DESIGN OF HORIZONTAL THREE-PHASE SEPARATOR

Submitted in partial fulfillment of the requirement for award of degree in

M. Tech (Gas Engineering)

2008 - 2010

By

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DEHRADUN

ACKNOWLEDGEMENT

I am whole hearted to thank everybody who has encouraged me in completion of project. The useful experience I gained from this project duration was very much helpful for my future career.

The first person to thank is my project coordinator **Mr. B. Umashankar,** (Assistant professor) who has given right path, guidance and support for the successful completion of the project.

I am also grateful to the course coordinator **Mr. P. Suresh Kumar** and others from the family of university of petroleum & energy studies for helping me and encouraging me in every moment for my success which result in the proper completion of my project.

Yours sincerely,

Shyam KumarInturi

ABSTRACT

This project explains the calculation procedure for the design of the three-phase horizontal drum.

Horizontal separators are most efficient where large volumes of total fluids and large amounts of dissolved gas are present with the liquid.

The horizontal three-phase separators handle gas plus two immiscible liquid phases.

The separator in this has baffle. It is equipped with an anti vortex system in the HC section .The cross-sectional partial areas and heights from the bottom of the drum is calculated by using different iterative formula. The calculation of the drum design is reported in two parts. In the first part the calculation basis of the different levels and of the minimum length of the drum are presented. In the second part the calculation procedure is explained.

CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the thesis entitled **"DESIGN OF HORIZONTAL THREE-PHASE SEPARATOR"** by **"SHYAM KUMAR INTURI"** in partial fulfillment of requirements for the award of degree of M. Tech. (Gas Engineering) submitted in the Department of Chemical Engineering at UNIVERSITY OF PETROLEUM & ENERGY STUDIES, DEHRADUN is an authentic record of my own work carried out under the supervision of **Asst Prof. B. UMASHANKAR**. The matter presented in this thesis has not been submitted by me in any other University / Institute for the award of M. Tech Degree. *Due to the confidentiality of data, the original name, location and identity of the data has been changed.*

I Shyam

Signature of the Student

This is to certify that the above statement made by the candidate is correct to the best of my/our knowledge

Umasankar

Signature of the SUPERVISOR (S)

The M. Tech Viva –Voce Examination of MEHAR VIDYA SAGAR .R has been held on____________ and accepted.

Umasankar

Signature of Supervisor(s) Signature of External Examiner

08/05/10.

Signature of the Head of the Department.

CERTIFICATE

This is to certify that the project work entitled **"DESIGN OF HORIZONTAL THREE-PHASE SEPARATOR"** being submitted by **Mr. SHYAM KUMAR INTURI** (R030308010), in partial fulfillment of the requirement for the award of the degree of **Master of Technology [Gas Engineering]** in University of Petroleum and Energy Studies-Dehradun, is a bonafide project work carried out by him under my guidance.

Dehradun

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NOMENCLATURE

LISLL	Level Interface Switch Low Low
dHL	diameter of the water outlet nozzle
LIL	Low Interface Level
NIL	Normal Interface Level
HIL	High Interface Level
NOL	Normal Oil Level
LSHH	Level Switch High High
HLL	High Liquid Level
LLL	Low Liquid Level
LSLL	Level Switch Low Low
$H^{1}3$	The height from the bottom of the vessel to the LLL of the HC section
$H^{1}2$	The height from the LSLL to the LLL of the HC section
$H^{1}1$	The height from the LLL to the NOL of the HC section

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1.0. INTRODUCTION

This Appendix provides a general discussion of the functional requirements of Oil and Gas separators and their controls as used in this specification.

1.1. Separator Components:

The function of a separator is to provide removal of free gas from and/or water at a specific pressure and temperature. For efficient and stable operation over a wide range of conditions, a gas-liquid separator normally has the following features.

1.2. Primary Separation Sections-

This section is for removing the bulk of the liquid in the inlet stream. Liquid slugs and large liquid particles are removed first to minimize gas turbulence and re-entrainment of liquid particles in preparation for the second step of separation. To do this, it is usually necessary to absorb the momentum and change the direction of flow by some form of inlet baffling.

1.3 Secondary Separation Section-

The major separation principle in this section is gravity settling of liquid from the gas stream after its velocity has been reduced. The efficiency of this section depends on the gas and liquid properties. Some designs use internal baffling to reduce turbulence and to dissipate foam. The baffles may also act as droplet collectors.

1.4 Liquid Accumulator Section-

The liquids are (are) collected in this section the liquid should have a minimum of disturbance from the gas stream. Sufficient capacity is necessary for efficient separation of gas breaking out of solution and separation free water from oil in three-phase separators. A vortex breaker may be located over the liquid outlet nozzles to prevent the oil entrainment with the bottom liquid.

1.5 Mist Extraction Section-

The mist extractor of the coalescing section can be of several designs (a series of vanes, woven wire mesh pad or a centrifugal device). The mist extractor removes fro the gas stream the small droplets (normally down to 10 micron diameter) of liquid before the gas leaves the vessel. Liquid carryover is normally less than 0.1 gallon per MMSCF.

