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بالمؤتمر الليبي الدولي للعلوم التطبيقية

والهندسية

27-28- سبتمبر 2022

# Influence of Flow Characteristics on the Design of Two-Phase Horizontal Separators

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**الملخص**

يمكن فصل الهيدروكربونات والماء بمساعدة الفواصل. أدى استخدامها إلى تحسين تصميم المصانع الكيماوية وكذلك قطاع النفط والغاز. إن تطوير كل من الحالة الثابتة والنماذج الديناميكية للفاصل الأفقي ثلاثي الطور في HYSYS هو الهدف من هذا الجهد. ثم تتم مقارنة النموذج الفاصل للتحسين والتحكم بالقيم الحقيقية لبيانات حقل الراقوبة في حوض سرت بليبيا.

## Abstract

Hydrocarbons and water can be separated with the help of separators. Its use has improved the design of chemical plants as well as the oil and gas sector. The development of both steady state and dynamic models of the three phase horizontal separator in HYSYS is the goal of this effort. The separator model for optimization and control is then compared to the real values of the Raguba field data in the Sirte Basin, Libya.

***Keywords***: Velocity, slenderness , seam-to-seam length, separator sizing

## 1. Introduction

Crude oil is produced from reservoirs in a form of mixtures consisting of oil, water, gas, and other contaminants. The produced fluids in their initially form are, therefore, subjected to step-by-step treatment processes to convert them to final products that meet requirements. One of the important treatment processes is the separation of oil, water, and gas.

The primary step is normally achieved by applying different theory based on the type of processed crude and interaction between the phases of the stream. The initial separation in almost all streams is achieved following the gravity difference theory which depends mainly on the density difference between oil, water, and gas .The use of the appropriate separator shape depends on many factors, such as the number of phases of the processed stream, the crude properties, and the separation conditions.

The function of field separation processing is to remove undesirable components and to separate the well stream into salable gas and petroleum liquids, recovering the maximum amounts of each at the lowest possible overall cost. The applications of separation processes are very importance, not only in designing chemical plants, but also in oil field production. The product stream from a reactor / production well is rarely close to the objective function desired by the operator. There are either impurities from undesirable side reactions or unreacted species from the inlet stream [1].

Aspen HYSYS V8.0 has an array of units that are able to simulate separation processes and estimate the composition of the product streams. By choosing parameters in the system in a consistent way, the operator can fully specify the system in a way that HYSYS can solve for the remaining parameters [2]. There are many different types of separations utilized by engineers to purify their desired product. Most separations used in industry involve multi-phase separation. Multi-phase separation refers to the heterogeneous composition of the product and its tendency to split into multiple discrete mixtures [3, 4]. Two common modes of this separation that can be modeled in HYSYS are flash separation and 3-phase separation. The common theme in these separations is that the mixture in the column is heterogeneous and one outlet stream will contain the desired product in a higher purity than it was at the inlet [3].

### *1.1 Phase Separation*

Sometimes, especially in the presence of hydrocarbons and water, the liquid phase of the separation will not be homogeneous. This results from the fact that species within the liquid phase are not miscible with each other. The resulting separation will result in 3 unique streams, one in the vapor phase and two in the liquid phase.

To simulate a useful 3-phase separator, a feed is needed that will separate into two liquid phases. The feed can be then specified as before and connected to the 3-Phase Separator. Vapor, light liquid, and heavy liquid product streams are added, Fig.1-a. However the addition of a duty allows the user to specify one aspect of the product streams. Usually it is useful to specify concentrations of one component in a product stream or possibly the flow rate of one of those streams, Fig.1-b. [3].

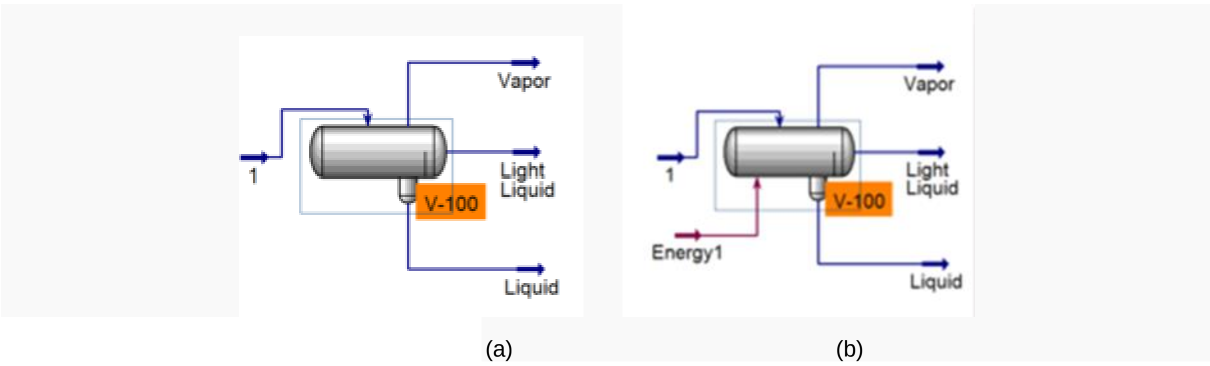


Figure 1: a- 3-Phase Separator, b-with duty

### *1.2 HYSYS Simulation*

To simulate a separation in HYSYS, first the simulation environment must be initialized. This includes first choosing all of the individual compounds that will exist in the overall system, and then choosing a fluid package that will accurately simulate all compounds in the range of expected temperatures and pressures. Once this is complete the simulation environment may be entered [3]. To begin building the process, first it is important to specify the feed stream that you are attempting to separate. These specifications include the composition, flow rate, temperature, and pressure of the stream. Once these parameters are entered, it is then necessary to connect the feed to the desired separator type and then run the simulation [3, 5-7].

