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SCOPE

This Project Standards and Specifications covers minimum requirements for the process design (including criteria for type selection) of gas (vapor)-liquid separators used in the production of the oil and/or gas, refineries and other gas processing and petrochemical plants. For the purpose of this Standard, separation techniques are defined as, those operation, which isolate specific immiscible ingredients of a mixture mechanically, i.e., without a chemical reaction or a mass transfer process taking place.

REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

1. ASME (American Society of Mechanical Engineers)
ASME Section VIII, Div.1 "Boiler and Pressure Vessel, Code". Edition 2007"
2. API (American Petroleum Institute)
API Spec. 12J "Specification for Oil and Gas Separators", 7th. Ed., Oct. 1989
API 510 "Pressure Vessel Inspection, Code: In Service Inspection, Rating, Repair, and Alteration". 9th Ed., June 2006.

DEFINITIONS AND TERMINOLOGY

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).

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.

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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 - Corrosion is defined as the destruction of a metal by chemical or electrochemical reaction with its environment.

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.

Fabric Filter - Commonly termed "bag filters" or "baghouses", are collectors in which dust is removed from the gas stream by passing the dust-laden gas through a fabric of some type.

Flash Tank - A vessel used to separate the gas evolved from liquid flashed from a higher pressure to a lower pressure.

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.

Knock-Out - A separator used for a bulk separation of gas and liquid. It falls into one of two categories as below:

- a) The free water knock-out is a vessel used to separate free water from a flow stream of gas, oil, and water. The gas and oil usually leave the vessel through the same outlet to be processed by other equipment. The water is removed for disposal.
- b) The total liquid knock-out is normally used to remove the combined liquids from a gas stream.

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.

Maximum Allowable Working Pressure - The maximum allowable working pressure (MAWP) is the maximum pressure, permissible by the ASME Code at

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the top of the separator in its normal operating position for a designated temperature.

Operating Pressure - The operating pressure is the pressure in the vessel during normal operation. The operating pressure shall not exceed the MAWP, and is usually kept at a suitable level below the setting of the pressure relieving devices to prevent their frequent opening.

Scrubber - A type of separator which has been designed to handle flow streams with unusually high gas-to-liquid ratios. These are commonly used in conjunction with dehydrators, extraction plants, instruments, or compressors for protection from entrained liquids.

Slug Catcher - A particular separator design able to absorb sustained in-flow of large liquid volumes at irregular intervals.

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.

Terminal Velocity or Drop-Out 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.

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

SYMBOLS AND ABBREVIATIONS

<u>SYMBOL/ABBREVIATION</u>	<u>DESCRIPTION</u>
A	Cross-sectional area for gas flow, (m ²).
a	Length of side, square cyclone inlet, (type 1), (m).
C	Drag coefficient of particle or droplet, (dimensionless).
D _f	Filter element outside diameter, (m).
D _p	Droplet or particle diameter, (m).
D _v	Internal diameter of a separator vessel, (m).
d _n	Nozzle diameter, (m).
d _{n1}	Feed nozzle (m)
d _{n2}	Gas outlet nozzle (m)
d _{n3}	Liquid outlet nozzle (m)
d ₁	Internal diameter of feed inlet, (m).
d ₂	Internal diameter of gas outlet, (m).
d ₃	Diameter of cylindrical cyclone baffle, (m).

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g	Local acceleration due to gravity, (m/s ²).
H	Height, (tangent to tangent) of vessel, (m).
H _c	Height of cyclone (from bottom plate to outlet pipe), (m).
h	Height of vessel required for hold-up, (m).
K	Empirical constant for separator sizing, (m/s).
K _{CR}	Proportionality constant.
LA (L)	Level Alarm (Low)
LA (H)	Level Alarm (High)
L _f	Filter element length, (m).
L _v	Length of a horizontal separator vessel, (tangent to tangent), (m).
M _g	Mass flow rate of gas, (kg/s).
M _l	Mass flow rate of liquid, (kg/s).
P _{in}	Pressure at inlet, (kPa).
P _{out}	Pressure at outlet, (kPa).
Q	Volumetric load factor, (m ³ /s).
Q _g	Volumetric flow rate of gas, (m ³ /s).
Q _l	Volumetric flow rate of liquid, (m ³ /s).
Q _{max}	Maximum value of Q, (m ³ /s).
R	Radius of cyclone scroll f, (m).
R _e	Reynolds number, (dimensionless).
s	Width of split between cyclone bottom plate and wall, (m).
T	Time (min).
t	Thickness of demister pad, (m).
V _c	Critical gas velocity necessary for particles to drop or settle, (m/s).
V _{g,in}	Gas velocity at inlet, (superficial), (m/s).
V _{g,out}	Gas velocity at outlet, (m/s).
V _m	Mixture velocity at inlet = (Q _g + Q _l)/(πdn ² /4), (m/s).
V _t	Terminal or free settling velocity of particle or droplet and terminal rising velocity of bubbles, in liquid phase, (m/s).
γ _l (gamma)	Liquid kinematic viscosity, cSt(mm ² /s)
μ (mu)	Dynamic viscosity of continuous phase, cP(mPa.s).
μ _g (mu)	Dynamic viscosity of gas, cP (mPa.s).
ρ _g (rho)	Gas phase density, (kg/m ³).
ρ _l (rho)	Liquid phase density, (kg/m ³).
ρ _m (rho)	Mixture density at inlet = (M _g +M _l)/(Q _g +Q), (kg/m ³).

