Section 3
Surface Equipment

Separators

Closed vessels to remove liquid from gases.

Separator Components

1) Primary Separation Section – Removes the bulk of the fluid from the well stream. A tangential inlet which imparts a circular motion to the fluids.

2) Liquid Accumulation Section – To receive the liquids after separation. Must be large enough to handle surges.

3) Secondary Separation Section – Removing smaller droplets of liquid by using gravitation. Slows the velocity of the gas to minimize turbulent flow.

4) Mist Extraction Section – Removes entrained droplets. Impingement is used for this. The fluid strikes obstructions which act as a collecting surface.

Types of Separators

Separators are classified by shape and size. Vertical, horizontal, and spherical are the most common.

Advantages of the different types, as listed by Campbell

Vertical
Liquid level control not as critical
Will handle large quantities of sand
Easier to clean
Has greater surge capacity
Less tendency for revaporization of liquid

Horizontal
Successfully used in handling foaming crudes
Cheaper than vertical?
Easier to ship on skid assemblies
More efficient for large volume of gas
Smaller diameter for a given gas capacity

Spherical
Cheaper than the other two
Better clean-out and bottom drain features than vertical type
More compact than the others

Factors Influencing Separation

1) Operating pressure, Pressure effects the densities of the fluids. The net effect is an increase in pressure causes an increase in the gas capacity.
2) Temperature, The net effect of Temperature is an increase in temperature causes a decrease in the capacity.
3) Densities of the fluids, efficiency of particle collection varies with the densities of the fluids. At constant pressure and temperature the gas capacity is the square root of the difference of the densities divide by the density of the gas.

$$\sqrt{\frac{\rho_l - \rho_g}{\rho_g}} \tag{3-1}$$

4) Gas velocity, since the gravity separation depends on the settling velocity of the droplets, a small decrease in the velocity of the gas will increase the capacity of the vessel.
5) Viscosity also affects the settling velocity of the droplets.

Sizing Separators

Capacities are determined under the following conditions:

1) No liquid foaming or undue surging
2) Adequate line and valve capacities
3) The operating temperature of 60 F is above the cloud point of the oil and the hydrate point of gas.
4) The smallest separable liquid particles are spheres of 10 microns in diameter.

The liquid carryover should not exceed .1 of a gallon per million cubic feet of gas.

The separator's oil capacity q is based on the relationship between the normal oil volume V and the retention time t, which is usually one minute to allow gas and water to separate from the oil.

$$q = \frac{V}{t} \qquad \text{V in ft3 and t in minutes} \qquad (3\text{-}2)$$

Since 1 ft3/min is 257 bbl/day, rated capacity is one half

$$q = 128\frac{V}{t}\ \text{bbl/day} \qquad (3\text{-}3)$$

The oil volume for a vertical separator is

$$V = .785D^2h \qquad (3\text{-}4)$$

where

D is inside diameter in feet

h is the height of the oil column above the bottom of the oil outlet in feet.

5' separator h = 2.50'

10' separator h = 3.25'

15' separator h = 4.25'

so

$$q_r = 100.5\frac{D^2 h}{t} \text{ bbls/day} \quad (3\text{-}5)$$

For a horizontal separator

$$V = .785D^2\frac{L}{2} \quad (3\text{-}6)$$

so

$$q_r = 50.24\frac{D^2 L}{t} \text{ bbls/day} \quad (3\text{-}7)$$

Gas Capacity

Gas capacity is related to the entrainment (suspending) velocity. The upward velocity for the suspension of a particle is determined from the particles resistance to the moving gas and the force of gravity on the particle.

$$F_a = \frac{k\rho_g \pi d^2 v^2}{4} \quad (3\text{-}8)$$

where

F_a = total force on the particle
k = empirical constant
d = diameter of particle
ρg = density of the gas
v = linear velocity of gas relative to the particle

The gravity force on a spherical particle, less buoyancy

$$F_g = \frac{\pi d^3}{6}(\rho_o - \rho_g)g$$ g = acceleration of gravity (3-9)

When Fa = Fg the particle remains suspended, so the theoretical suspending velocity is

$$v = \left[\frac{2gd(\rho_o - \rho_g)}{3k\rho_g}\right]^{1/2}$$ d & k are constants (3-10)

So if $C = \sqrt{2gd/3k}$ then 3-10 becomes

$$v = C\left[\frac{(\rho_o - \rho_g)}{\rho_g}\right]^{1/2}$$ C is the separation constant (3-11)

The volume of gas flowing, q, in ft3/sec is

$$q = \frac{q_{sc}}{86{,}400} \times \frac{\rho_{gsc}}{\rho_g}$$ (3-12)

So the flow in a vessel of diameter D in feet becomes

$$q_{sc} = \frac{67824CD^2}{z} \times \frac{p}{p_{sc}} \times \frac{T_{sc}}{T}\left[\frac{\rho_o - \rho_g}{\rho_g}\right]^{.5}$$

C = separator constant

Reminder D here in the ID of the vessel, and the vessels sizes are given in OD.

To find the required d for various operating conditions the equations can be rearranged.

Gas volume at operating conditions

$$q_g = \frac{.327 z q_{sc} T}{p}$$ qsc in mmscfpd (3-13)

So

$$A_s = {q_g}/{v_a}$$ As in ft2 (3-14)

$$d = 13.53 \sqrt{A_s}$$ d in inches (3-15)

Heater Treaters

Used to break emulsions of oil and water.

Conditions needed to form an emulsion

1) The liquids must be immiscible
2) Sufficient agitation for one liquid to disperse in the other
3) An emulsifying agent must be present

Methods of treating emulsions are aimed at the effects of the emulsifying agent. To steps taken first are the removal of the gas and the free water from the well fluid. So the heater treater incorporates a separator as well as a treating section.

Heat is used to break down the emulsion in three ways

1) Decreases the viscosity of the oil and stickiness of the agent
2) Lowers surface tension
3) Increases the difference in the specific gravities of the oil and water

Treater Design

1) Determine the type of emulsion (tight or loose).
2) Determine if the well is producing free water.
4) Determine the amounts and characteristics of the oil, water and gas.
5) Determine the treating temperatures needed to break the emulsion.
6) Determine the fire box size.