## 2. Objective

Aspen HYSYS V8.6 was used to model the Raguba oil well separator as a three phase horizontal gravity separator. The main goal is to integrate imperfect phase separation into HYSYS. By defining the dispersions at the inlets and droplet sizes, it was feasible to remix the phases to a situation found in real life. To investigate the separator's performance, simulations were run [8].

## 3. Theory of Separations

This section covers the separation concepts, relevant laws, and equations utilized in the Raguba oil well separator.

### 3.*1 Sedimentation*

By utilizing the disparity in their densities, sedimentation uses gravity to separate a liquid that is dispersed in the continuous phase of another liquid. In a medium with density, if we take a droplet with volume Vd and density d, we can see that it will be buoyed up by gravity as in:

$$Fg = Vd\,(\rho d - \rho)\,g \qquad (1)$$

Where g is the gravitational acceleration, and can be substituted if the driving force is another factor other than gravity (e.g. centrifugal force).

### 3.*2 Viscosity of Emulsions*

The viscosity of the mixture has an inversely proportionate relationship to the terminal velocity of a droplet in a gravity separator. Along with other factors, the oil-to-water ratio and the dispersed phase's droplet size affect an emulsion's viscosity [9].

### 3.*3 Diffusion*

There are concentration gradients in the direction of separation because the gravitational sedimentation forces start the separation process in the separator. Additionally, Brownian movements will cause diffusion as a result, which will have the opposite effect on the separation.

### 3.*4 Coalescence*

As shown in Figures 2-a and 2-b, coalescence happens when two droplets combine into one in a separator and when droplets join the continuous phase at the bulk interface. Very small droplets, such as fog or mist, cannot be separated practically by gravity and must use a coalesce (liquid -liquid) separator. These droplets have the potential to combine to generate larger ones that will sink due to gravity. [10]

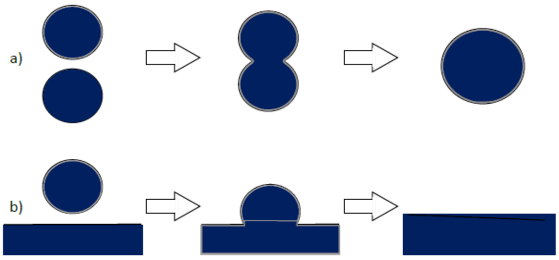



Figure 2: a) 2-droplets coalesce to form one bigger droplet. b) A droplet coalesces with the bulk phase.

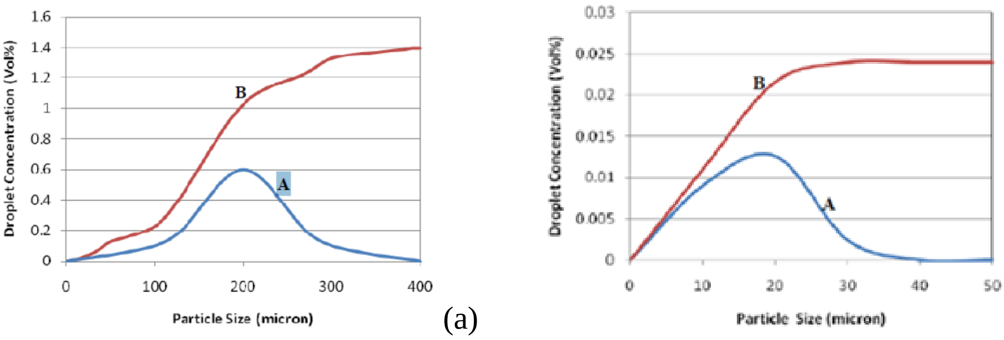
### *3.5 Separation Efficiency*

It is crucial that the product streams in liquid-liquid separation adhere to the legal product requirements. Further effluent treatment is required to separate the entrained oil since water in oil has the potential to impair product quality. Environmental authorities set the requirements for the oil and water products. The separation efficiencies of a separator are frequently used to describe its performance. Depending on the feed requirements, some of the frequently utilized methods include the dilute or dispersed efficiencies; a designer can use many strategies to achieve the desired separation.

### *3.6 Droplet distribution*

The number of droplets of various sizes should be counted in the lab, and a distribution curve should be drawn, according to a purportedly ideal way of determining the separator feed (Fig. 3-a). A typical curve called Curve-A plots droplet volume % against droplet size. The droplet generation mechanism, system setup, and liquid physical characteristics all influence the distribution of droplet volume sizes. Compared to chemical reactions, mechanical processes (such as pumping, mixing, and conveying two phase flow) result in substantially bigger droplet sizes.

From curve A, curve B is created, and it displays the cumulative droplet concentration. A designer can choose the best separation technology and equipment performance with the aid of this curve. This is the typical practicable size for separation with gravity when the difference in phase densities is minor and/or the continuous phase has a lower viscosity. According to Fig. 3-b, separation efficiencies are lower for particles smaller than 40 microns. It is vital to remember that the dispersion of oil droplets in water and the effectiveness of internal devices in removing oil droplets may not be the same [11].



