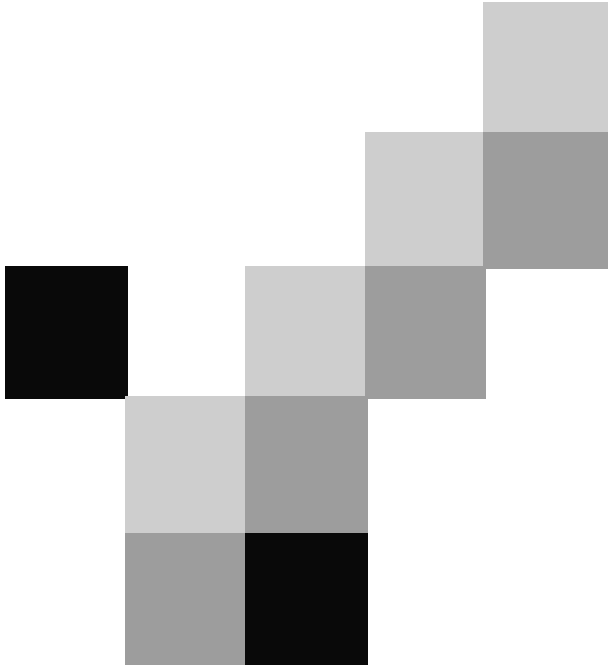


SEPARATOR: PRINCIPLES AND DESIGN

MAB 4633/ EMB 5443

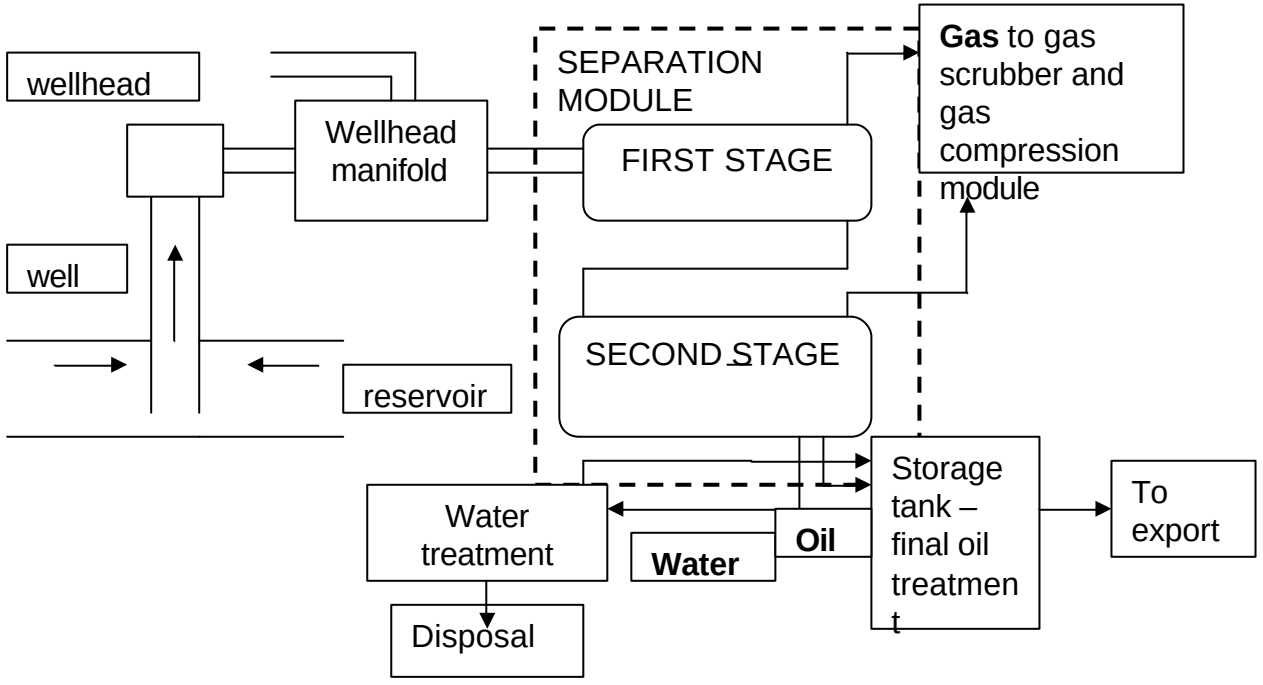
LECTURER: PUTRI NURIZATULSHIRA BUANG

SEPARATOR?

SEPARATOR…

The production process…

"SEPARATORS form the HEART of the production process"



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

Source: International Training & Development, M. Stewart

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?

Principles of separation!