1.6 Process Controls-

The operating pressure may be controlled by a weight loaded, spring loaded, or pilot.... operated gas back pressure valve. Where the gas is being delivered to a pipeline, the minimum separator pressure is usually set by the transmission or gathering system pressure. Separators should be equipped with one or more liquid level controls. Usually a liquid level control for the liquid accumulation section of two phase separators activates liquid dump valve to maintain the required liquid level. Two liquid level control systems are normally used for three-phase separators .internal weirs and baffles are used in conjunction with these liquid level controls. Separators are equipped with gauge glasses or sight glasses to indicate one or two levels. A pressure gauge and thermometer well are usually installed on separators.

1.7 Relief Devices –

All separators, regardless of size or pressure shall be provided with pressure protective devices and set in accordance with ASME code requirements .Multiple pressure relief devices such as a pressure relief valve in conjunction with rupture disk may be used to provide the necessary relieving capacity. The relief valve is normally set at the maximum allowable working pressure (MAWP).the rupture disk is normally selected to relive valve. The pressure relief devices need not be provided by the separator manufacturer. But over-pressure protection shall be provided prior to placing the separator in service. The purchaser should determine who has responsibility to furnish relief devices.

1.8 Discharge Lines –

Discharge a line from pressure relief devices should receive consideration on an individual basis. A detailed discussion is beyond the scope of this standard .recommendations for discharge line consideration may be obtained from ASME.

2.0. PRINCIPLE OF SEPARATION:

Separation equipment employs one or more of the following mechanisms:

- Gravity settling
- Centrifugal force
- Impingement
- Electrostatic preparation
- Sonic preparation
- Filtration
- Adhesive separation
- Adsorption
- Thermal

The primary mechanisms in oil-gas separation are 1, 2, and3.The problem is complicated because particles of varying size and characteristics, both liquid and solid, must be removed.

2.1. Particle Size:

This is normally defined by its diameter in microns,

$1\mu = 1\times10^{-6}\ m = 3.3\times10^{-6}\ ft$

Particles larger than about 20-30 μm may be separated by properly designed equipment. Properly sized coalescing filter separators can remove droplets to about 1 μm

There are several ways of describing the average particle diameter:

1. Diameter of sphere having average volume:

$$D_P = \left[\frac{\sum(nD^3)}{\sum n}\right]^{1/3}$$

2. Diameter of sphere having average area:

$$D_P = \left[\frac{\sum(nD^2)}{\sum n}\right]^{1/2}$$

3. Diameter of sphere geometric mean diameter:

$$D_P = e^B$$

Where

e = natural logarithm base

$B = \Sigma(n \ln D)/ \Sigma n$

D_P =average particle diameter

D = diameter of given size particle

n =number of particles of given sized

Oil- water separation proceeds in three steps:

1. **Destabilization:** Emulsions can be destabilized through the use of chemicals and gentle mixing. Heat may also help destabilize the emulsion by reducing the effectiveness of the emulsifying agents.
2. **Coalescence:** coalescence is the key step in separation. Droplet settling velocity is proportional to D_P^2. Coalescence rates can be increased by gentle mixing and mechanical coalescers such as plate packs and fibre mats. In crude oil dehydrators, where the water concentration is low (<5vol %) electrostatic coalescers are sometimes used.
3. **Settling:** the final step in oil- water separation is settling. Higher settling rates are favored by larger droplet sizes, reduced viscosity of the continuous phase and reduced turbulence. Settling vessels are sometimes heated especially in the case of heavier, viscous crude oils. Adequate residence time and interfacial area

critical aspects of design. Centrifugal separation is used in some applications. This increases settling velocity by increasing the gravitational term, g, in Stokes law.

2.2. Retention Time

The usual approach in design is to allow equal retention time for the two liquid phases. The following are recommendations from API 12J

Oil Relative Density	Retention Time, min
Below 0.85	3-5
Above 0.85 and > 100^{0}F	5-10
80-100^{0}F	10-20
60-80^{0}F	20-30

For glycol/hydrocarbon separation in a cold separator, a minimum retention time of 30 minutes in the glycol phase is recommended.

2.3. Settling Velocity

Settling velocity sets the cross-sectional area of the oil-water separation section.

The basic settling characteristics of two immiscible phases are represented by stroke's law.

$$V_t = k\sqrt{\frac{\rho_l-\rho_g}{\rho_g}}\left(\frac{L}{3.05}\right)^{0.56}$$

Where

V_t = terminal velocity, m/s

K = an empirical constant

ρ_l = liquid density, kg/m^3

ρ_g = gas density, kg/m^3

The above equation is valid for horizontal separator with mist extractor

2.4. Three Phase Separation Control

There are various types of controls available

In *interface control* a displacement float reacts to the different density of the two adjacent liquid phases.

Buckets are chambers within the vessel where one or more liquid phases are segregated.

