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INTRODUCTION

Scope

This guideline covers the basic elements of coalescer design in sufficient detail to allow a practicing engineer to design a coalescer with the suitable size including diameter, length media velocity, and terminal settling velocity.

For coalescers, as with any process equipment, successful sizing and selection is always a combination of empirical observation/experience and analytical modeling. Of the three steps in coalescing – droplet capture, combining of the collected droplets, and gravity separation of the enlarged droplets – the first and the last can be modeled with good accuracy and repeatability. The modeling of the middle and the actual coalescing step is a complex function of surface tension and viscous effects, droplet momentum, and the dynamics of the sizes of the droplets in the dispersion.

The design of coalescer may be influenced by factors, including process requirements, economics and safety. In this guideline there are tables that assist in making these factored calculations from the various reference sources. Include in this guideline is a calculation spreadsheet for the engineering design. All the important parameters used in this guideline are explained in the definition section which helps the reader understand the meaning of the parameters and / or the terms used.

The theory section explains source, type of coalesces and its characteristic of droplet, treated and untreated coalescer and how to calculate sizing and selection of the coalescer. The application of the coalescer theory with an example will help the practicing engineer understand the coalescer and be ready to perform the actual design of the coalescer.

General Design Consideration

The biggest development in recent years is the widespread recognition that the actual performance of a separator may fall far short of the theoretical performance due to the actual flow patterns within the vessel being far from the ideal. It has, however been helped by two visualization techniques computational fluid dynamics (CFD) and physical modeling, which vividly show what can go wrong and how to correct it.

The following factors must be determined before beginning separator design.

1. Gas and liquids flow rates (minimum, average, and peak).
2. Operating and design pressures and temperatures.
3. Surging or slugging tendencies of the feed streams.
4. Physical properties of the fluids, such as density, viscosity, and compressibility.
5. Designed degree of separation

The most important areas to ensure a separator performs to design are as follows.

1. Correct inlet nozzle sizing and a good inlet device (momentum breaker).
2. Primary fluid distribution–distribution plates to translate the reduced but still high velocities from the inlet device into quiescent flows in a liquid–liquid separator body, or distribution plates either side of a vane pack (downstream is best as upstream ones shatter droplets unnecessarily) or other gas demister.
3. Intermediate fluid distribution when necessary.
4. Exit devices: vortex breakers and anti-liquid–pickup details.

Coalescer is a mechanical process vessel with wet-able, high-surface area packing on which liquid droplets consolidate for gravity separation from a second phase (for example gas or immiscible liquid), where small particles of one liquid phase must be separated or removed from a large quantity of another liquid phase. The coalescers might be designed vertically or horizontally.

The vertical design is used to separate water from hydrocarbons when the interfacial tension is greater than 3 dyne/cm. The separation stage is achieved using hydrophobic separator cartridges that provide an effective barrier to aqueous coalesced drops, but allow hydrocarbon to pass through them. The separator cartridges can be stacked below the coalescers for the most efficient utilization of the separator medium. This configuration only applies to the separation of water or aqueous contaminants from hydrocarbons.

After leaving the coalescing stage, the large aqueous coalesced drops and hydrocarbon then flow axially in a downward direction and the flow direction is from the outside of the separator to the inside. The large coalesced drops are repelled by the separators and are collected in the bottom sump. The purified hydrocarbon passes through the separators and exits at the top of the housing. The aqueous phase in the collection sump can be drained manually on a periodic basis or equipped with an automatic level control and drain system.

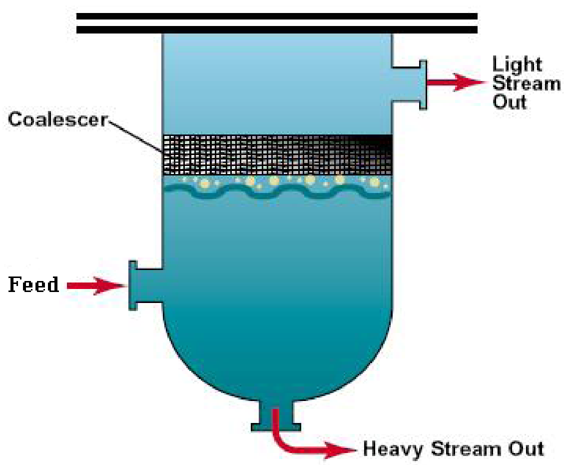

Figure 1 Vertical coalescer

In the horizontal configuration, a settling zone achieves separation by gravity. This configuration is used when the interfacial tension is less than 3 dyne/cm or for the separation of oil from the water phase. The coalescer housing contains a settling zone that relies on the difference in densities between the coalesced droplets and the bulk fluid

This configuration can be used for both hydrocarbon from water and water from hydrocarbon separation, but the location of the collection sump and outlet nozzle will need to be reversed. For the case of removal of hydrocarbon from water, a collection sump is located at the top of the housing and the purified water leaves at the bottom outlet nozzle. The sump can be drained manually on a periodic basis or equipped with an automatic level control and drain system.

