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PROCESS REQUIREMENTS OF VESSELS AND SEPARATORS

(PROJECT STANDARDS AND SPECIFICATIONS)

TABLE OF CONTENT

SCOPE

This Project Standards and Specifications covers minimum process requirement of separators, vessels and reactors used in OGP production plants.

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. API (American Petroleum Institute)

   API Standard 620, "Design and Construction of Large, Welded, Low Pressure Storage Tanks" 11th Ed., 2009

   API Spec. 12J "Specification for Oil and Gas Separators" , 7th.Ed,. Oct. 1989

2. ASME (American Society of Mechanical Engineers)

   ASME Section VIII, Div. 1 "Boiler and Pressure Vessel, Code"

3. NACE (National Association of Corrosion Engineers)

   MR0103 "Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments"

   MR0175/ISO 15156-3 CIR 2 "Petroleum and Natural Gas Industries — Materials for use in H2S-Containing Environments in Oil and Gas Production — Part 3: Cracking- Resistant CRAs (Corrosion-Resistant Alloys) and other Alloys" Fractional Research Incorporated

DEFINITIONS AND TERMINOLOGY

Coalescers - 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 - Is 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.

Critical Diameter - "Critical diameter" or "cut point", is the diameter of particles, those particles larger than which will be eliminated in a sedimentation centrifuge.

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.

Filter Medium - The "filter medium" or "septum" is the barrier that lets the flow pass while retaining most of the solids; it may be a screen, cloth, paper, or bed of solids.

Filtrate - The liquid that passes through the filter medium is called the filtrate.

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, particularly when the liquid volume fraction is high.

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.

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

Mesh = 25 / (w + d) Eq. (1)

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

Open Area - Open area is defined as a percentage of the whole area of woven wire filter, is shown by (Fo) and can be calculated from the equation:

$$F_o = \frac{w^2}{(w+d)} x100 \qquad \text{Eq. (2)}$$

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.

Scrubber - Is a type of separator which has been designed to handle flow streams with unusually high gas-to-liquid ratios.

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

Target Efficiency - Is 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 - Is the velocity at which a particle or droplet will fall under the action of gravity, when drag force just balance gravitational force and the particle (or droplet) continues to fall at constant velocity.

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.

SYMBOLS AND ABBREVIATIONS

SYMBOL/ABBREVIATION	DESCRIPTION
API	American Petroleum Institute.
BSI	British Standards Institution
C_D	Drag Coefficient, (dimensionless).

d	Interval in (mm)
d_1	Nozzle Diameter, in (m).
d_2	Diameter of the Gas Outlet Nozzle, in (m).
d_3	Diameter of the Liquid Outlet Nozzle, in (m).
D_p	Diameter of Droplet, in (m).
d_p	Double Pocket Vanes.
DN	Diameter Nominal, in (mm).
EOR	End of Run.
Eq.	Equation.
F_o	The Whole Area of A Woven Wire Filter, in (mm²).
FWKO	Free Water Knock-Out.
g	Acceleration of Gravity, in (m/² s).
GOR	Gas/Oil Ratio.
H_l	Height of Liquid Space, in (m).
HLL	High Liquid Level.
IE	Ion Exchange.
Inf	Infinity.
IP	Institute of Petroleum.
K	Entrainment Coefficient, in (m/s).
L	Distance between the Inlet Nozzle and Outlet Nozzle, in (m)
$M_G + M_L$	Mass of Gas and Liquid in the Mixture, in (kg).
MMNCM	Million Normal Cubic Meter
MMSCF	Million Standard Cubic Foot
Mod	Moderate.
NLL	Normal Liquid Level.
n_p	No-Pocket Vanes.
OD	Outside Diameter, in (mm).
OGP	Oil, Gas and Petrochemical.
ppm	Parts per Million.
$Q_G + Q_L$	Volume of Gas and Liquid in the Mixture, in (m³).
Q_{max}	Liquid Handling Capacity as Droplets.
S_h	Specific Gravity (Relative Density) of the Heaviers, (Dimensionless).
S_1	Specific Gravity (Relative Density) of the Lighters, (Dimensionless).
SOR	Start of Run.
S_P	Single-Pocket Vanes.
TCA	Total Corrosion Allowance.
TGU	Thermal Gas Oil Unit.
U_t	Terminal Velocity of the Heavier Fine Particles, in (m/s).