- 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

Source: International Training & Development, M. Stewart

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

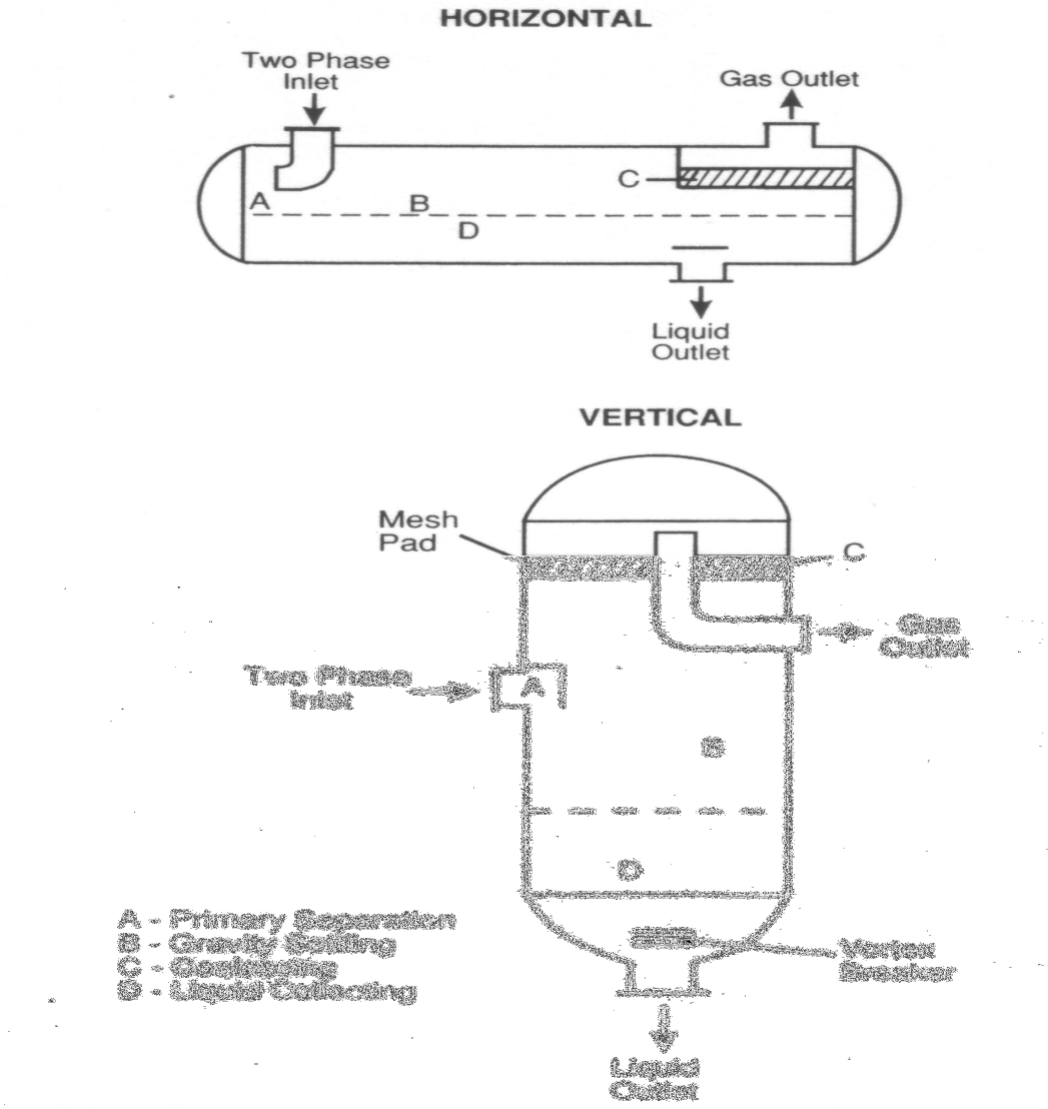
Source: International Training & Development, M. Stewart

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!

Source: International Training & Development, M. Stewart


HORIZONTAL
Two Phase Inlet
Gas Outlet
C
A
B
D
Liquid Outlet
VERTICAL
Mesh Pad
C
Gas Outlet
Two Phase Inlet
A
B
D
Vortex Breaker
Liquid Outlet
A - Primary Separation
B - Gravity Settling
C - Coalescing
D - Liquid Collecting

4 main principles…

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

Source: International Training & Development, M. Stewart

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

Source: International Training & Development, M. Stewart

3. COALESCING

- Occurs at mist extractor
- Before gas leaves vessel, it flows through mist extractor → 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