Weirs are used to aid in segregation to eliminate the need for interface controls.

HORIZONTAL THREE-PHASE SEPARATOR

3.0. INPUTS:

The design of horizontal three phase separator is based on the following input parameters:

Q_G (m^3/h): vapor volumetric flow rate = 511 m^3/h

ρ_G (kg/m^3) : vapor density = 02 kg/m^3

Q_{LL} (m^3/h): light liquid volumetric flow rate =127 m^3/h

ρ_{LL} (kg/m^3) : light liquid density =775 kg/m^3

μ_{LL} (cp): light liquid viscosity =000 cp

θ_{LL} (min) : light liquid holdup time = 3 minutes

Q_{HL} (m^3/h): heavy liquid volumetric flow rate = 002 m^3/h

ρ_{HL} (kg/m^3) : heavy liquid density = 931kg/m^3

μ_{HL} (cp): heavy liquid viscosity = 000 cp

θ_{HL} (min) : heavy liquid holdup time = 3 minutes

S_{LL}(min): light liquid surge holdup time =01 minutes

D_P (μm): liquid droplet diameter =300 microns

P (bar): operating pressure = 00 bar g

3.1. Separation Data

Demister pad: yes

Liquid out let anti-vortex: yes

Pumped outlet liquid: no

Emergency shutdown LSHH: yes

Emergency shutdown LSLL: yes

3.2. HC Data

Pumped outlet liquid: no

Emergency shutdown LSHH: yes

Emergency shutdown LSLL: yes

4.0. CALCULATION PROCEDURE FOR VESSEL:

The design of horizontal three-phase separator requires the calculation of partial cross-sectional areas as follows

From literature

$$Y = \frac{a+cx+ex^2+gx^3+ix^4}{1.0+bx+dx^2+fx^3+hx^4}$$

Where:

H/D to A/A_t		A/A_t to H/D	
$Y = A/A_t$	$X = H/D$	$Y = H/D$	$X = A/A_t$
a = -4.755930 E-5		a = 0.00153756	
b = 3.924091		b = 26.787101	
c = 0.174875		c = 3.299201	

d = 6.3588505 d = -22.923932

e = 5.668973 e = 24.353518

f = 4.018448 f = -14.844824

g = -4.916411 g = -36.999376

h = -1.801705 h = 10.529572t

i = -0.145348 i = 9.892851

A_t : vessel total cross sectional area $A_t = \pi D^2/4$

D: vessel inside diameter

Calculation of A/At from H/D is given by the following equation

$$\frac{A}{A_t} = \frac{1}{\pi} Cos\left(1 - 2\frac{H}{D}\right) - \frac{2}{\pi}\left(0.5 - \frac{H}{D}\right)\sqrt{4\frac{H}{D} - 4\left(\frac{H}{D}\right)^2}$$

The above formula is valid for H < D/2

The above equation is more rigorous, for reducing calculation time first formula is used.

Calculation of drum design is divided in two parts

The first part (part 4.1), basis calculation for different levels and minimum length of the drum.

The second part (part4.2), calculation procedure was explained

4.1. Basis Calculation

4.1.1. Separator Calculation

1. H7: if not specified by the user, the height from the bottom of the vessel to the LISLL (level interface switch low) depends on the presence or not of an anti-vortex system on the liquid.

   a. if there is no anti-vortex system , H7 =150 mm

b. if there is an anti-vortex system, H7 = (200mm,125+ dHL)

dHL is the diameter of the water outlet nozzle.

2. H6: if not specified by the user through the LIL, the height from the LISLL to the LIL (low interface level):

a. if there is no LISLL , H6 = 0

b. if there is a LISLL, H6 is based on the holdup time between the LISLL and the LIL which should be 20% of total water holdup time with a range of 1 to 2 minutes.

The minimum allowable value of H6 is 100mm.

3. H5: the height from the LIL (normal interface calculated on the basis of the volume V_5 which should support the water holdup time.

$$V5 = \frac{Q_{HL}(\frac{m^3}{h}) \times \theta_{HL(min)}}{60}$$

Note: this formula is valid only if the water holdup time is considered between the LIL and NIL.

If the user decides to consider the water holdup time between different levels, then a correction should be brought to this calculated V_5.

4. H4: if not specified by the user, the height from the NIL to the HIL (high interface level) is equal to H5.

5. H3: the height from the NIL to the NOL (normal oil level) is calculated on the basis of the volume V3 which should support the HC holdup time

$$V3 = \frac{Q_{LL}(\frac{m^3}{h}) \times \theta_{LL(min)}}{60}$$

The minimum allowable value of this height is H3 = H4+200mm.

6. Hw: the baffle height is

$H_W = H_{HIL} + 150 = H4+H5+H6+H7+150$

7. H2: the height from the NOL to the LSHH (level switch high) is calculated on the basis of the volume V2 which should support the slug capacity

V2 = slug capacity

Note: for the calculation of the slug height H2, the total length of vessel has to be considered (and not only the separation length).

