شركة قطر للكيماويات المحدودة
QATAR CHEMICAL COMPANY LTD.

PROJECT NO.

PO. 4500098732 / 10 / 01.01.2018

PROJECT TITLE

Supply of PF Process Calculation Spreadsheet (Excel Forma)

DOCUMENT TITLE

Two Phase (Gas - Oil) Vertical Separator: As per "Petroleum and Gas Field Processing - Hussein K. Abdel-Aal, Mohamed Aggour, M. A. Fahim"

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DATE	REV.	REASON FOR REVISION	PREP.	CHKD.	APPD.	APPD.

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BASIS

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DISCUSSION

This spreadsheet provides an easy and simple approach to 2 phase vertical separator sizing. Formulae and references are also provided for process engineers to edit/duplicate this work.

There is as much art as there is science to properly design a separator. Three main factors should be considered in separator sizing:
1) vapor capacity, 2) Liquid capacity, and 3) operability.
The vapor capacity will determine the cross-sectional area necessary for gravitational forces to remove the liquid from the vapor.
The liquid capacity is typically set by determining the volume required to provide adequate residence time to "de-gas" the liquid or allow immiscible liquid phases to separate.
Operability issues include the separator's ability to deal with solids if present, unsteady flow/liquid slugs, turndown, etc. Finally, the optimal design will usually result in an aspect ratio that satisfies these requirements in a vessel of reasonable cost. These factors often result in an iterative approach to the calculations.

Several useful guidelines for separator design are provided below;

Momentum & Velocity criteria for nozzles (Source: DEP 31.22.05.12 - Gen.- 2008)

Inlet Nozzle	**Momentum or Velocity Limit**
No Internal	Max. Momentum, $\rho_m V^2_m \leq 1400$ Pa
Half open pipe	Max. Momentum, $\rho_m V^2_m \leq 2100$ Pa
Schoepentoeter used as inlet device	Max. Momentum, $\rho_m V^2_m \leq 8000$ Pa
Gas outlet Nozzle	Max. Momentum, $\rho_g V^2_{g,out} \leq 4500$ Pa
Liquid outlet Nozzle	Maximum velocity, 1 m/s

Selection guideline for separator types

System Characteristics	Type of Separator
Large vapour, less liquid Load (by volume)	Vertical
Large liquid, less vapour Load (by volume)	Horizontal
Large vapour, large liquid Load (by volume)	Horizontal
Liquid-liquid separation	Horizontal
Liquid-solid separation	Vertical

Level setting in the separator

Level type	**Level setting**
Level Alarm High High (LAHH)	30 – 60 seconds or 200 mm whichever is greater
Level Alarm High (LAH)	30 – 60 seconds or 200 mm whichever is greater
Normal Alarm Level (NAL)	60% of horizontal separator
Level Alarm Low (LAL)	30 – 60 seconds or 200 mm whichever is greater
Level Alarm Low Low (LALL)	30 – 60 seconds or 200 mm whichever is greater Should be at least 200 mm above the

Typical K factors for the sizing of wire mesh demisters (Source: IPS-E-PR-880, 1997)

Separator type	**K factor (m/s)**
Horizontal (with vertical pad)	0.122 to 0.152
Spherical	0.061 to 0.107
Vertical or horizontal (with horizontal pad)	0.055 to 0.107
At atmospheric pressure	0.107
At 2100 kPa	0.101
At 4100 kPa	0.091
At 6200 kPa	0.082
At 10300 kPa	0.064
Wet steam	0.076
Most vapours under vacuum	0.061
Salt and caustic evaporators	0.046

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NOMENCLATURE

A	total cross sectional area of the separator.
A_w	cross sectional area of the separator occupied by water, ft^2
A_o	cross sectional area of the separator occupied by oil, ft^2
A_g	cross sectional area of the separator occupied by gas, ft^2
C_D	drag coefficient
d	vessel internal diameter, in.
d_m	bubble or drop diameter, μm
D	vessel diameter, ft
h	liquid height, in.
h_g	gas-phase space height, in.
h_o	oil pad height, in.
h_w	water pad height, in.
K	mesh capacity factor, ft/sec
L_{eff} or L	effective length of the vessel where separation occurs, ft
L_{ss} or L_s	seam-to-seam vessel length, ft
N_{LL}	normal liquid level, %
P	operating pressure, psia
Q_c	continuous liquid-phase flow rate, bbl/day
Q_g	gas flow rate, MMSCFD or ft^3/s
Q_o	oil flow rate, bbl/day
W or Q_w	water flow rate, bbl/day
Re	Reynolds number
T	operating temperature, °R
V	liquid settling volume
V_a	max. allowable velocity through secondary separation section
V_m	velocity of the mixture, m/s
Z	gas compressibility
μ_c	continuous phase dynamic viscosity, cp
μ_w	water dynamic viscosity, cP
ρ	density, lbm/ft^3
ρ_g	gas density, lbm/ft^3
ρ_l	liquid density, lbm/ft^3
ρ_o	oil density, lbm/ft^3
ρ_m	mean density of mixture, kg/m^3
ρ_w	water density, lbm/ft^3