V_G	Gas Superficial Velocity, in (m/s).
V_h	Horizontal Liquid Velocity, in (m/s).
$V_{m,in}$	Velocity of the Mixture in the Inlet Nozzle, in (m/s).
VBU	Visbreaker Unit.
yr	Year.
w	Width of Woven Wire Opening, in (mm).
ρ_G (rho)	Gas Density, in (kg/m³).
ρ_h (rho)	Density of Droplet, in (kg/cm³).
ρ_L (rho)	Density of Liquid, in (kg/m³).
ρ_i (rho)	Density of the Continuous Phase, in (kg/m³).
ρ_m (rho)	Mean Density of Mixture, in (kg/m³).
ρ_v (rho)	Vapor Density, in (kg/m³).
μ (mu)	Particle Size, in Microns or Micrometers (μm).
μ (mu)	Viscosity (Dynamic) of Continuous Phase, in [cP = mPa.s].
λ lambda	Gas Handling Maximum Capacity.

UNITS

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

SEPARATORS

Gas-Liquid Separators

1. The function of a separator is to provide removal of free gas from oil and/or water at a specific pressure and temperature.
2. Selection criteria
   a. General

      The followings outline various criteria and features which play a role in separators performance and selection. Table A.1 in Appendix A summarizes the relative performance of various types of separators.

   b. Orientation

      In general, a vertical vessel is preferred for gas/liquid separation for the following reasons:

      - When the gas/liquid ratio is high;
      - A smaller plan area is required (critical on offshore platforms);
      - Easier solids removal;

- Liquid removal efficiency does not vary with liquid level;
- Vessel volume is generally smaller.

However, a horizontal vessel should be chosen if:

- Large volume of total fluid is available;
- Large amount of dissolved gas is available;
- Large liquid slugs have to be accommodated;
- There is restricted head room;
- A low downward liquid velocity is required (for degassing purposes, foam breakdown or in case of a difficult liquid/liquid separation).

c. Components

For efficient and stable operation over a wide range of conditions, a gas-liquid separator normally has the following features:

i) Primary separation section

This section is for removing the bulk of the liquid in the inlet stream. Liquid slugs and large liquid particles are removed first to minimize gas turbulence and re-entrainment of liquid particles in preparation for the second step of separation. To do this, it is usually necessary to absorb the momentum and change the direction of flow by some form of inlet baffling.

Following the gas/liquid flow path through the Primary separation section, the following parameters should be identified:

- Feed inlet

  This comprises the upstream piping, inlet nozzle, and the inlet devices (if any).

  - The diameter of the inlet nozzle is a function of the feed flow rate and pressure.
  - Information on the nature of the feed (foaming tendency, feeds with solids, wax or cocking tendency) are given in this standard.
  - The criterion for the nozzle sizing is that the momentum of the feed shall not exceed prescribed levels. The maximum allowable inlet momentum can be increased by applying inlet devices.
  - The momentum criteria are given in Appendix C.
  - The function of the inlet device is to initiate the gas/liquid separation and to distribute the gas flow evenly in the gas compartment of the vessel.

- Commonly used inlet devices are the half-open pipe and their specific proprietory inlet devices designed for introducing gas/liquid mixtures into a vessel or column.

ii) Secondary separation section

The major separation principle in this section is gravity settling of liquid from the gas stream after its velocity has been reduced.

iii) Liquid accumulator section

The liquid(s) is (are) collected in this section. The liquid should have a minimum of disturbance from the flowing gas stream. Sufficient capacity is necessary to allow for surges and to provide the retention time necessary for efficient separation of gas breaking out of liquid. The flowing parameters should be identified:

- Separator internals

  In knock-out vessels the diameter should be selected sufficiently large to keep the gas velocity low at which the major portion of the droplets could be settled by gravity.

  In all other types of gas/liquid separators, internals should be considered. For selection the required duty, wire mesh, vane-pack (either horizontal or vertical flow), multicyclones axial or reversed flow, filter candles, etc. should be studied.

iv) Gas and liquid outlets section

A vortex breaker may be located over the liquid outlet nozzle(s) to prevent gas or oil entrainment with the bottom liquid. The mist extractor of the coalescing section can be one of several designs (a series of vanes, woven wire mesh pad or a centrifugal device). The mist extractor removes from the gas stream the small droplets (normally down to 10 micron diameter) of liquid before the gas leaves the vessel. Liquid carryover is normally less than 14 liter per MMNCM (0.1 gallon per MMSCF).