8. H1: the height from the LSHH (or the HLL if there is no LSHH) to the top of the vessel is the maximum of the following:

a. The H1 calculated on the basis of the required vapor cross-sectional area.

b. H1 = 300 mm (with out demister) or H1 = 600 mm (with demister)

c.H1 = 0.2 D

Where

D is the inside diameter of the vessel

9. H8: the height from the HLL 9high liquid level) to the LSHH is the maximum of the following

a. the H8 calculated on the basis of the volume between the HLL and the LSHH which should supply 20% of the HC holdup time.

b. H8 = 100 mm

Note: if there is no LSHH, then H8 = 0

4.1.2. HC Calculation

1. H^13: the height from the bottom of the vessel to the LSSL of the section depends upon the presence of an anti vortex system on the HC outlet

   a. If it is an anti vortex system H^13 =200mm

   b. If it is not anti vortex system H^13 =150mm

2. H^1 2: If it is not specified by the user through the LLL the height between LSLL and LLL the HC section is the maximum as follows

   a. The H^12 is based on the holdup capacity between the LSLL and LLL which should be 1minute of the HC inflow

   b. H^12: 100mm

3. H^11: the height from the LLL of HC section to the NOL is based on the HC surge holdup time.

4.1.3. Minimum Length For Vessel

4.1.3.1. Calculation of L_{min} based on the separation of the liquid droplets from the gas:

L_{min} calculation procedure is as following:

a. Vertical vapor terminal velocity

$$U_t = K_t \left(\frac{\rho_{LL}-\rho_G}{\rho_G}\right)^{1/2}, \text{m/s}$$

Where

Kt=0.35-0.0001(p-100) p in psia

Converting the K_t value multiplying by 0.35

K_t=0.035×(0.35-0.0001(817-100)) =0.000

U_t=000 m/s

b. set the vapor vertical velocity to

$U_v = 0.75\ U_t$,m/s

$U_v = 0.75 \times 0.000 = 000$m/sec

c. Calculate the liquid droplet time by given formula

$$\varnothing = \frac{H1}{U_V}\ ,\ s$$

Where

H1 is the height between the top of the drum and LSHH .

Dropout time (top-LSHH) =005S

d. Calculate the actual vapor velocity.

$$U_{VA} = \frac{Q_G}{A_V \times Nb\ of\ pass},\ m/s$$

e. Calculating the minimum allowable length from the inlet nozzle to the baffle:

$$L_{min1} = U_{va} \times \varnothing \times Nb\ of\ pass,\ m$$

4.1.3.2. Calculation Of L_{min} Based On The Decantation Of The Heavy Liquid Droplets From Light Liquid. (Heavy liquid settling out minimum length):

L_{min2}: This minimum allowable vessel length is calculated knowing the heavy liquid droplets should be separated from the light liquid phase before the baffle.

To make this liquid-liquid separation possible, the time required by the heavy liquid droplets to cover the vertical distance between the LSHH to the bottom of the boot must be smaller than the time required covering the horizontal distance from the vessel tangent line to the baffle.

The minimum length is calculated as follows.

a. Calculate the vertical velocity of heavy liquid droplets in the light liquid phase, according to the Reynolds number given as follows.

$$Re=\frac{D_P \rho_{LL} V_P}{\mu_{LL}\times 10^{-3}}$$

If Re<2, then

$$V_p= 5.45\times 10^{-10}\frac{D_P^2(\rho_{HL}-\rho_{LL})}{\mu_{LL}}$$

If Re>2, then

$$V_p=2.25\times 10^{-6}\frac{D_P^{1.14}(\rho_{HL}-\rho_{LL})^{0.71}}{\rho_{LL}^{0.29}\mu_{LL}^{0.43}}$$

Note the maximum allowable vertical velocity for the calculation is 0.004 m/sec (10in/min).

b. Calculate time required by the droplets to cover the vertical distance from the LSHH to the bottom of the boot.

$$T_{HL}=\frac{D-H_1-H_W}{V_P}$$

c. Calculate the light liquid velocity (corresponding to the horizontal velocity of the heavy liquid droplets):

$$V_{LL}=\frac{Q_{LL}/3600}{A_t-A_V-A_W}$$

d. Calculate the corresponding vessel minimum length

$L_{min2}=V_{LL}\times T_{HL}+L\ (HC)$

4.1.3.3. Determination of L_{min}:

Lmin is the greatest value of the two values Lmin1and Lmin2. It should be noted that it is necessary to calculate another Lmin based on the required liquid hold up, and then take the greater of the two.

4.2 Calculation Procedure:

The calculation procedure for the horizontal 3-phase separator is given as follows

Determine the L/D ratio from the following table according to the operating pressure.

Operating pressure(bar g)	L/D
P<20	2-3
20<P<80	3-4
80<P<150	4-5
150<P	5-6

The operating pressure in this case is 56 bar.

Each entry in the trial and error procedure consists in choosing a new value for the L/D ratio until all the required volumes in the drum are respected.

