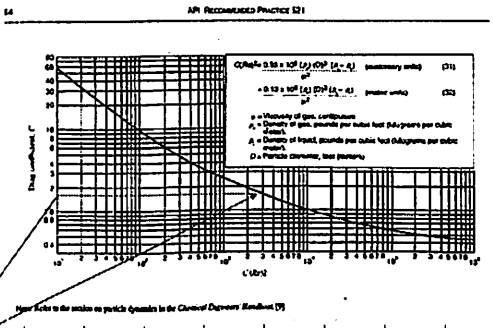
= **4.94 ft (or) 59.2 inch**

Project Number:-9017
Project Name:- Matix

Equipment Tag :- UFS VE 001

Sizing of Knock out Drum

ESSAR



Extract from API Recommended Practice 521 Page No:64

Step 1

Determination of Terminal Settling Velocity

$$U_c = 1.15\sqrt{\frac{gD(\rho_l - \rho_v)}{\rho_v(C)}}$$

Ref API Recommended Practice 521, Page No 64

Where

D is particle diameter in m	0.0003	
r_l is Liquid density in Kg/m^3	1000	
r_v is Vapour density in Kg/m^3	0.724	
Vascocity of gas in centipoise	0.01	
$C(Re)^2$	2539.4	
C (drag co-efficient can be obtained from sketch)	1.8	
g acceleration due to gravity in m/s^2	9.81	
Therefore Terminal Setting Velocity U_c is	1.73	m/s

Step 2

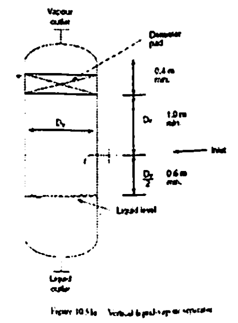
Determination of diameter of Knock out drum

Mass Flow rate of Gas in Kg/hr	7200	
Volumetric flow rate of gas in m^3/s (V)	2.76	

Knock Out Drum Diameter is calculated using the formula

$$D = (4V/U_c\pi)^{0.5}$$

Therefore Knock out Drum Diameter (D) 1.43 m



Extract form Coulson & Richardson Vol 06, Page No:461

Step3

Determination of total height og Knock Out Drum

Calculation of hold up height

Assumption: Hold up time in minutes	20	
Mass flow rate of Liquid in Kg/hr	72	
Volumetric flow rate of liquid in m^3/hr (V)	0.072	
Hold up Volume	V*Hold up Time	
Therefore hold up volume in m^3	0.024	
Corresponding Liquid depth required in m	0.02	
Height of minimum liquid level in m	0.2	
Therefore total height of K.O.Drum	2.76	M

NOTE
1 Input Values in yellow cells
2 The values in red cells are calculated.

Step 4

Nozzle Sizing

a) Inlet :

$\rho_m v^2_{m,in} \leq 1400$

ρ_m is the mean density of the mixture in the feed pipe

$\rho_m = (M_G + M_L)/(Q_G + Q_L)$

DEP 20 Shell Document

ρm 0.73 Kg/m^3

Therefore V_m 43.76 m/s

$v_{m,in} = (Q_G + Q_L)/(\pi d_1^2 / 4)$

Therefore d_1= 0.28 m 11.102 inch
(Shall be rounded to the nearest available pipe size say 24"

b) Gas outlet nozzle

$\rho_G v^2_{G,out} \leq 3750$

Therefore V_g= 71.97 m/s

Therefore d_2= 0.22 m 8.7035 inch
(Shall be rounded to the nearest available pipe size say 20")

c) Liquid outlet nozzle

Assumption: Liquid velocity < 1m/s & Dia should not be less than 2"

Therefore d_3= 0.0508 m
(Shall be rounded to the nearest available pipe size say 18")

Therefore velocity 0.01 m/s

API 521 Horizontal KO Drum

Item No.	UFS VS-002			
Diameter of Liquid Particle		300	microns	Input Cells
		0.0003	m	
Liquid Density		992	kg/m^3	
Operating Pressure		0.5	kg/cm^2g	
Operating Temperature		95	°C	
Mol wt.		18.33	kg/kmol	
z factor of vapour		0.995		
Vapour Density		0.9050301	kg/m^3	
Vapour Viscosity		0.0101	cp	
$C(Re)^2$		3086.332		