(a) (b)

Figure 3: Water droplet distribution at separator at inlet (a) and outlet (b) [11]

### *3.7 Residence Time*

By directly measuring the amount of time needed for the oil and water to separate, laboratory techniques may be helpful in defining the parameters of feed separation. The laboratory test yields an estimate of the phases' or separator's overall residence time. This residence duration is only accurate if the contamination level is confirmed through repeated monitoring of the oil and water phases. Gravity separation benefits from this kind of feed specifications and separation requirements. Some customers cite API-12J, a specification for oil and gas separators, where average residence times for various types of oil are listed in Table 1. The drawback of this approach is that it does not customize based on the real feed characteristics [12].

**Table 1: API Recommendation on residence time [12].**

| Oil API gravities | Separation Temp., o F | Residence time, min |
|---|---|---|
| > 35 | any | ( 3 - 5) |
| < 35 | > 100 | (5 - 10) |
| | > 80 | (10 - 20) |
| | > 60 | (20 - 30) |

### *3.8 Cut-off Diameter*

There are many projects where it is impossible to specify the necessary liquid-liquid separation using any of the approaches mentioned above. In other words, the separator output for the project is stated, but the separator feed is not adequately defined. In situations like this, it is necessary to make the assumption of an adequate droplet distribution curve with an adopted cut-off diameter. A minimum of three points—the highest droplet size (dmax), the mass mean droplet size (d50), and the Sauter mean droplet size—are required to produce such a graph (d32). Additionally, providing these data necessitates laboratory screening of the droplets, which is impractical during the design phase. As a result, it is advised to size the separator on a cut-off diameter basis. Fig. 4 [8] illustrates the connection between the specification of the separator output and a specified cut-off diameter.

## 4. Case Study

The active handling and treatment of streams or fluids produced by the Raguba oil wells is referred to as processing. The main procedures involve: pumping; gas/liquid separation; gas treatment and compression; and water removal.

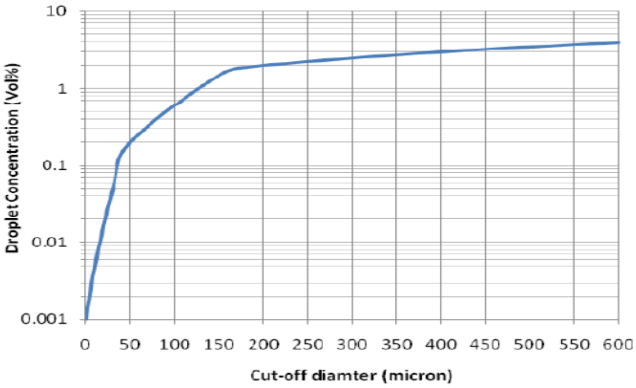
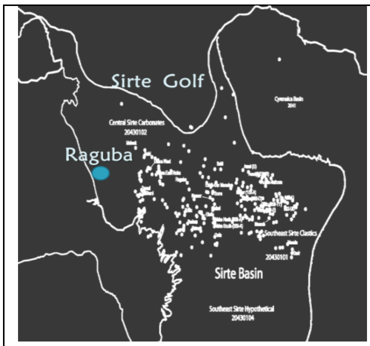



Figure 4: Droplet carry over versus cut-off diameter

### *4.1 Raguba Field:*

Raguba field is located in Sirte Basin, Lybia, Fig. 5




**Location:** Libya, Sirte Basin

**Started:** in 1963, by Sirte Oil Company

**Production rate:**

| | | |
|---|---|---|
| **At start:** 120,000. | **Now:** 24,000 bbl/d | (oil) |
| 100. | 30 MMscf/day | (gas) |

Figure 5: Location and data of Raguba field.

### *4.2 Data and Results of Raguba Separators:*

Figure 6 shows the flowchart of Raguba gas–oil separators by software. The Raguba refining plant has two main categories of gas-oil wells: High pressure (HP) and Law Pressure (LP). So, the separators are classified into two stages, the 1st stage for HP, while the 2nd stage for LP-gas-oil wells. The stages of Raguba separators plant can be summarized in Fig.7.

### *4.3 First Stage Separator of High Pressure HP:*

The 1st stage (A1 & B1) separators receive oil from the high pressure wells (HP = 265 psia). The gas separated at this pressure flows to a K.O. drum, while the oil flows to the 2nd stage (A2 & B2), Figs (6, 7). The pressure here is at 100 psia. The flashed gas flows to a K.O. drum. Oil from (A2 & B2) flows into the boot, which operates at 15 psia. The oil from the boot flows then to a surge tank for further separation of water, oil, and gas. The oil from the surge tank is pumped to Brega for exporting. Table 2 shows data input for the 1st stage (A1 & B1). Input data and output results obtained, using Excel sheet or Aspen HYSYS V.8, for the separation stages can be summarized as following:

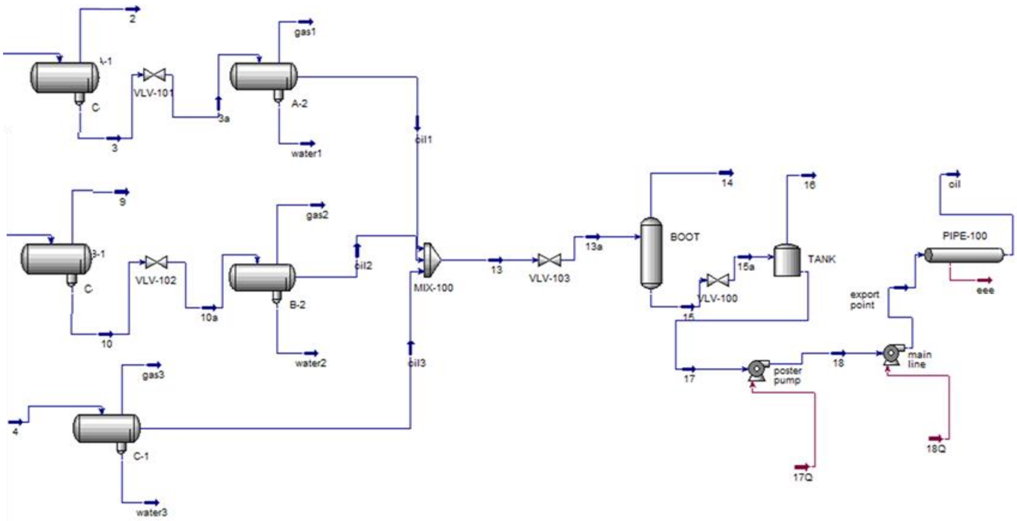



Figure 6: Flowchart of Roguba gas–oil separators

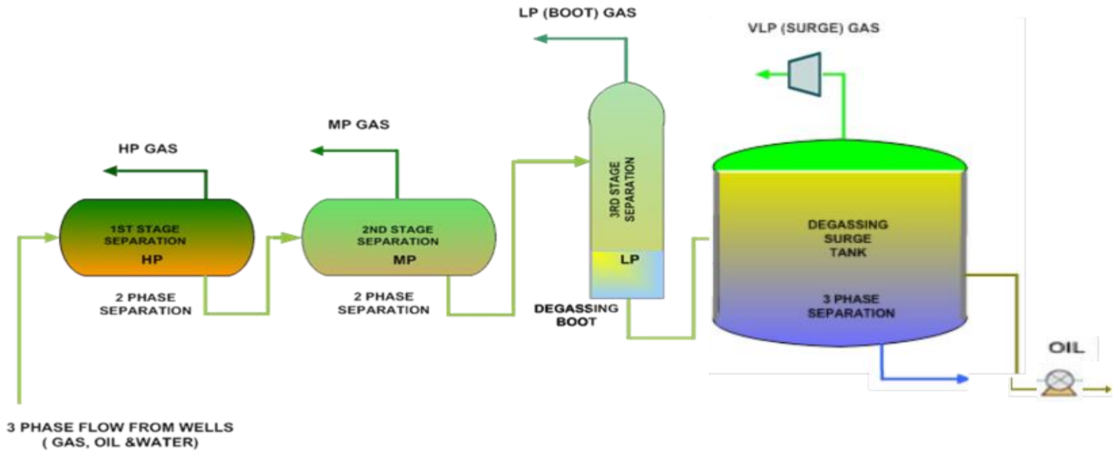



Figure 7: Stages and operations of Raguba-gas-oil separators

**Table 2: Input data for 1st stage A1, B1 separators at design condition (*for HYSIS)**

| Properties | Symbol | A-1 | B1 |
|---|---|---|---|
| Operating pressure | P, psia | 265 | 265 |
| Operating temperature | T, R | 605 | 605 |
| Molecular weight of water | Mw, lbm/lb-mole | 24.664, 24.61* | 24.664, 24.61* |
| Compressibility factor | Z, | 0.94 | 0.94 |
| Mass flow rate of gas | Qg, MMscf/d | 51.156 | 33 |
| Mass flow rate of liquid | Qr, BPD | 62654 | 43195, 40380* |
| Liquid density | ρL, lb/ft3 | 48.01 | 48.01 |
| Gas density | ρg, lb/ft3 | 1.07 | 1.07 |
| Gas specific gravity | - | 0.85 | 0.85 |
| Gas constant | R, - | 10.73 | 10.73 |
| Gas viscosity | μ, cp | 0.013 | 0.013 |
| Drop diameter | dm, μ in | 140 | 140 |
| Retention time for Liquid (desired) | t, min | 5, 3* | 5, 3* |
| Inside diameter | D, ft | 8 | 8 |
| Length of separator | L, ft | 35 | 35 |

### *4.3.1 Calculations of separation parameters:*

1. Liquid-density, (ρL) is a function of temperature, (ΔρT) and pressure, (ΔρP); compared with density at standard condition, ρsc ; where:

$$\rho_L = \Delta\rho_T + \Delta\rho_P + \rho_{sc} \qquad (2)$$

$$\Delta\rho_T = [\ 0.00302 + 1.505\ (\rho sc^{-0.9951}) * (T-60)^{0.938}\ ] - [\ 0.0216 - 0.0233 * (10)^{-0.0161*\rho sc} * (T-60)^{0.475}\ ]$$

$$\Delta\rho_P = [\ 0.167 + 16.18 *(10^{-0.0425*\rho sc}) * (\frac{P}{1000})\ ] - [\ 0.01*(0.299 + 263 *10^{-0.603*\rho sc}* (\frac{P}{1000})^2\ ]$$

$$= 2.792 + 0.216 + 45.337 = 48.345 \text{ lb/ft}^3$$

1. Gas-density, (ρg) depends upon: Molecular weight, (Mw); Operating pressure & temperature, (P & T); Compressibility factor, (z). Gas-density is then:

$$\rho_g = \frac{M_W * P}{R* z* T} \qquad (3)$$

$$\rho_g = \frac{24.664 * 265}{10.73* 0.94* 605} = 1.0711 \text{ lb/ft}^3$$

3. Mass flow rate (M):

A. For the liquid: $M_L = Q_r * \rho_L$ (4)

= 62654 * 48.345 * 5.615 = 17006691 lb/d

B. For the gas: $M_g = Q_g * M_w$ (5)

= 51.156 * 24.664 / 379.5 = 3.3247 lb/d

4. Droplet size:

The following parameters for all separation stages are calculated:

I. Vessel internal diameter, d, with effective length, Leff, (dLeff):

The steps of calculation are as follows:

a) Terminal settling velocity of the droplet, Vt

From droplet diameter, dm, assuming drag coefficient, CD = 0.34, Vt can be obtained:

$$V_t = 0.0119\ [(\frac{\rho L-\rho g}{\rho g})\ \frac{dm}{CD}]^{0.5} \quad (6)$$

$$V_t = 0.0119\ [(\frac{48.345-1.0711}{1.0711})\ \frac{140}{0.34}]^{0.5} = 1.6042 \text{ ft/s}$$

b) Reynolds number, Re

$$Re = 0.0049\ \frac{\rho g\ dm\ Vt}{\mu} \quad (7)$$

$$Re = 0.0049[\frac{1.0711*140*1.6042}{0.013}] = 90.6724$$

c) Drag coefficient, CD

$$CD = \frac{24}{Re} + \frac{3}{Re^{0.5}} + 0.34 \quad (8)$$

$$CD = \frac{24}{90.6724} + \frac{3}{90.6724^{0.5}} + 0.34 = 0.9197$$

Repeat the same procedure by iterative method to obtain the accurate value of CD, which equals to 1.2974.

d) dLeff

$$dLeff = 420(\frac{T*Z*Qg}{P})\ [(\frac{\rho g}{\rho L-\rho g})\ \frac{CD}{dm}]^{0.5} \quad (9)$$

$$dLeff = 420(\frac{605*0.94*51.156}{265})\ [(\frac{1.0711}{48.345-1.0711})\ \frac{1.2974}{140}]^{0.5} = 668.13$$

II. The value $d^2Leff$ :

$$d^2 Leff = \frac{t_r\, Q_r}{0.7} \quad (10)$$

$$= 5 * 62654 / 0.7 = 447528.6$$

III. The value Leff :

a) For Liquid: $d^2Leff / d^2$ (11)

$$Leff = \frac{447528.6}{(96)^{\wedge}2} = 48.56 \text{ ft}$$

b) For Gas: dLeff / d (12)

$$Leff = \frac{668.13}{96} = 6.96 \text{ ft}$$

IV. Estimate seam-to-seam length:

For liquid: $Lss = Leff * \frac{4}{3}$ (13)

$$= 48.56 * 4/3 = 64.75 \text{ ft}$$

Slenderness ratio (SR) $= 12 \frac{Lss}{d}$ (14)

$$= \frac{12 * 64.75}{96} = 8.09 \text{ ft}$$

Table 3 gives slenderness ratio (SR) for different separator diameters at 1st stage (A1-B1), which is chosen in the range 3-5, Table 1.

**Table 3: Optimal design (D & L) at 1st stage (A1-B1) for retention time 5 min**

| D, in | A1-separator | | | | B1-separator | | | |
|---|---|---|---|---|---|---|---|---|
| | Gas Leff, ft | Liquid Leff, ft | Lss, ft | 12 Lss D | Gas Leff, ft | Liquid Leff, ft | Lss, Ft | 12 Lss d |
| 96 | 6.96 | 48.56 | 64.75 | 8.09 | 4.49 | 33.48 | 44.64 | 5.58 |
| 102 | 6.55 | 43.01 | 57.35 | 6.75 | 4.23 | 29.66 | 39.54 | 4.65 |
| 108 | 6.19 | 38.37 | 51.16 | 5.68 | 3.99 | 26.45 | 35.27 | 3.92 |
| 114 | 5.86 | 34.44 | 45.91 | 4.83 | 3.78 | 23.74 | 31.65 | 3.33 |
| 120 | 5.57 | 31.08 | 41.44 | 4.14 | 3.59 | 21.43 | 28.57 | 2.86 |
| 126 | 5.3 | 28.19 | 37.59 | 3.58 | 3.42 | 19.43 | 25.91 | 2.47 |
| 132 | 5.06 | 25.68 | 34.25 | 3.11 | 3.26 | 17.71 | 23.61 | 2.15 |

From the calculation results in table 3, the chosen separator geometry is: D = 114 in. (2.9 m), and length Leff = 34.44 ft (10.5 m) for (A1) separator, while D = 102 in (2.59 m) and B1-separator length is 29.66 ft (9 m).

*4.4 Second stage separation of low pressure LP:*

This stage includes A2, B2, and C as shown in Figs (6, 7). Table 4 shows data input for them:

**Table 4: Input data for 2nd stage (A2, B2, & C) 3 phase separators at design condition (* for HYSIS)**

| Properties | Symbol | A-2 | B2 | C |
|---|---|---|---|---|
| Operating pressure | P, psia | 100 | 100 | 100 |
| Operating temperature | T, R | 600, 600.8* | 600, 600.8* | 600 |
| APIo gravity | APIo | 40 | 40 | 40 |
| Mole. weight of water | Mw, lbm/lb-mole | 31.651, 31.39* | | 38.1, 31.39* |
| Water specific gravity | (S.G)w | 1.07 | 1.07 | 1.07 |
| Compressibility factor | Z, | 0.985 | 0.985, 0.959* | 0.985 |
| Mass flow rate of gas | Qg, MMscf/d | 4.427, 3.63* | 2.854, 2.34* | 1, 0.9327* |
| Mass flow rate of liquid | Qr, BPD | 63899, 60680* | 41197, 39112* | 5, 4.35* |
| Mass flow rate of water | Qw, BPD | 123.8 | 78.17 | 119.8 |
| Liquid density | ρL, lb/ft3 | 47.968,48.77* | | 47.968, 44.84* |
| Gas density | ρg, lb/ft3 | 0.51* | | |
| Gas specific gravity | - | 1.09, 1.08* | | 1.314 |
| Gas constant | R, | 10.73 | 10.73 | 10.73 |
| Viscosity | μ, cp | 0.013 (g), 0.906 (o) | | 0.013 (g), 0.906 (o), 0.467(o)* |
| Droplet diameter | dm, μ in | 500 (o), 100 (g) | | |
| Retention time for Liquid | tr, min | 5, 10 (w), 7.5 (o) | | |
| Inside diameter | D, ft | 7 | | |
| Length of separator | L, ft | 32 | | |

