SEPARATOR: PRINCIPLES AND DESIGN

MAB 4633/ EMB 5443

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SEPARATOR?
SEPARATOR...
The production process…

“SEPARATORS form the HEART of the production process”

Wellhead → Wellhead manifold → FIRST STAGE → SECOND STAGE → Storage tank – final oil treatment → To export

Gas to gas scrubber and gas compression module

Water treatment → Water → Disposal

Oil

Reservoir
FUNDAMENTALS
What is a separator?

- A SEPARATOR is a pressure VESSEL designed to DIVIDE a combined liquid-gas system into individual COMPONENTS that are relatively free of each other for SUBSEQUENT PROCESSING or disposition.
Why separator is needed?

- **Downstream equipment cannot handle gas-liquid mixtures**
  - Pumps require gas-free liquid
  - Compressor/dehydration equipment require liquid-free gas

- **Product specifications has limits on impurities**
  - Oil should not contain > 1% BS&W
  - Gas sales contract → no free liquids in gas

- **Measurement devices (metering) for gases/liquids highly inaccurate when the other phase is present**

Source: International Training & Development, M. Stewart
How separation happens?

- **Momentum**
  - Fluid phases at different densities have different momentum
  - Changes in fluid direction will separate fluids at different momentum

- **Gravity**
  - Liquid phase separated from gas due to difference in weight of droplets

- **Coalescence**
  - Small droplets coalesced when “combined” together
  - Coalescing devices force small droplets flowing through it to collide, form larger droplets and then settling out of the gas phase by gravity

Source: International Training & Development, M. Stewart
What properties affect separation?

- Gas and liquid flow rates
- Operating & design pressures and temperatures
- Surging or slugging tendencies of the feed streams
- Fluid physical properties – density, compressibility
- Desired phase separation - gas-liquid or liquid-liquid
- Desired degree of separation - e.g. remove 100% particles >10 micron in size
- Presence of impurities – paraffin, sand, scale
- Foaming tendencies
- Corrosive tendencies

Must know and understand the characteristics of the flow stream in order to design separators!

Source: International Training & Development, M. Stewart
Separator classification and types

Classification

- Two-phase separation (gas-liquid)
- Three-phase separation (liquid-liquid i.e. water/oil/gas separation)

Types

- Gravity separators
  - Horizontal
  - Vertical
  - Spherical
- Centrifugal separators
  (effect of gravity is enhanced by spinning the fluids at a high velocity)

Selection of separators is based on obtaining the desired results at the lowest cost.

Source: International Training & Development, M. Stewart
BASIC SEPARATOR CONSTRUCTION
We focus on gravity separators…

- Working principle: Depends on density difference between the phases to be separated
- They are large cylindrical pressure vessels (up to 5 m diameter and 20 m long)
- Used in either 2-phase or 3-phase separation
- Mounted in a series of 2, 3 or even 4 separators
- Mounted either vertically or horizontally
4 main sections…

1. INLET DIVERTER
   - Primary section

2. GRAVITY SETTLING
   - Secondary section

3. MIST EXTRACTOR
   - Coalescing section
   - Gas outlet

4. LIQUID COLLECTION
   - Sump section
   - Liquid outlet under level control to evacuate liquid

Must remember these!
**HORIZONTAL**

- Two Phase Inlet
- Gas Outlet
- Liquid Outlet

**VERTICAL**

- Mesh Pad
- Gas Outlet
- Liquid Outlet

A - Primary Separation
B - Gravity Settling
C - Coalescing
D - Liquids Collecting

**Features**
- Two Phase Inlet
- Gas Outlet
- Liquid Outlet
- Mesh Pad
- Vertical Breaker
4 main principles…

1. **MOMENTUM**
   - Occurs at inlet diverter
   - Initial separation of gas phase from the free liquid phase $\rightarrow$ gross separation
   - Fluid stream hits diverter, changes its flow direction, fluids at different momentum are separated
2. GRAVITY

- Occurs at gravity settling section
- As gas flows through the section, gravitational force causes small liquid droplets to fall out from the gas stream
- Droplets then fall to the gas-liquid interface below → droplet settling section
- 100 to 400 micron droplet removal
3. COALESCING

- Occurs at mist extractor
- Before gas leaves vessel, it flows through mist extractor $\rightarrow$ 99% droplets $>10$ micron removed
- Refine gross separation by removing the remaining entrained mist (very small liquid droplets) from gas phase
- Mist extractor uses vanes, wire mesh or plates

Source: International Training & Development, M. Stewart
4. “EQUILIBRIUM”

- Occurs at liquid collection
- Provide *retention time* required to allow entrained gas to evolve out from the liquid phase and rise to the vapour space
- After a certain period of retention time, phases become equilibrium with each other and separated ‘naturally’ due to density differences
TWO-PHASE (GAS-LIQUID) SEPARATION
Main types

- HORIZONTAL separator
- VERTICAL separator
- SCRUBBERS
Horizontal (2-P) separator

Operation?
Vertical 2-P separator

Source: International Training & Development, M. Stewart
Horizontal - advantages...