L/D=004 (final L/D).

4 .2.1 Vapor Area:

1. Vapor critical velocity:

$$V_C = 0.048\times\sqrt{\frac{\rho_{LL}-\rho_G}{\rho_G}}$$

Vapor critical velocity = 000m/sec

2. Vapor velocity:

$V_V = k \times V_C$.

The k standard values for all types of separators (with or without demister pads) is 1, 7.

k=02,

Maximum vapor velocity =000m/sec.

3. Vapor required area is

$$A_v = \frac{(Q_G/3600 \times Nb\ of\ pass)}{V_V},\ m^2$$

Vapor required area=001m^2.

4.2.2. Ant vortex Section Height and Area

H7: if not specified by the user, H7is obtained from the above calculation without liquid outlet antivortex.

H7=150mm

Then

$$A7 = A_t \times \frac{a+cX+eX^2+gX^3+iX^4}{1.0+bX+dX^2+fX^3+hX^4}$$

With X=H7/D

4.2.3 Vessel Diameter:

1. The total liquid holdup capacity from the LISLL to the LSHH is:

$$V_h = \frac{\theta_{HL} \times Q_{HL}}{60} + \frac{\theta_{LL} \times Q_{LL}}{60} + \frac{1.25 \times Q_{HL}}{60} + \text{slug capacity.}$$

V_h=(15×00)/60+(00×00)/60+00+80.

Required volume from LISLL TO LSHH=080m^3.

2. In the other hand, the volume between the LISLL and LSHH is

$$V_h = (A_t - A_V - A_7)L = (\frac{\pi D^2}{4} - A_V - A_7)D \times L/D$$

$$V_h = (\frac{\pi D^2}{4} - A_V - \frac{\pi D^2}{4} \times \frac{a+cX+eX^2+gX^3+iX^4}{1.0+bX+dX^2+fX^3+hX^4})D \times L/D = 80m^3.$$

Where

A_V=001m^2

H7=150mm

L/D=004.

3. The vessel diameter is obtained by solving the above equation, where D is the Unknown value. D=003m with a 0,000m error.

Vessel inside diameter= 3400mm ×(at the end of the trial and error procedure)

Total vessel cross sectional area =009m^2.

There may be selected difference between the selected diameter (003m) and the final vessel diameter. The difference is due to the fact that selected diameter doesn't satisfy the required volumes in the vessel, and moreover the new vapor area calculated hereafter is much greater than the required vapor area with which the selected diameter was obtained. So, in order to meet the liquid hold up capacity requirement, the drum diameter gets increased.

4.2.4 Calculation of the Vessel Minimum Length:

4.2.4.1 Calculation of L_{min} based on the liquid holdup requirement:

1. H1: the height from the LSHH to the top of the vessel is the maximum of:

a. A_V/A_t = (001/009) =0,000 so, H1/D= 0,000& H1=532mm.

b. H1= 300mm (without demister) or H1= 600mm with demister.

c. H1=0.2D= (0.2×3400)=680mm=700mm(app.)

2 Av: the final vapor cross sectional area is

H1/D= (700/3400)=0,000 so Av=001m2

And the calculated Av is =001m2.

3. A7: calculate antivortex section area:

H7=150mm so H7/D= 0,000 and

$A7/A_t$ =0,000, therefore water anti vortex area =000m2.

4. A_h: calculation of final cross-sectional area between the LISLL and the LSHH:

A_h=At-Av-A7= (009-001-000) =008m².

5. L_{min}: the minimum allowable vessel length Lmin1 (between the inlet nozzle and the baffle), based on the holdup requirement capacity is:

L_{min} = total holdup volume/total volume area

= (V_h/A_h) = (080/008) = 11m

4.2.4.2 Calculation of L_{min} based on the separation of the liquid droplets from the gas:

1. Liquid dropout time:

ø=H1/U_V=001/000=005m/sec.

(Dropout time between the top and the LSHH).

2. Actual vapor velocity:

$U_{VA}=\frac{Q_G}{A_V \times Nb\ of\ pass}$= 000/ (001×1) =000m/sec.

3. The corresponding minimum allowable vessel length L_{min2} is:

L_{min2}= (U_{VA}×ø×Nb of pass), m. and L_{min2} = (000×005×1) =01m.

4.2.4.3 Determination of L_{min}:

The minimum length to consider (between the inlet nozzle and baffle) is the maximum of L_{min1} and L_{min2}, so L_{min}=11m.

4.2.5. Calculation of Vessel Length:

4.2.5.1: Calculation of HC section length:

L (HC) = the HC section length is given by the formula as:

L (HC) = DIAM.X+400+100.

NOTE: The 400m correspond to the vessel support and the 100mm to the header and baffle welding required areas.

The value of the DIAM.X is obtained from the following table according to the HC outlet nozzle diameter (d=2*, calculated in the section 3.3).