In this stage 3 phase (gas, oil, & water) separators (A2, B2, & C) are considered. Some differences in calculations of droplet size here are carried out as follows:

1) Specific Gravity of oil $(S.G)_o$ according to API°, and difference $(\Delta SG)_{wo}$ with water

$$(S.G)o = \frac{141.5}{131.5+API°} \quad (15)$$

$$= \frac{141.5}{40+131.5} = 0.825$$

$$(\Delta SG)_{wo} = (SG)_w - (SG)_o \quad (16)$$

$$= 1.07 - 0.825 = 0.245$$

Assume droplet size for oil = 500 micron, maximum oil layer ($(h_o)_{max}$) is defined by:

$$(h_o)_{max} = 320 * \frac{(tr)o * \Delta SG}{\mu o} \quad (17)$$

depending on the retention time for oil $(t_r)_o$, = 7.5 min for API°, and oil viscosity, $\mu_o$ = 0.906

$$(h_o)_{max} = 320 * 7.5 * 0.245 / 0.906$$
$$= 648.92 \text{ in}$$

2) Fraction of water area, $A_w$, to the vessel area, A, is:

$$\frac{Aw}{A} = 0.5 * \frac{Qw*(tr)w}{Qo*(tr)o+Qw*(tr)w} \quad (18)$$

$$= 0.5 * \frac{123.8*10}{(63899*7.5)*(123.8*10)} = 0.0013$$

3) Determination of maximum diameter ($d_{max}$) from:

$$d_{max} = (h_o)_{max} / \beta \quad (19)$$

The coefficient β is obtained from Fig.8, at $A_w/A$ = 0.0013, β = 0.49

$$d_{max} = 648.92 / 0.49 = 1324.32 \text{ in}$$

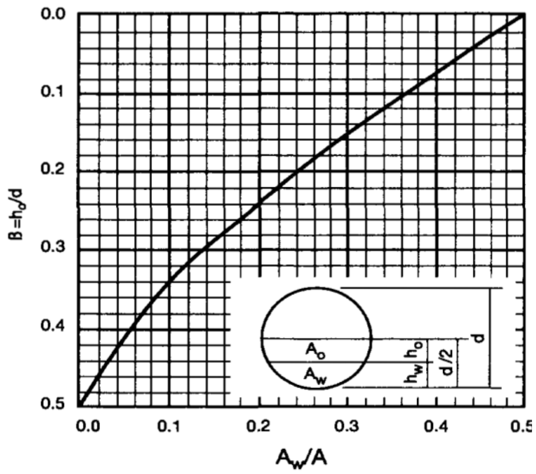



Figure 8: Coefficient "β" for a cylinder half filled with liquid

4) $d^2 L_{eff} = 1.42 [ (tr)_o * Q_o + (tr)_w * Q_w ]$ (20)

$= 1.42 [ ( 7.5 * 63899 ) + ( 10 * 123.8 ) ] = 682282$

$L_{eff} = 682282 / (108)^2 = 58.5$ ft

Calculation results for 2nd stage (A2, B2 & C) are in Table 5.

**Table 5: Optimal design (D & L) at 2nd stage (A2-B2-C) for retention time 10 min (w), 7.5 min (o)**

| D, in | A-2 | | | B2 | | | D, in | C | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Liquid Leff, ft | Lss, ft | 12 Lss D | Liquid Leff, ft | Lss, Ft | 12 Lss D | | Liquid Leff, ft | Lss, ft | 12 Lss D |
| **108** | **58.50** | **78** | **8.67** | **37.71** | **50.28** | **5.59** | **16** | **6.85** | **9.14** | **6.85** |
| **114** | **52.50** | **70** | **7.37** | **33.85** | **45.13** | **4.75** | **20** | **4.39** | **5.85** | **3.51** |
| **120** | **47.38** | **63.17** | **6.32** | **30.55** | **40.73** | **4.07** | **24** | **3.05** | **4.06** | **2.03** |
| **126** | **42.98** | **57.30** | **5.46** | **27.71** | **36.94** | **3.52** | **30** | **1.94** | **2.60** | **1.04** |
| **132** | **39.16** | **52.21** | **4.75** | **25.24** | **33.66** | **3.06** | **36** | **1.35** | **1.80** | **0.60** |
| **144** | **32.90** | **43.87** | **3.66** | **19.55** | **28.28** | **2.36** | | | | |
| **150** | **30.32** | **40.43** | **3.23** | **18.07** | **26.07** | **2.09** | | | | |

The chosen diameter D = 132 in (3.35 m) and A2-separator length is 39.16 ft (12 m), while D = 114 in (2.9 m) and B2-separator length is 33.85 ft (10.32 m). For C-separator, D = 20 in (0.508 m) with length = 4.39 ft (1.34 m), as shown in table 5.