After completion of the gas/liquid separation process the two phases will leave the vessel via the gas and liquid outlet respectively. The nozzle sizing criteria are given in Appendix C.

d. Gas handling capacity

The separator shall be large enough to handle the gas flow rate under the most severe process conditions. The highest envisaged gas flow rate should be determined by including a margin for surging, uncertainties in basic data. This margin is typically between 15 and 50%, depending on the application. For the recommended margin see Appendix D.

e. Process controls

The operating pressure may be controlled by a weight loaded, spring loaded, or pilot operated gas back pressure valve. Where the gas is being delivered to a pipeline, the minimum separator pressure is usually set by the transmission or gathering system pressure. Separators should be equipped with one or more liquid level controls. Usually a liquid level control for the liquid accumulation section of two-phase separators activates a liquid dump valve to maintain the required liquid level.

f. Relief devices

All separators, regardless of size or pressure, shall be provided with pressure protective devices and set in accordance with ASME Code requirements.

g. Separator shapes

There are three different shapes of separators: vertical, horizontal, and spherical. The four main components are located differently in the various vessels.

h. Selection strategy

To facilitate the choice of a separator for a given application, the performance characteristics of various separators are summarized in Appendix A, Table A.1.

i) Gas handling capacity:
   - Max. capacity (gas load factor);
   - Turndown ratio.

ii) Liquid removal efficiency:
   - Overall;
   - With respect to fine mist;
   - With respect to the possible flooding above the maximal load factor (which will affect the sharpness of the efficiency decline above the maximum capacity).

iii) Liquid handling capacity:
   - Slugs;
   - Droplets.

iv) Fouling tolerance:
   - Sand;
   - Sticky material.

v) Pressure drop:

The following selection strategy is suggested:

First define the mandatory requirements which the separator shall satisfy. With the aid of Table A.1 in Appendix A, a number of separators can then be ruled out.

3. Design criteria

   a. General

      Unless explicitly stated otherwise, both the maximum gas and liquid flow rates should contain a design margin or surge factor as defined in Appendix D. Table A.1 in Appendix A, summarizes the performance data which can enable a comparison of the various separators.

   b. Vertical and horizontal separators

      Specific indication to process application, characteristics, recommended and non-recommended use of various vertical/horizontal separators used in OGP production plants are given hereunder for design consideration:

      i) Vertical knock-out drum

         <u>Application:</u>

         - Bulk separation of gas and liquid.

         <u>Characteristics:</u>

         - Unlimited turndown;
         - High slug handling capacity;
         - Liquid removal efficiency typically 80-90% (ranging from low to high liquid load).

           Warning: Liquid removal efficiency for mist is very poor
         - Very low pressure drop;
         - Insensitive to fouling.

         <u>Recommended use:</u>

         - Vessels where internals have to be kept to a minimum (e.g., flare knock-out drums);
         - Fouling service e.g., wax, sand, asphaltenes;
         - Foaming service.

         <u>Non-recommended use:</u>

         - Where efficient demisting of gas is required.

         <u>Typical process applications:</u>

         - Vent and flare stack knock-out drums;
         - Production separator;
         - Bulk separator (e.g., upstream of gas coolers);

- Flash vessel.

ii) Horizontal knock-out drum

Application:

- Bulk separation of gas and liquid.

Characteristics:

- Can handle large liquid fractions;
- Unlimited turndown;
- Very high slug handling capacity;
- Liquid removal efficiency typically 80-90% (ranging from low to high liquid load).

  Warning: Liquid removal efficiency for mist is very poor
- Insensitive to fouling;
- Very low pressure drop.

Recommended use:

- Vessels where internals have to be kept to a minimum and where there are height limitations;
- Slug catchers;
- Fouling service, e.g., wax, sand, asphaltenes;
- For foaming or very viscous liquids.

Non-recommended use:

- Where efficient demisting of gas is required.

Typical process applications:

- Vent and flare stack knock-out drums;
- Production separator-low GOR;
- Bulk separator;
- Slug catcher.

iii) Vertical wire mesh demister

Application:

- Demisting of gas.

Characteristics:

- High turndown ratio;
- High slug handling capacity;
- Liquid removal efficiency > 98%;
- Sensitive to fouling;
- Low pressure drop.

Recommended use:
- For demisting service with a moderate liquid load;
- Where slug handling capacity may be required.

Non-recommended use:
- Fouling service (wax, asphaltenes, sand, hydrates);
- For viscous liquids where degassing requirement determines vessel diameter;
- For compressor suction scrubbers unless precautions are taken to prevent the possibility of loose wire cuttings entering the compressor or plugging of the demister mat increasing suction pressure drop.