HC outlet nozzle diameter(inches)	DIAM.X
2	180
4	250
6	310
8	380
10	470
12	560
14	620
16	690

18	780
20	870
22	948
24	1050
26	1105
28	1184
30	1263

So in this case DIAM.X=180mm

Therefore L (HC) = 180+400+100=680mm.

Length of the HC section =01m.

4.2.5.2 Calculation of the separation section length:

L_w: The separation section length is used as the iteration factor in the procedure. For each try in the method, the L_w value is modified until all the required volumes in the vessel are respected.

Length of the separation section=11m.

4.2.5.3 Calculation of the vessel total length:

L: Calculation of the vessel total length:

$L = L_w + L\ (HC) = 011 + 001 = 012m$

Total length=12m.

4.2.6 Calculation Of Levels In The Separator Section:

H7: The height from the bottom to the LISLL has been calculated in the above section 2.2.2

H7=150mm

4.2.7. Calculation Of The Levels In The Separating Section:

1. H6: The height from the LISLL to the LIL is the maximum of:

a. H6=100 mm.

b. V6= (0, 2×000×000)/60=000m^3 20% of the total holdup time.

V6= (1×000)/60=000m^3 1minute

V6= (2×000)/60=000m^3 2minutes

V6= 000m^3 selected

A6= V6/L= 0,000/11=0,000m^2

(A6+A7)/A_t =0,000 so, (H6+H7)/D=0,000

H6+H7=143mm.

H6= -7mm

H6=100mm

Note if there is no LSLL, then H6=0.

2. H5: the height from the LIL to the NIL depends on the user specified criterion on the total water holdup time:

Water holdup time criteria:

From bottom to NIL $V5 = \frac{\theta_{HL} \times Q_{HL}}{60}$ -V6-V7.

From LISLL to NIL $V5 = \frac{\theta_{HL} \times Q_{HL}}{60}$-V6

From LIL to NIL $V5 = \frac{\theta_{HL} \times Q_{HL}}{60}$

From bottom to HIL $2 \times V5 = \frac{\theta_{HL} \times Q_{HL}}{60}$-V6-V7.

From LISLL to HIL $2 \times V5 = \frac{\theta_{HL} \times Q_{HL}}{60}$-V6.

From LIL to HIL $2 \times V5 = \frac{\theta_{HL} \times Q_{HL}}{60}$/60.

Here, $V5=000m^3$

$A5=V5/L= 000/11=0,000m^2$.

$(A5+A6+A7)/A_t = 0,000$ So, (H5+H6+H7)/D=0,000

(H5+H6+H7)=248mm,

H5= -2mm.

H5= 50mm.

3. H4: The height from the NIL to the HIL is H4=H5=50mm, H4=50mm.

4 .H3: The height from the NIL to the NOL (HC holdup height) is given by:

$V3= \square_{LL} \times Q_{LL} / 60 = (015 \times 00)/60= 0,000m3$

A3= (V3/L) = (00,000/11) = 00,000m2

$(A3+A5+A6+A7)/A_t$ =0,000 So, (H3+H5+H6+H7)/D=0,000

(H3+H5+H6+H7) =300mm, H3=0 mm.

Note: the minimum allowable value for this height is H3=H4+200=250mm.

Therefore H3 =250mm.

5. H2: the height from the NOL to the LSHH (slug height) is given by:

H2= {D-(H1+H3+H4 from the NOL to the LSHH (slug height) is given by :

$H2= \{D-(H1+H3+H5+H6+H7)\} =2150mm.$

$H2=2150mm.$

6. H_W: the baffle height (weir height) is given by:

$H_W=H4+H5+H6+H7+150=500mm.$

$H_W=500mm.$

4.2.8. Calculation of levels in the HC section:

1. H^13: If not specified by the user, H^13 is obtained from the above section without liquid antivortex:

$H^13=150mm.$

2. H^12: the height from the LSLL to the LLL is given by:

$V^12=1\times QLL/60=$ 000m3. (Holdup time=1minute).

$A^12=V^12 / L= (000/01) = (0,000m^2)$

$(A^12+A^13)/A_t=0,000$ so, $(H^12+H^13)/D= 0,000.$

$H^12=100$ mm.

Notes:

1. The minimum allowable value for H^12 is 100mm.

2. There should be a security height between the LLL and the top of the baffle of 100mm. the maximum allowable value for H^12 is consequently: 250mm

$H^12=100mm.$

3. H'1: the height from the LLL to the NOL is:

$H^11= \{D-(H1+H2+H^12+H^13)\} =300mm.$

$H^11=300$ mm

4.2.9. Calculation of L_{min}

According to the decantation of the heavy liquid droplets from light liquid:

1. The vertical velocity of the heavy liquid droplets in the light liquid phase is:

a. If Re<2:

$$V_P = (5.45\times10^{-10})\times D_P^2 \times \frac{\rho_{HL}-\rho_{LL}}{\mu_{LL}}$$

= 00,000m/s.