## 5. Aspen HYSYS and Simulation:

Aspen HYSYS V8.0 has an array of units that are able to simulate separation processes and estimate the composition of the product streams. By choosing parameters in the system in a consistent way, the operator can fully specify the system in a way that HYSYS can solve for the remaining parameters. Figure 6 shows the flow sheet in Raguba separation plant, which consists of:

- 2-phase separators (A1 & B1)
- 3-phase separators (A2, B2, & C).

Two common modes of this separation that can be modeled in HYSYS are flash separation and 3-phase separation, Fig.1. The common theme in these separations is that the mixture is heterogeneous and one outlet stream will contain the desired product in a higher purity than it was at the inlet. Figure 9 shows input data for A1-separator, given from table 2. The obtained results by HYSIS are in table 6.

aspentech LEGENDS Bedford, MA USA

Case Name: finally surge tank and bout design2.hsc
Unit Set: NewUser6
Date/Time: Sat Aug 05 20:20:41 2017

**Material Stream: 1**

Fluid Package: Basis-1
Property Package: Peng-Robinson

CONDITIONS

| | | Overall | Vapour Phase | Liquid Phase | Aqueous Phase |
|---|---|---|---|---|---|
| Vapour / Phase Fraction | | 0.5242 | 0.5242 | 0.4655 | 0.0103 |
| Temperature: | (F) | 145.0 * | 145.0 | 145.0 | 145.0 |
| Pressure: | (psia) | 265.0 * | 265.0 | 265.0 | 265.0 |
| Molar Flow | (lbmole/hr) | 1.074e+004 | 5629 | 4999 | 110.4 |
| Mass Flow | (lb/day) | 2.070e+007 | 3.324e+006 | 1.733e+007 | 4.774e+004 |
| Std Ideal Liq Vol Flow | (barrel/day) | 8.750e+004 * | 2.471e+004 | 6.265e+004 | 136.5 |
| Molar Enthalpy | (Btu/lbmole) | -8.322e+004 | -3.837e+004 | -1.329e+005 | -1.218e+005 |
| Molar Entropy | (Btu/lbmole-F) | 48.43 | 40.81 | 57.75 | 15.04 |
| Heat Flow | (Btu/hr) | -8.936e+008 | -2.160e+008 | -6.642e+008 | -1.345e+007 |
| Liq Vol Flow @Std Cond | (barrel/day) | 8.305e+004 * | 9.063e+006 | 6.088e+004 | 134.2 |

PROPERTIES

| | | Overall | Vapour Phase | Liquid Phase | Aqueous Phase |
|---|---|---|---|---|---|
| Molecular Weight | | 80.32 | 24.61 | 144.4 | 18.02 |
| Molar Density | (lbmole/ft3) | 7.436e-002 | 4.351e-002 | 0.3337 | 3.392 |
| Mass Density | (lb/ft3) | 5.973 | 1.070 | 48.20 | 61.11 |
| Act. Volume Flow | (barrel/day) | 6.172e+005 | 5.531e+005 | 6.403e+004 | 139.1 |
| Mass Enthalpy | (Btu/lb) | -1036 | -1559 | -919.9 | -6759 |

Figure 9: input data for A1-separator

**Table 6: Results from HYSYS at 1st stage (A1-B1)**

| D, in | A1-separator | | | | D, in | B1-separator | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Gas Leff, ft | Liquid Leff, ft | Lss, Ft | 12 Lss D | | Gas Leff, ft | Liquid Leff, ft | Lss, ft | 12 Lss d |
| 96 | 6.98 | 29.13 | 38.85 | 4.86 | 90 | 4.80 | 21.37 | 28.49 | 3.80 |
| 102 | 6.57 | 25.81 | 34.41 | 4.05 | 96 | 4.50 | 18.78 | 25.04 | 3.13 |
| 108 | 6.21 | 23.02 | 30.69 | 3.41 | 102 | 4.24 | 16.63 | 22.18 | 2.61 |
| 114 | 5.88 | 20.66 | 27.55 | 2.90 | 108 | 4.00 | 14.84 | 19.78 | 2.20 |
| 120 | 5.89 | 18.65 | 24.86 | 2.49 | 114 | 3.79 | 13.32 | 17.75 | 1.87 |
| 126 | 5.32 | 16.91 | 22.55 | 2.15 | 120 | 3.60 | 12.02 | 16.02 | 1.60 |
| 132 | 5.08 | 15.41 | 20.55 | 1.87 | 126 | 3.43 | 10.90 | 14.53 | 1.38 |

Selecting slenderness ratio, (12Lss/d), in the range 3-4, the chosen diameter is 108 in (2.7 m) and A1-separator length is 23.02 ft (7.02 m), while the chosen diameter is 90 in (2.3 m) and B1-separator length is 21.37 ft (6.5 m).

The input data in A2-separator, table 4, the obtained results by HYSIS are in table 7.

**Table 7: Results from HYSYS at 2nd stage (A2-B2, & C)**

| D, in | A-2 | | | B2 | | | D, in | C | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Liquid Leff, ft | Lss, ft | 12 Lss d | Liquid Leff, ft | Lss, Ft | 12 Lss d | | Liquid Leff, ft | Lss, ft | 12 Lss d |
| 108 | 58.50 | 78 | 8.67 | 55.56 | 42.85 | 5.30 | 16 | 6.83 | 9.10 | 6.83 |
| 114 | 52.50 | 70 | 7.37 | 49.86 | 38.67 | 4.51 | 20 | 4.37 | 5.83 | 3.50 |
| 120 | 47.38 | 63.17 | 6.32 | 45 | 35.08 | 3.87 | 24 | 3.03 | 4.05 | 2.02 |
| 126 | 42.98 | 57.30 | 5.46 | 40.82 | 31.96 | 3.34 | 30 | 1.94 | 2.59 | 1.04 |
| 132 | 39.16 | 52.21 | 4.75 | 37.19 | 26.86 | 2.91 | 36 | 1.35 | 1.80 | 0.60 |
| 144 | 31.25 | 24.75 | 2.24 | 20.14 | 24.75 | 2.24 | | | | |
| 150 | 28.80 | 22.88 | 1.98 | 18.56 | 22.88 | 1.98 | | | | |