- Horizontal separators smaller and less expensive than vertical for given gas capacity
  - In gravity settling section, liquid droplets fall perpendicular to the gas flow
  - So more easily separated out of gas continuous phase
  - Interface area also larger so easier for gas bubbles that come out of the liquid phase to reach vapour space

Source: International Training & Development, M. Stewart
Cont.

- Horizontal separators offer greater liquid capacity
  - Well suited for liquid-liquid separation
  - And foaming crude
Vertical - advantages...

- Good in handling solids
  - Liquid dump can be placed at bottom centre so that solids don’t build up inside
    - Continue to next vessel
    - or install drain that allows solid to be disposed periodically

- Less plan area for same separation
  - Very important in offshore platforms

Source: International Training & Development, M. Stewart
Cont.

- Larger liquid SURGE capacity for same flow rate
  - For same liquid surface elevation, vertical has smaller increase in liquid volume than horizontal
  - High level (shutdown) controller could be placed much higher than normal operating level – so level controller and dump valve have more time to react to surge

Source: International Training & Development, M. Stewart
Scrubbers

- Designed to recover liquids carried over from production separators or condenses after initial separation
- Liquid loading level much lower than separator
- Applications
  - Upstream of compressors
  - Downstream of coolers (liquids can condense)
  - Upstream of dehydration equipment
  - Upstream of a vent of flare outlet

Source: International Training & Development, M. Stewart
THREE-PHASE (OIL-WATER) SEPARATION
Types (Horizontal and/or Vertical)

- Interface level control design
- Bucket-and-weir design
Horizontal (3-P) Separator – Interface level controller design
Horizontal (3-P) Separator – “Bucket-and-Weir” design
Operation of 3-P separation...

- **Inlet diverter** → gross separation
- **Downcomer** → directs liquid flow below oil-water interface
- **Liquid collection**
  - Oil/water mixture then mixes with water continuous phase → "**Water-washing**"
  - By “water-washing”, water droplets entrained in oil continuous phase will **coalesce**
  - Oil and emulsion has sufficient time to form layer of “oil pad” & Free water settles to bottom

Source: International Training & Development, M. Stewart
Interface level control

- Located at the oil-water-interface
- Senses the height of the interface → sends signal to water dump valve
- If level reach “high level” then fully open water valve
- If level “low level” then fully close valve

Advantage
- Easily adjustable to handle unexpected changes in oil/water specific gravity or flow rates

Disadvantage
- Heavy oil/large amount of emulsions, paraffin → difficult to sense interface level

Source: International Training & Development, M. Stewart
Bucket-and-Weir design

- Alternative of not using interface level controller
- Has oil bucket and weir, and water weir
- Level controller for both oil and water uses displacer float → both connected to dump valve
- But design decrease liquid capacity
- Critical → height of water weir sufficiently below oil weir height
  - To provide sufficient oil retention time, so that oil will not be swept under oil box and out of water outlet
  - Why? Because oil/water specific gravity or flow rates changes

“Balancing” effect

Source: International Training 
Development, M. Stewart
Cont.

- **Height of oil weir** controls **liquid level** in vessel
- **Difference** in height of oil weir and water weir controls the **thickness of oil pad**
  - Oil pad thickness changes as specific gravity or flow rate changes
  - HOW?
  - So, either oil or water weir is adjusted so that these changes can be accommodated

Source: International Training & Development, M. Stewart
Determination of oil pad thickness

\[ \Delta h = h_o \left[ 1 - \frac{\rho_o}{\rho_w} \right] \]

\[ \Delta h = \text{distance below oil weir (in)} \]
\[ h_o = \text{desired oil pad height (in)} \]

Remember the derivation of the equation!

Source: International Training & Development, M. Stewart
- But, this equation assumes NO inflow
- If there is inflow, then problem
  - Large oil inflow
    - Top oil rise, oil pad thicker
    - Oil pad thick could make oil swept below oil bucket
    - To accommodate this, make oil bucket deeper
  - Large water inflow
    - Water flow over water weir rises
    - At same time, pushes oil pad up and oil flows into oil weir rises
    - So what to do? Make weirs as long as possible
Vertical 3-P separator – “Bucket-and-weir” design

Source: International Training & Development, M. Stewart
Vertical 3-P separator – Interface Level Controller design

Know the advantages and disadvantages of each method

Source: International Training & Development, M. Stewart
VESSEL INTERNALS
Main Vessel internals

- Inlet diverter
  - Baffle plates or centrifugal diverters
  - Baffle plates $\rightarrow$ spherical dish, flat plate, cone etc

- Mist extractor
  - As gas flows through the vanes / wire mesh, it makes numerous directional changes
    - Due to greater mass, liquid droplets cannot follow the rapid change in flow direction
    - These droplets impinge and collect on vanes / mesh

Source: International Training & Development, M. Stewart
Types of mist extractor…

Source: International Training & Development, M. Stewart
Production Problems
Operational Production Problems

- Foaming
- Solids
  - Scale
  - Wax
  - Asphaltenes
  - Sand
- Emulsion
- Surging flow → high, instantaneous feed rates which cause level to rise above normal operating values
- Liquid carry over and Gas blowby

Source: International Training & Development, M. Stewart
END.
THE REST YOU READ YOURSELF, OK...