Source: International Training & Development, M. Stewart

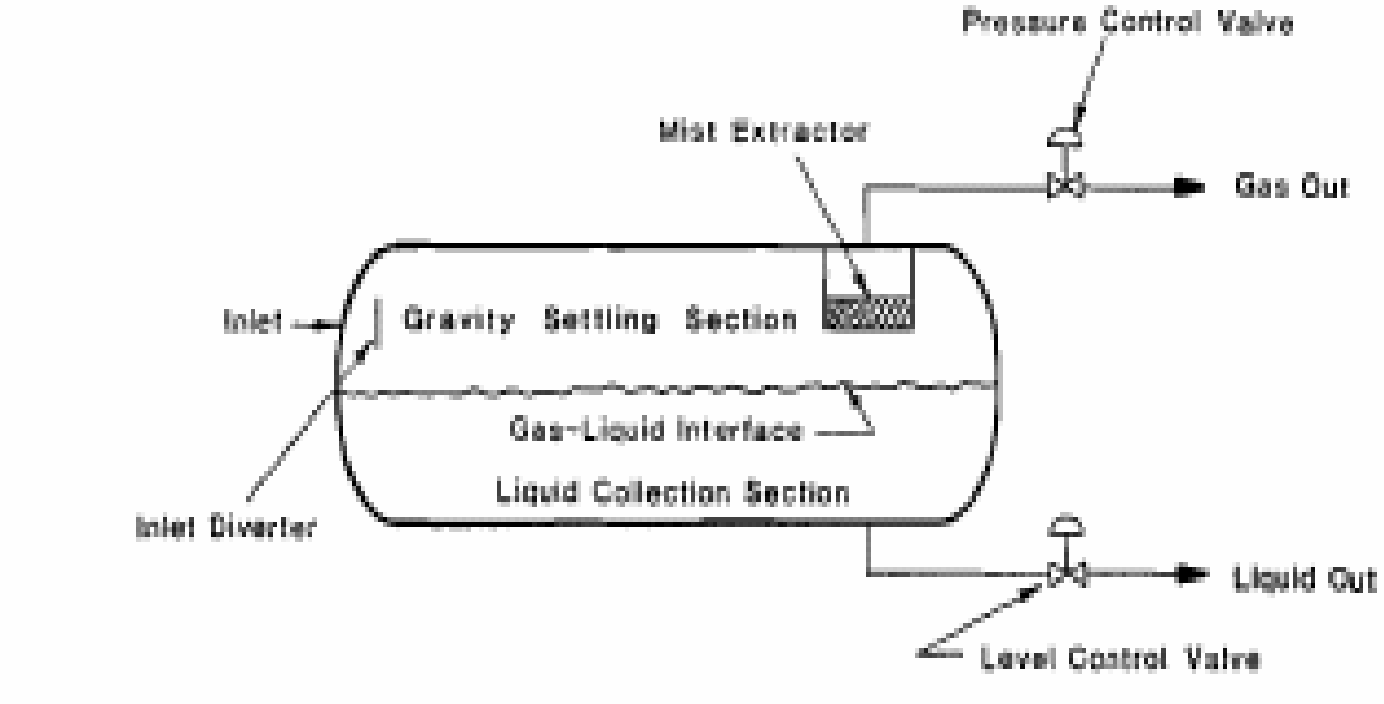
TWO-PHASE (GAS-LIQUID) SEPARATION

Main types

- HORIZONTAL separator
- VERTICAL separator
- SCRUBBERS

Source: International Training & Development, M. Stewart

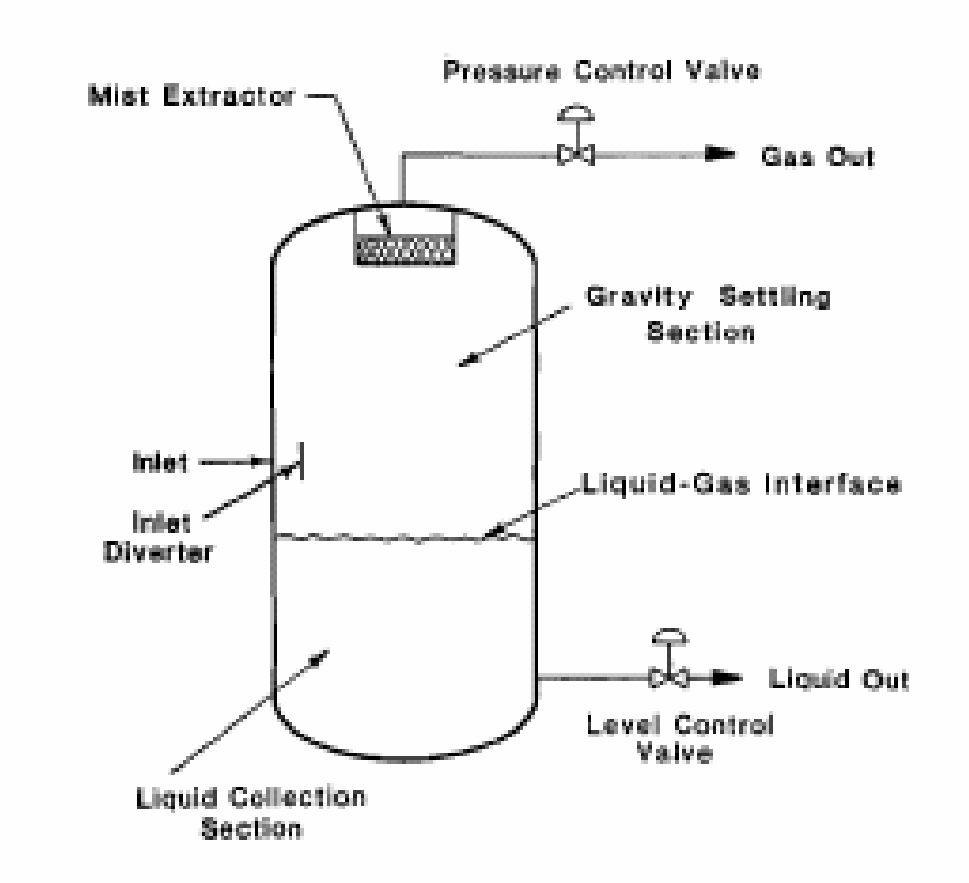
Horizontal (2-P) separator



Operation ?