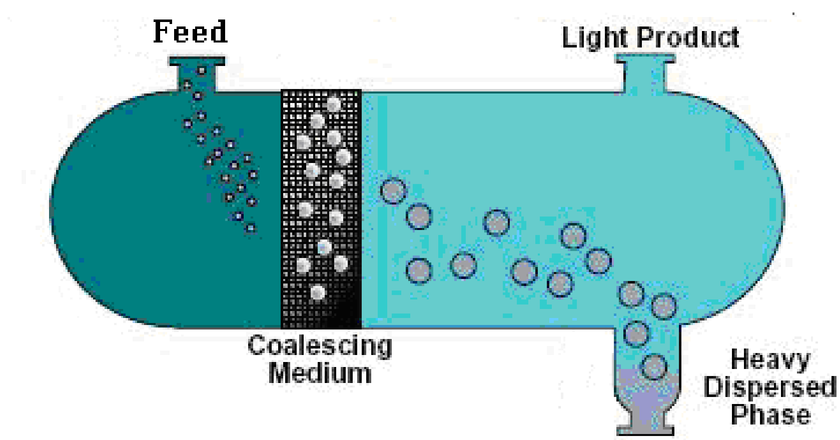

Figure 2 Horizontal coalesce

DEFINITIONS

Air standard - Air having a temperature of (20°C), a relative humidity of 36 percent, and under a pressure of 14.70 PSIA. The gas industry usually considers (16°C) as the temperature of standard air.

Annular velocity - the actual flow rate divided by the annulus area. Modeled as a linear function with vertical distance, and the annular velocity is zero at the bottom of the cartridge and increases to a maximum value at the top of the cartridge.

Annulus - A ring-like part or, the orifice of a hollow die, through which extruded metal flows from the press*.*

Coalescence - Liquid particles in suspension that unite to create particles of a greater volume.

Coalescer - a mechanical process vessel with wettable, high-surface area packing on which liquid droplets consolidate for gravity separation from a second phase (for example gas or immiscible liquid), where small particles of one liquid phase must be separated or removed from a large quantity of another liquid phase.

Control Volume- A certain liquid volume necessary for control purposes and for maintaining the velocity limit requirement for degassing and to counter foam in separators.

Conventional Gas-Liquid Separator - In this Standard, the term "Conventional Gas-Liquid Separator" is referred to vertical or horizontal separators in which gas and liquid are separated by means of gravity settling with or without a mist eliminating device.

Corrosion – The gradual destruction of materials, by chemical reaction with its environment.

Critical Diameter- Diameter of particles larger than which will be eliminated in a sedimentation centrifuge.

Demister Mist Extractor- A device installed in the top of scrubbers, separators, tray or packed vessels, etc. to remove liquid droplets entrained in a flowing gas stream.

Disengaging Height- The height provided between bottom of the wire-mesh pad and liquid level of a vapor-liquid separator

Entrainment - A process in which the liquid boils so violently that suspended droplets of liquid are carried in the escaping vapor.

Extraction column - Vertical-process vessei in which a desired product is separated from a liquid by countercurrent contact with a solvent in which the desired product is preferentially soluble.

Filter- A piece of unit operation equipment by which filtration is performed.

Gas filter - A device used to remove liquid or solid particles from a flowing gas stream

Hold-Up Time- A time period during which the amount of liquid separated in a gas-liquid separator is actually in the vessel for the purpose of control or vapor separation.

Hydrocarbon – An organic compound consisting entirely of hydrogen and carbon.

Immiscible - Not capable of mixing (as oil and water)

Interfacial tension - the accumulation of energy and the imbalance force at the interface of two different phases such as liquid–solid

Knock-Out - A separator used for a bulk separation of gas and liquid.

Line Drip- A device typically used in pipelines with very high gas-to-liquid ratios to remove only free liquid from a gas stream,and not necessarily all the liquid.

Liquefied Natural Gas – Natural gas which predominantly methane that has been converted to liquid form.