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REFERENCES

API 12J, Specification for oil and gas separators, 1989

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

IPS-E-PR-880, 1997

GPSA - Engineering Data Book (13th Edition)

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STANDARD SEPARATOR SIZES AS PER API

D [in] x H or L [ft]
12¾ in x 5 ft
12¾ in x 7½ ft
12¾ in x 10 ft
16 in x 5 ft
16 in x 7½ ft
16 in x 10 ft
20 in x 5 ft
20 in x 7½ ft
20 in x 10 ft
24 in x 5 ft
24 in x 7½ ft
24 in x 10 ft
30 in x 5 ft
30 in x 7½ ft
30 in x 10 ft
36 in x 5 ft
36 in x 7½ ft
36 in x 10 ft
36 in x 15 ft
42 in x 7½ ft
42 in x 10 ft
42 in x 15 ft
48 in x 7½ ft
48 in x 10 ft
48 in x 15 ft
54 in x 7½ ft
54 in x 10 ft
54 in x 15 ft
60 in x 7½ ft
60 in x 10 ft
60 in x 15 ft

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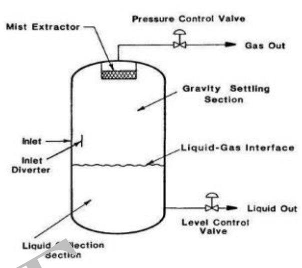
INPUT PARAMETERS

Q_g	15	mmscfd	Gas rate
Q_o	3000	bbl/d	Oil rate
γ	0.6		Gas specific gravity
ρ'_o	35.0	^oAPI	Oil density
γ_o	0.85		Oil specific gravity
P	985	psia	Operating pressure
T'	60	^oF	Operating temperature
T	520	^oR	Operating temperature
t	3	minutes	Retention time (Refer Table 1)
Z	0.84		Gas compressibility
μ_g	0.013	cP	Gas viscosity
d_m	100	Micron	Smallest oil droplet size to be removed

Yellow boxes are input boxes.

SCHEMATIC



CALCULATIONS

Step 1: Determine gas and oil properties

ρ_g	3.7	lb/ft^3	Gas operating density
ρ_o	53.0	lb/ft^3	Oil operating density

Step 2: Determine C_d

C_d	1.21	Assume	Drag coefficient
u	0.40	ft/s	Settling velocity of oil droplet
Re	55		Reynolds no.
C_d	1.19		
Error	0.00	Click me	Use goal seek to get error zero, by changing asssumed C_d

Step 3: Check for gas capacity constraint

D^2	1007	in^2	
D_{min}	31.7	in	Minimum allowable vessel diameter for separation of oil droplets down to 100 micron

Step 4: Check for liquid capacity constraint

D^2H	77085

EQUATIONS

$$\rho_g = 2.7\gamma \frac{P}{TZ}$$

$$\rho_o = \rho_w \gamma_o$$

$$u = 0.01186\left[\left(\frac{\rho_o - \rho_g}{\rho_g}\right)\frac{d_m}{C_d}\right]^{1/2}$$

$$\mathrm{Re} = 0.0049\frac{\rho_g d_m u}{\mu_g}$$

$$C_d = 0.34 + \frac{3}{\mathrm{Re}^{0.5}} + \frac{24}{\mathrm{Re}}$$

$$D^2 = 5,058 Q_g\left(\frac{TZ}{P}\right)\left[\frac{\rho_g}{(\rho_o - \rho_g)}\frac{C_d}{d_m}\right]^{1/2}$$

$$D^2H = 8.565 Q_o t$$

$D < 36$ in.

$$L_s = \frac{H + 76}{12}\ \mathrm{ft}$$

$D > 36$ in.

$$L_s = \frac{H + D + 40}{12}\ \mathrm{ft}$$

Try different combinations of D.

TABLE 1

D, in	H, in	L_s, ft	SR
30	85.7	13.5	5.4
36	59.5	11.3	3.8
42	43.7	10.5	3.0
48	33.5	10.1	2.5
54	26.4	10.0	2.2
60	21.4	10.1	2.0
66	17.7	10.3	1.9
72	14.9	10.6	1.8
78	12.7	10.9	1.7
84	10.9	11.2	1.6
90	9.5	11.6	1.6

TABLE 2 (Ref. API 12J)

Oil Gravities	Retention time, minutes (Typical)
Above 35 ^oAPI	1
20 to 30 ^oAPI	1 to 2
10 to 20 ^oAPI	2 to 4

L_s	11.3	**ft**	**Seam to seam length (select from Table 1)**
SR	3.8		Slenderness ratio (typical value 3 to 4) (select from Table 1)
D	36.0	**in**	**Separator diameter (select from Table 1)**

NOTES

1. As per GPSA, typical vertical H/D ratios are normally in the 2 to 4 range.