Selecting slenderness ratio, (12Lss/d), in the range 3-5 are common. The chosen diameter is 132 in (3.35 m) and A2-separator length is 39.16 ft (11.34 m), while the chosen diameter is 114 in (2.9 m) and B2-separators length is 32.14 ft (9.8 m). For C-separator, D = 20 in (0.508 m) with length = 4.39 ft (1.34 m), as shown in table 7.

## 6. Discussion

The presence of hydrocarbons and water, makes the separation not be homogeneous. This results from the fact that species within the liquid phase are not miscible with each other. The resulting separation will result in 3 unique streams, one in the vapor phase and two in the liquid phase. To simulate a useful 3-phase separator, a feed is needed that will separate into two liquid phases. The feed can be then specified as before and connected to the 3-Phase Separator.

In this work, Raguba gas oil separation plant was used as input data to calculate the actual operating conditions for oil flow rate, liquid mass flow rate, and droplet size diameter respectively. Using HYSYS simulation package, comparison of manual sheet and software results is carried out, table 8-10.

**Table 8: Operating and design for oil flow rate in Raguba field.**

| Separa. Type | Separator | Operating Condition | Design Condition, B/d | HYSYS Simulation, B/d |
|---|---|---|---|---|
| 2-phase | A-1 | 8660 | 62654 | 62650 |
| | B-1 | 4270 | 43195 | 40380 |
| 3-phase | A-2 | 6268 | 63899 | 60680 |
| | B-2 | 2325 | 41197 | 39112 |
| | C | 15355 | 5 | 4.35 |

**Table 9: Liquid mass flow rate in Raguba field**

| Separa. type | Separator | Design Condition, lb/d | HYSYS Simulation, lb/d |
|---|---|---|---|
| 2-phase | A-1 | 1.701*107 | 1.733*107 |
| | B-1 | 1.172*107 | 1.703*107 |
| 3-phase | A-2 | 1.793*107 | 1.117*107 |
| | B-2 | 1.092*107 | 1.098*107 |
| | C | 1347 | 1128 |

**Table 10: Droplet size parameters in Raguba field**

| Separa. Type | Separator | Design Condition | HYSYS Simulation |
|---|---|---|---|
| 2-phase | A-1 | d = 108 in (2.7 m)<br>Lss = 30.69 ft (9.4 m) | d = 108 in (2.7 m)<br>Lss = 23.02 ft (7.02 m) |
| | B-1 | d = 96 in (2.4 m)<br>Lss = 20.09 ft (6.1 m) | d = 90 in (2.3 m)<br>Lss = 21.37 ft (6.5 m) |
| 3-phase | A-2 | d = 132 in (3.35 m)<br>Leff = 39.16 ft (12 m) | d = 132 in (3.35 m)<br>Leff = 37.19 ft (11.34 m) |
| | B-2 | d = 114 in (2.9 m)<br>Leff = 33.85 ft (10.32 m) | d = 114 in (2.9 m)<br>Leff = 32.14 ft (9.8 m) |
| | C | d = 20 in (0.508 m)<br>Leff = 4.39 ft (1.34 m) | d = 20 in (0.508 m)<br>Leff = 4.37 ft (1.33 m) |

## 7. Conclusion

In recent years, as oil and gas fields become less accessible and their hydrocarbon quality lower and more variable, maintaining or increasing production levels has emerged as a key field development goal. One of the most pronounced challenges in meeting this goal is managing the complex hydraulics of pipelines used in gathering systems and to transport the oil and gas from wells to processing facilities. Aspen HYSYS® has been widely used to model many facets of the oil and gas production fields, including separation systems, environmental control systems, gas dehydration, H2S and CO2 removal, and more. It is the tool of choice to determine the heat and material balance, separation performance, and regulatory compliance, among other key performance criteria [13].

The process of simulating separation in HYSYS is once the user has a fully specified feed. The feed specifications come from the description of the problem that the user is attempting to solve. The full specification of the feed is all the information that HYSYS needs to simulate the separation.

The choice of 3-phase separator depends on the species in the feed stream. If there are 3 phases in the feed stream it is necessary to simulate with a 3-phase separator.

It was found that:

1. Higher oil flow rate requires larger diameter to prevent the liquid interface in gas phase.
2. Gas flow rate increases always results in increase of required diameter as long as the separator operates under gas capacity constraint.
3. Increase of liquid density decreases the slenderness ratio but it will not affect the choice of separators.
4. Higher compressibility gases require larger diameter to separate.
5. The required minimum diameter decreases with the increase of separation pressure. Form this result it can be concluded that when stage separation is applied larger diameter are required for low pressure separation.
6. Increasing retention time will increase the effective length for a selected diameter which leads to larger seam-to-seam length. This will turn in increasing the slenderness ratio, and hence, larger diameter is required to avoid liquid re-entrainment.
7. Oil production rate decreasing and equipment size discrepancy becomes greater. This creates problems with gas/oil flow velocity appearance of liquid hold ups in the gas lines, slugging –surging-corrosion cleaning problem with the main oil line (low velocity).(more purified)

## References

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