Laminar flow - Streamlined flow of a fluid where viscous forces are more significant than inertial forces, generally below a Reynolds number of 2000.

Liquid-liquid extraction - The removal of a soluble component from a liquid mixture by contact with a second liquid, immiscible with the carrier liquid in which the component is preferentially soluble.

Media velocity - the actual flow rate divided by the coalescer filter area.

Mesh- The "mesh count" (usually called "mesh"), is effectively the number of openings of a woven wire filter per 25 mm, measured linearly from the center of one wire to another 25 mm from it.

Mercury – Chemical element with the symbol Hg, commonly known as quicksilver.

mmscfd - Abbreviation for million standard cubic feet per day; usually refers to gas flow.

Mud sump - Upstream area in a process vessel where, because of a velocity drop, entrained solids drop out and are collected in a sump.

Overflow- The stream being discharged out of the top of a hydrocyclone, through a protruding pipe, is called "overflow". This stream consists of bulk of feed liquid together with the very fine solids.

Process analyzer - An instrument for determining the chemical composition of the substances involved in a chemical process directly, or for measuring the physical parameters indicative of composition.

Regenerative Process – A process that utilizes silver on molecular sieve to chemisorb elemental mercury while providing dehydration at the same time.

Surge tanks- These are storage tanks between units, and can serve a variety of purposes. They can dampen fluctuations in flow rate, composition or temperature. They can allow one unit to be shut down for maintenance without shutting down the entire plant.

Separator - a cylindrical or spherical vessel used to isolate the components in mixed streams of fluids.

Stokes' law - the law that the force that retards a sphere moving through a viscous fluid is directly proportional to the velocity of the sphere, the radius of the sphere, and the viscosity of the fluid.

Suspension - a system consisting of a suspension of solid particles in a liquid

Terminal Velocity - The velocity at which a particle or droplet will fall under the action of gravity, when drag force just balances gravitational force and the particle (or droplet) continues to fall at constant velocity.

Target Efficiency- The fraction of particles or droplets in the entraining fluid of a separator, moving past an object in the fluid, which impinge on the object.

Underflow- The stream containing the remaining liquid and the coarser solids, which is discharged through a circular opening at the apex of the core of a hydrocyclone is referred to as "underflow".

Vapor Space- The volume of a vapor liquid separator above the liquid level.

NOMENCLATURE

$\lvert\Delta\rho\rvert$	Absolute value of the difference between the densities of the continuous and dispersed phase, lb/ft^3
A	Cross sectional area, ft^2
A_{ann}	Cross sectional annular area, ft^2
A_{med}	Media area for one coalesce, ft^2
C'	Drag coefficient.
C1	Sheet coefficient
d	Droplet Diameter, in
d	Droplet Diameter, microns
Dc	Diameter of house, ft
d_p	Droplet diameter, microns or ft
E	Effective Length Multiplier
g	Gravitational constant, ft/s^2
h	Corrugated plate spacing or structured packing crimp height, in
K	Kuwabara's Hydrodynamic Factor
L	Element length required for removal of all droplets, in
M	Mass flow at standard condition, lb/s
N	Number of coalescers
Q_a	Actual system flow rate, ft/s
Ql	Liquid/liquid emulsion flow, US GPM
Q_s	Standard system flow rate,ft/s
R_c	Radius of coalescer end cap, ft
R_h	Radius of the housing, ft
S_g	Specific gravity
tdr	Droplet Rise Time, s
tr	Droplet Residence Time, s
V_C	Coalescer volume, ft^3
v_{max}	Emulsion velocity, ft/s
vs	Superficial Velocity, ft/s

vt	Terminal Settling Velocity, ft/s
α	Volume Fraction of Fibers or Wires
ΔS_g	Specific Gravity Difference between the Continuous and Dispersed
η_D	Collection Efficiency of a Single Target by Direct Interception
η_s	Fractional Collection Efficiency by Stokes Settling, typically 0.999

Greek Leters

μ	Continuous Phase Viscosity, cP
ρ_{air}	Density of air at standard temperature and pressure, lb/ft^3
ρ_g	Density of gas, lb/ft^3
ρ_L	Density of liquid, lb/ft^3
Σ	Overall collection efficiency by direct interception

Superscript

A	Cross sectional area, ft^2
E	Effective Length Multiplier
Fg	Fibreglass
K	Kuwabara's Hydrodynamic Factor
L	Element length required for removal of all droplets, in
M	Mass flow at standard condition, lb/s
M	minimum
N	Number of coalescers
pI	polyester I
pIII	polyester II

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