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UNITS

This Standard is based on International System of Units (SI) except where otherwise specified.

GENERAL

Gas-Liquid Separators can be generally divided into two main groups, high gas to liquid ratio (e.g. flare knock-out drums, scrubbers), and low gas to liquid ratio (e.g. oil/gas separators, flash tanks) separators. In this Standard, process aspects of three types of most frequently used gas (vapor) - liquid separators are discussed more or less in details, these three types are:

- Conventional gas-liquid separators (including oil/gas separators).
- Centrifugal gas-liquid separators.
- Gas-liquid filter separators.

Types of mechanical separators are generally shown in Fig. F.1 of Appendix F.

Gas-Liquid Separators

Gas-liquid separator types often used in processes which are discussed in this Standard are:

- Conventional Gas/Liquid Separators.
- Cyclones.
- Oil/Gas Separators.
- Flare Knock-out Drums.
- Filter Separators.

Separation Mechanisms

Gas-liquid separation processes most frequently employed in industries are based on either one or a combination of "Gravity Settling", "Impingement" and "Centrifugation", mechanisms. Some types of "Filtration" are seldom employed in this field. The principles of mechanical separation in general, can be classified as momentum, gravity and filtration that are briefly described in the following sections. Note that as a general rule, mechanical separation occurs only when the phases are immiscible and have different densities.

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1. Mechanical separation by momentum

Fluid phases with different densities will have different momentum. If a two phase stream changes direction sharply, greater momentum will not allow the particles of heavier phase to turn as rapidly as the lighter fluid, so separation occurs. Momentum is usually employed for bulk separation of the two phases in a stream.

2. Mechanical separation by gravity

Liquid droplets or solid particles will settle out of a gas phase if the gravitational force acting on the droplet or particle is greater than the drag force of the gas flowing around the droplet or particle. The same phenomenon happens for solid particles in liquid phase and immiscible sphere of a liquid immersed in another liquid. Rising of a light bubble of liquid or gas in a liquid phase also follows the same rules, i.e. results from the action of gravitational force. Regarding gravity settling, an overall picture of the range and distribution of particle sizes as well as the significant laws governing the particle settling in each range are shown in Fig. A.1 of Appendix A.

3. Mechanical separation by filtration

Filtration is the separation of a fluid-solid or liquid-gas mixture involving passage of most of the fluid through a porous barrier which retains most of the solid or liquid particulates contained in the mixture.

Filtration processes can be divided into three broad categories, cake filtration, depth filtration and surface filtration.

General Notes on Separator Piping

Piping to and from the separator shall interfere as little as possible with the good working of the separator. The following constraints should be observed:

1. There should be no valves, pipe expansions or contractions within 10 pipe diameters of the inlet nozzle.
2. There should be no bends within 10 pipe diameters of the inlet nozzle. except the following:
 - For knock-out drums and demisters, a bend in the feed pipe is permitted if this is in a vertical plane through the axis of the feed nozzle.
 - For cyclones a bend in the feed pipe is permitted if this is in a horizontal plane and the curvature is in the same direction as the cyclone vortex.

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3. If desired, a pipe reducer may be used in the vapor line leading from the separator, but it should be no nearer to the top of the vessel than twice the outlet pipe diameter.
If these conditions cannot be complied with, some loss of efficiency will result.

If a valve in the feed line near to the separator cannot be avoided, it should preferably be of the gate or ball type fully open in normal operation. High pressure drops which cause flashing and atomization should be avoided in the feed pipe. If a pressure-reducing valve in the feed pipe cannot be avoided, it should be located as far upstream of the vessel as practicable.