Typical process applications:
- Production/test separator:
  - o Moderate GOR;
  - o Non-fouling;
- Inlet/outlet scrubbers for glycol contactors;
- Inlet scrubbers for gas export pipelines;
- For small diameter and/or low pressure vessels, where extra costs of vane of screen mesh sizes (SMS) internals cannot be justified.

iv) Horizontal wire mesh demister

Application:
- Demisting of gas where a high liquid handling capacity is required.

Characteristics:
- High turndown ratio;
- Very high slug handling capacity;
- Liquid removal efficiency > 98%;
- Sensitive to fouling;
- Low pressure drop.

Recommended use:
- Typically for demisting service with a high liquid load and low GOR;
- Where slug handling capacity may be required;
- For viscous liquids where liquid degassing requirement determines vessel diameter;
- In situations where head room is restricted;

- For foaming liquids.

v) Vertical vane-type demister

<u>Application:</u>

- Demisting of gas.

<u>Characteristics:</u>

- Liquid removal efficiency >96%
- Moderate turndown ratio;
- Suitable for slightly fouling service (if without double-pocket vanes);
- Robust design;
- Sensitive to liquid slugs (in-line separator cannot handle slugs).

<u>Recommended use:</u>

- Typically for demisting service;
- In-line separator to be used only with relatively low flow parameter (øfeed < 0.01);
- Two-stage separator to be used if øfeed ≥0.01;
- Attractive for slightly fouling service (if without double-pocket vanes);
- May be used where demister mats may become plugged, i.e., waxy crudes.

<u>Non-recommended use:</u>

- Heavy fouling service (heavy wax, asphaltenes, sand, hydrates);
- For viscous liquids where degassing requirement determines vessel diameter;
- The in-line vertical flow vane pack separator shall not be used where liquid slugging may occur or where øfeed ≥0.01;
- If pressure exceeds 100 bar (abs), due to the consequent sharp decline in liquid removal efficiency.

<u>Typical process applications:</u>

- Compressor suction scrubbers, where vane packs are preferred to demister mats since their construction is more robust;
- Demisting vessels with slightly fouling service.

vi) Horizontal vane-type demister

<u>Application:</u>

- Demisting of gas where a high liquid handling capacity is required.

<u>Characteristics:</u>

- Liquid removal efficiency > 96%;

- Moderate turndown ratio;
- Suitable for slightly fouling service (if without double-pocket vanes);
- High slug handling capacity;
- Robust design.

Non-recommended use:

- Heavy fouling service (heavy wax, asphaltenes, sand, hydrates);
- If pressure exceeds 100 bar (abs).

Typical process applications:

- Production separator where GOR is low and the service is slightly fouling.

vii) Cyclone

Application:

- Demisting of gas in fouling service.

Characteristics:

- Liquid removal efficiency > 96%;
- Limited turndown ratio;
- Insensitive to fouling;
- High pressure drop.

Recommended use:

- Typically for use in a fouling (e.g., coke-formation) environment and where a high demisting efficiency is still required.

Non-recommended use:

- If high pressure drop can not be tolerated.

Typical process application:

- In oil refineries:
  Thermal Gas-Oil Unit (TGU);
  Visbreaker Unit (VBU);
- In chemical plants:
  Thermoplastic Rubber Plants.

viii) Vertical multicyclone separator

Application:

- Demisting and dedusting of gas in slightly fouling service and high pressure.

Characteristics:

- Liquid removal efficiency > 93%

- Suitable for slightly fouling service (e.g., low sand loading);
- High pressure drop;
- Compact separator;
- Sensitive to high liquid loading or slugs.

Recommended use:

- Typically for use in a slightly fouling environment where the gas pressure is higher than 100 bar (abs) and a compact separator is required.

Non-recommended use:

- Low gas pressure;
- Heavy fouling service (high sand loading will cause erosion);
- High liquid loading;
- Slug;
- When high liquid removal efficiency is required.

Typical process application:

- Wellhead separators;
- Primary scrubbers under slightly fouling service and when the liquid loading is low;
- Compressor suction scrubbers if sand is present in the feed.

ix) Filter separator

Application:

- After-cleaning (liquid and solids) of already demisted gas when a very high liquid removal efficiency is required.

Characteristics:

- Liquid removal efficiency > 99%;
- Very high pressure drop;
- Sensitive to high liquid loading or slugs;
- Sensitive to fouling by sticky material.

Recommended use:

- Typically as a second-line gas/liquid separator to after-clean the gas stream exiting from the first-line gas/liquid separator.
- Use filter candles with the flow from OUT to IN where solids are present.
- Use filter candles with the flow from IN to OUT where ultimate efficiency is required and NO solids are present.