And then $Re = \frac{D_P \rho_{LL} V_P}{\mu_{LL}\times10^{-3}} = 0{,}021$

b. if Re>2:

$$V_P = 2.25\times10^{-10}\times D_P^{1.14} \times \frac{(\rho_{HL}-\rho_{LL})^{0.71}}{\rho_{LL}^{0.29}\mu_{LL}^{0.43}}$$

=00,000 m/s

Note: The maximum allowable vertical velocity for the calculation is 0,004m/s (10 in/min), V_P=00,000m/s.

2. the time required by the droplets to cover the vertical distance from the LSHH to the bottom of the boot is:

$$T_{HL} = \frac{D-H_1-H_W}{V_P}$$

Required time for the droplets=550s.

3. Calculating the light liquid velocity (corresponding to the horizontal velocity of the heavy liquid droplets)

$$V_{LL} = \frac{Q_{LL}/3600}{A_T-A_V-A_W}$$

Horizontal velocity of the heavy liquid droplets= 0,000m/s.

4. L_{min}: Calculating the corresponding vessel minimum length:

$L_{min}=V_{LL}\times T_{HL}+L\ (HC)=001m$.

$L_{min}=001m$ (smaller than the vessel length).

5.0. Nozzle Sizing:

Note: if the connecting diameters have already been defined, the nozzle diameters will be equal to the line diameters.

5.1 Inlet Nozzles(S)

1. Sizing criterion:

The inlet nozzle sizing criterion is based on the maximum value of the ρv^2.

If not specified by the user ,the standard maximum value of ρv^2 is 10000

$$\rho V^2= 10000$$

2. Calculation of the liquid/gas mixture density;

$$\rho_{Mix}=\frac{W_G+W_{LL}+W_{HL}}{(\frac{W_G}{\rho_G}+\frac{W_{LL}}{\rho_L}+\frac{W_{HL}}{\rho_{HL}})}$$

Where

W_G= Mass flow rate of gas=012kg/sec.

W_{LL}= mass flow rate of light liquid (HC) =000kg/sec.

W_{HL}= mass flow rate of heavy liquid (water) =000kg/sec.

Mixture density= 78kg/m3.

3. Calculation of maximum velocity based on maximum allowable ρv^2.

$V_{max}= \sqrt{\rho V_{max}^2} / \sqrt{\rho_{mix}}$

Maximum velocity =011m/sec.

4. The inlet nozzle inside diameter is then calculated and rounded up to the nearest standard pipe diameter:

$$\text{Nozzle diameter}=\sqrt{\frac{4\times Q_{mix}}{3600\times\pi\times V_{max}\times Nb\ of\ pass}} = \sqrt{4\times\frac{Q_G+Q_{LL}+Q_{HL}}{3600\times\pi\times V_{max}\times Nb\ of\ pass}}$$

Inlet nozzle diameter=6 in (nominal).

5.2. Gas out Nozzle

1. Sizing criterion:

The gas outlet nozzle sizing criterion is based on the maximum value of the ρv^2.

If not specified by the user, the standard maximum value of ρv^2.

Can be taken as 10000, so in this case it becomes 10000.

2. Calculation of maximum velocity based on maximum allowable ρV^2

$V_{max}=\sqrt{(\rho V^2)_{max}} / \sqrt{\rho_G}$

Outlet gas Maximum velocity =011m/sec.

3. The gas outlet nozzle diameter is then calculated and rounded up to the nearest pipe diameter:

$$\text{Nozzle diameter}=\sqrt{\frac{4\times Q_G}{3600\times\pi\times V_{max}}}$$

Gas outlet nozzle diameter=6 in (nominal).

5.3 Liquid Outlet Nozzles:

5.3.1 HC Outlet Nozzle.

1. Sizing criterion:

The hydrocarbon outlet nozzle sizing criterion is based on the maximum allowable liquid velocity, if not specified by the user, this value differs if the outlet liquid is pumped or not.

a. If the outlet liquid is pumped, then the standard maximum velocity is 3m/s.
b. Otherwise, the standard maxim um allowable velocity is 2 m/sec.
c. Liquid outlet maximum allowable velocity=02m/sec.

2. The HC outlet nozzle diameter is calculated and rounded up to the nearest standard pipe diameter.

Nozzle diameter= $\sqrt{\frac{4 \times Q_{LL}}{3600 \times \pi \times V_{max}}}$

HC outlet nozzle diameter=2 in (nominal).

5.3.2 Water Outlet Nozzle:

1. Sizing criterion:

The water outlet nozzle sizing criterion is based on the maximum allowable liquid velocity, if not specified by the user, this value differs if the outlet liquid is pumped or not.

a. If the outlet liquid is pumped, then the standard maximum velocity is 3m/s.
b. Otherwise, the standard maxim um allowable velocity is 2 m/sec.
c. Liquid outlet maximum allowable velocity=03m/sec.

2. The water outlet nozzle diameter is calculated and rounded up to the nearest standard pipe diameter.

Nozzle diameter= $(\sqrt{4 \times Q_{HL}})/(\sqrt{3600 \times \pi \times V_{max}})$

Water outlet nozzle diameter=2 in (nominal).