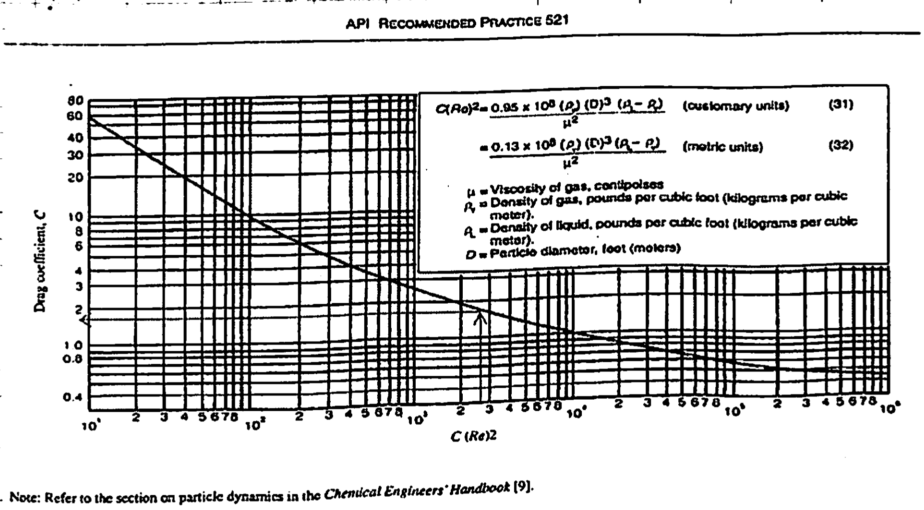


Figure 20—Determination of Drag Coefficient

C	(Refer Fig 20 of API 521)	1.7		

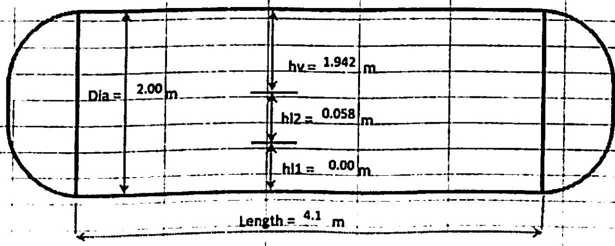
$$U_c = 1.15\sqrt{\frac{gD(\rho_l-\rho_v)}{\rho_v(C)}}$$

Uc		1.583	m/sec	
Inlet Flow		32010	kg/hr	
		35368.99	m^3/hr	
Liquid Flow		320	kg/hr	
		0.323	m^3/hr	
Vapour Flow		31690	kg/hr	
		35015.411	m^3/hr	
Number of Vapour Passes		1		(Assumption)
Drain Volume		0	m^3	
Assume Diameter of KOD		2	m	
Assume Length of KOD		4.1	m	
At	(Cross Sectional Area)	3.14	m^2	
Al1	(Bottom Segment)	0	m^2	
Holdup Time		20	mins	
Al2		0.026	m^2	
Al1+Al2		0.026	m^2	
Av		3.115	m^2	

hl1	0.000	m
(hl1 + hl2)	0.058	m
hl2	0.058	m
hv	1.942	m
theta	1.226	sec
Uv	3.122	m/sec
Lmin	3.829	m

Design is OK

Diameter 2 m
Length 4.1 m



Nozzle Sizing

a) Inlet :

$\rho_m v^2_{m,in} \leq 1\,400$

ρ_m is the mean density of the mixture in the feed pipe
$\rho_m = (M_G + M_L)/(Q_G + Q_L)$

ρm 10.91 Kg/m^3

Therefore V_m 39.13 m/s

$v_{m,in} = (Q_G + Q_L)/(\pi\, d_1^2 / 4)$

Therefore d_1= 0.57 m 22.511694 inch
(Shall be rounded to the nearest available pipe size say 24")

b) Gas outlet nozzle

$\rho_G v^2_{G,out} \leq 3750$

Therefore V_g= 64.37 m/s

Therefore d_2= 0.44 m 17.26862 inch
(Shall be rounded to the nearest available pipe size say 18")

c) Liquid outlet nozzle

Assumption: Liquid velocity < 1m/s & Dia should not be less than 2"

Therefore d_3= 0.0508 m
(Shall be rounded to the nearest available pipe size say 2")

Therefore velocity 0.04 m/s

CONCLUSION

1. From the above given data and the calculations hence done for Sizing of Oil-gas Vertical Separators comes as 16 – 18 feet.

2. From the above given data and calculations hence done for Sizing of Oil-gas Horizontal Separators and area of size is 4.94 feet.

3. The Case Studies have been done and the values needed to bring out have been calculated in the ESSAR Excel Sheets.

RECOMMENDATION

1. Care should be taken that when operating the separators then there should be as less impurities as possible so that there is no problem in calculations.

2. Vortex formation in vessels should be prevented so as for proper calculation of separators.

REFERENCES

1. Coulson & Richardson's chemical Engineering vol. 6

2. Applied Process Design for Chemical and Petrochemical plants Volume 1 , Third Edition by Ernest E. Ludwig.

3. Petroleum Engineers Handbook , Oil and Gas Separators by H. Vernon Smith

4. Chemical Engineering Design , Principles, Practice And Economics of Plant and Process Design by Gavin Tower and Ray Sinnott.

5. Case Studies on Horizontal And Vertical Knock Out Drums from ESSAR OIL, Vadinar.

6. www.egpet.net for the designing Vertical and Horizontal Separators.

7. Petroleum and Gas Field Processing by H.K Abdel-Aal , Mohamed Aggour and M.A. Fahim.

8. Surface Production Operations Vol1., Design Of Oil Handling Systems and Facilities by Ken Arnold & Maurice Stewart.

9. Perry's Chemical Engineers Handbook 8th Edition by James R. Couper , Darryl W. Hertz, F. Lee Smith.