Separator Material

1. ASME Code

Separators furnished to this specification shall conform to the material requirements stipulated in the latest edition of the ASME Code.

2. Material selection for corrosive fluids should be selected based on a review of related API or NACE publications for materials that conform to Paragraph 6.4.1. Consideration should be given to material selection as it relates to weight loss, sulphide stress cracking, chloride stress cracking, or other forms of corrosion. It is the responsibility of the user to determine what consideration for corrosion should be made to the vessel during its intended life.
3. Corrosion consideration for separators furnished to this specification shall be for the pressure containing parts of the vessel only, and as can be identified as falling within the requirements of the applicable section of the ASME Code.

Corrosion considerations for vessel internals (non-pressure parts) is by mutual agreement between the purchaser and the manufacturer and not a part of this specification.

CONVENTIONAL GAS/LIQUID SEPARATORS

General

Conventional gas/liquid separators are usually characterized as vertical, horizontal, or spherical. Horizontal separators can be single or double barrel and can be equipped with sumps or boots.

Mist extractor can be installed in this type of separators.

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1. Vertical separators

Vertical separators (see Fig. B.1-a of Appendix B) shall be selected when the gas-liquid ratio is high. In cases where there is a frequent fluctuation in inlet liquid flow or where re-vaporization or remixing of fluids in the vessel should be prevented, vertical separators should be preferred.

2. Horizontal separators

Horizontal separators (see Fig. B.1-b) are practically used where large volumes of total fluids and large amount of dissolved gas are present with the liquid. They are also preferred where the vapor-liquid ratio is small or where three phase separation is required.

3. Spherical separators

These separators are occasionally used for high pressure service where compact size is desired and liquid volumes are small, (see Fig. B.1-c).

Design Criteria

Separators furnished to this specification may be vertical, horizontal, or Spherical, and are available in sizes and maximum allowable working pressure ratings shown in Tables 4.1, 4.2, and 4.3 API SPEC 12J. Available sizes and working pressures may vary from the stated ratings in the referenced tables. Other sizes, pressure, and temperature ratings may be furnished by agreement between purchaser and manufacturer.

Separators without mist extractors may be designed for gravity settling using Stokes' law equations.

Typically the sizing is based upon removal of 150 micrometers and larger diameter droplets.

For practical purposes, to be in safe side, use of the methods presented in the following sections is recommended.

1. Design flow rates

A separator may be incorporated in a process scheme for which there are different modes of operation. In this case, the separator design shall be based upon the operation mode with the severest conditions. For the gas/liquid separation in a knock-out drum or demister, the severest condition is that with the highest value of Q, where this is defined by:

$$Q = Q_g \left(\frac{\rho_g}{\rho_l - \rho_g} \right)^{1/2} \text{ m}^3/\text{s} \quad \text{Eq (1)}$$

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Having identified the severest mode from the highest value of Q, it is then necessary to add on a margin to give the value on which the separator design shall be based. This value, Q_{max} should include margins for over design, safety or surging. It represents the 'flooding' condition.

The margin to be applied over the normal (process design) flow rate depends on the application. For oil processing, a margin of 15-25% is common; for oil production, margins up to 50% may be required.

2. Nature of the feed

The type of flow in feed pipe to the separator, transition from one flow regime to another, formation of droplets, foaming tendency of the liquid which may lead to carry over the liquid or carry through of gas and other factors such as existence of sands, rust, wax and other solids and cocking tendency of the liquid are points which should be taken into account when fixing design conditions.

3. Efficiency and separator type

The efficiency of a separator is defined here as the fraction (or percentage) of the liquid entering the vessel that is separated off.

Table 1 gives the preferred choice of separator according to feed description and the approximate efficiency expected:

Table 1 - Efficiency Vs Type of Flow of Separators

TYPE OF FLOW	EFFICIENCY EXPECTED	
	<90%	>90%
Bubbly Stratified, smooth	Knock-Out drum	Knock-Out drum
Stratified, wavy	Knock-Out drum	Demister or cyclone
Intermittent	Knock-Out drum	Demister or cyclone
Annular		Demister or cyclone

Although a demister separator fitted with wire mesh demister pad will often have efficiency better than 99%, it should be noted that a substantial fraction of droplets less than 20 micrometers in diameter, may pass through a wire mesh demister.

4. Liquid handling requirements

In checking the capacity of the separator to handle liquid, the following points should be considered.