6. Results:

1) Vessel dimensions:

Vessel diameter=340mm

Separation section length=11200mm

HC section length=700mm

Vessel total length=11900mm.

2) Separating section levels:

NOL=550mm

HIL=350mm

NIL=300mm

LIL=250mm

LISLL=150mm.

3) HC section levels:

LSHH=2700mm.

HLL=2250mm.

LLL=250mm.

LSLL=150mm.

Gas outlet nozzle=6 in

HC outlet nozzle= 2 in

Water outlet nozzle=2 in

4) Nozzles Diameters:

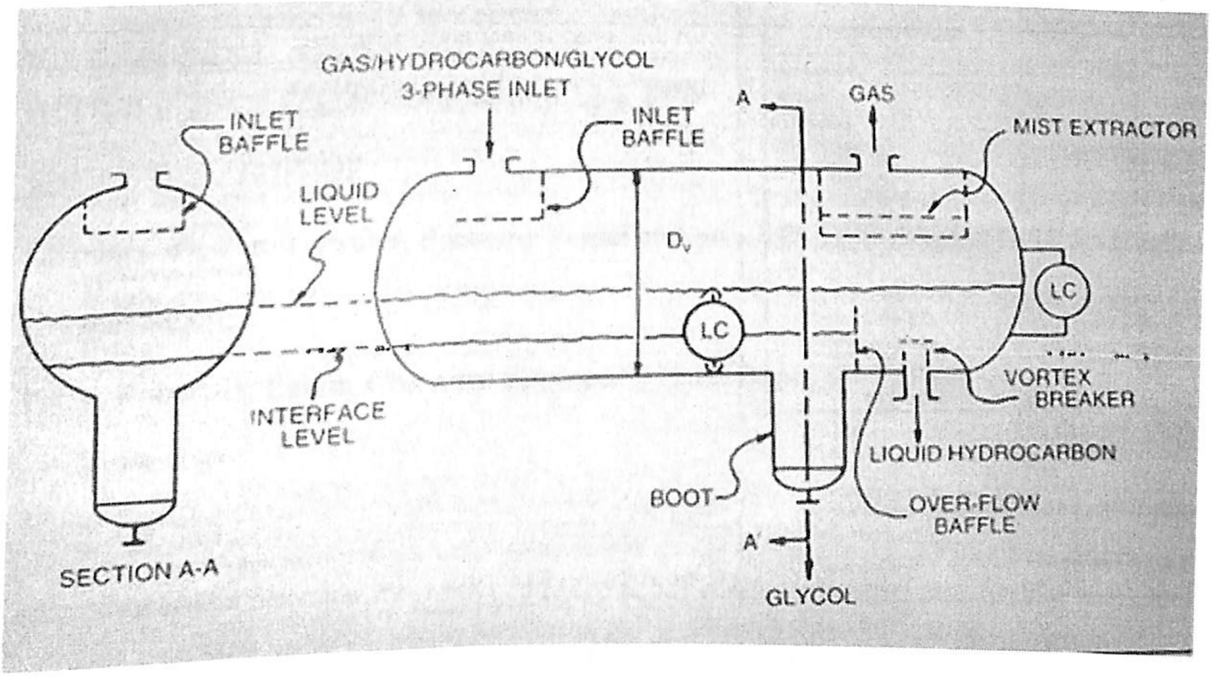
Inlet nozzles = 6 in

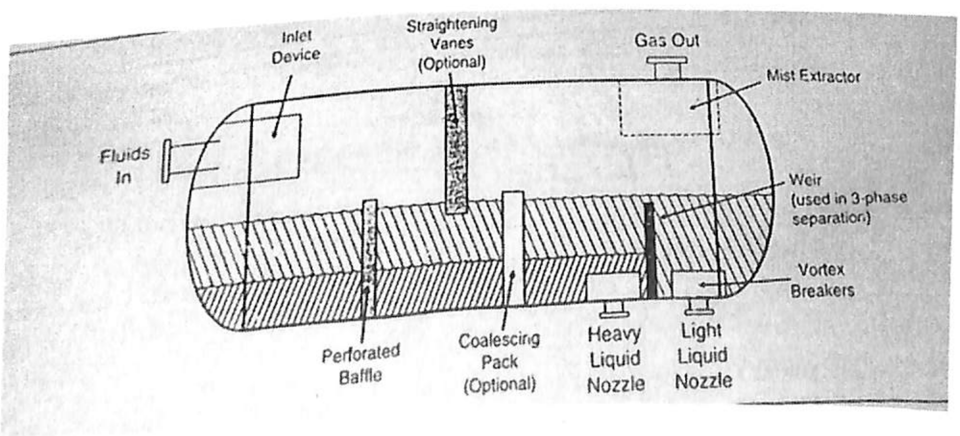
Gas outlet nozzle = 6 in

HC outlet nozzle = 2 in

Water outlet nozzle = 2 in

7.0. List of Figures





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