Source: International Training & Development, M. Stewart

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

Source: International Training & Development, M. Stewart

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

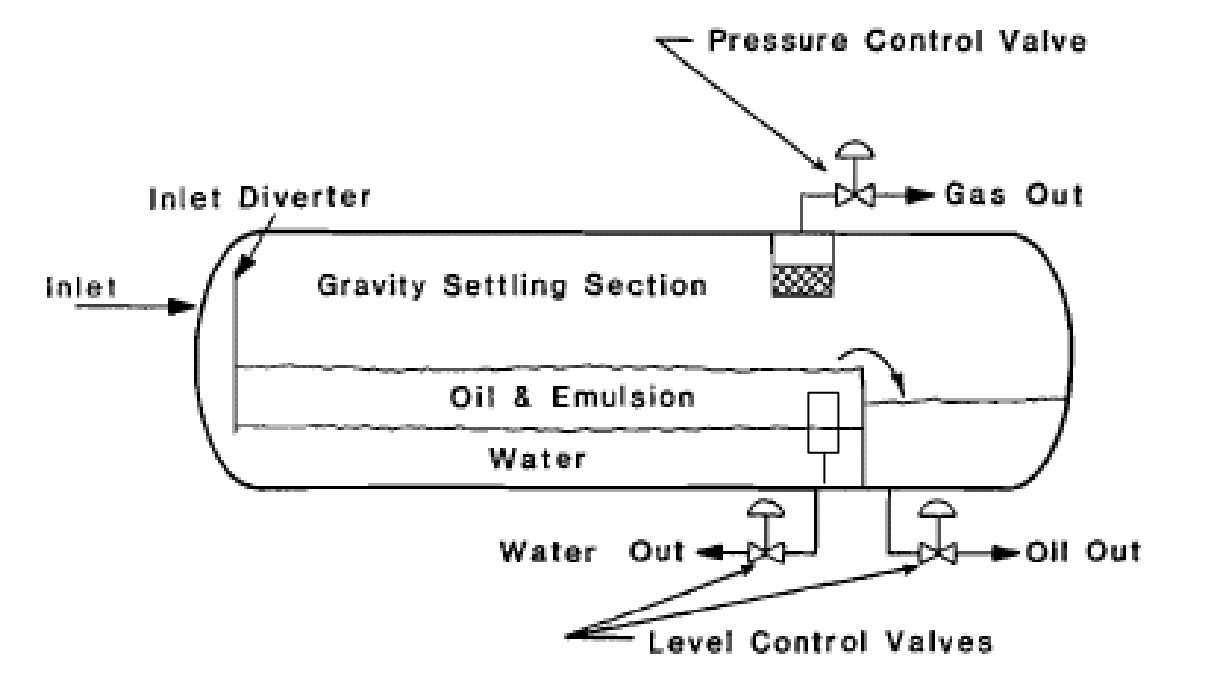
THREE-PHASE (OIL-WATER) SEPARATION

Types (Horizontal and/or Vertical)

- Interface level control design
- Bucket–and–weir design

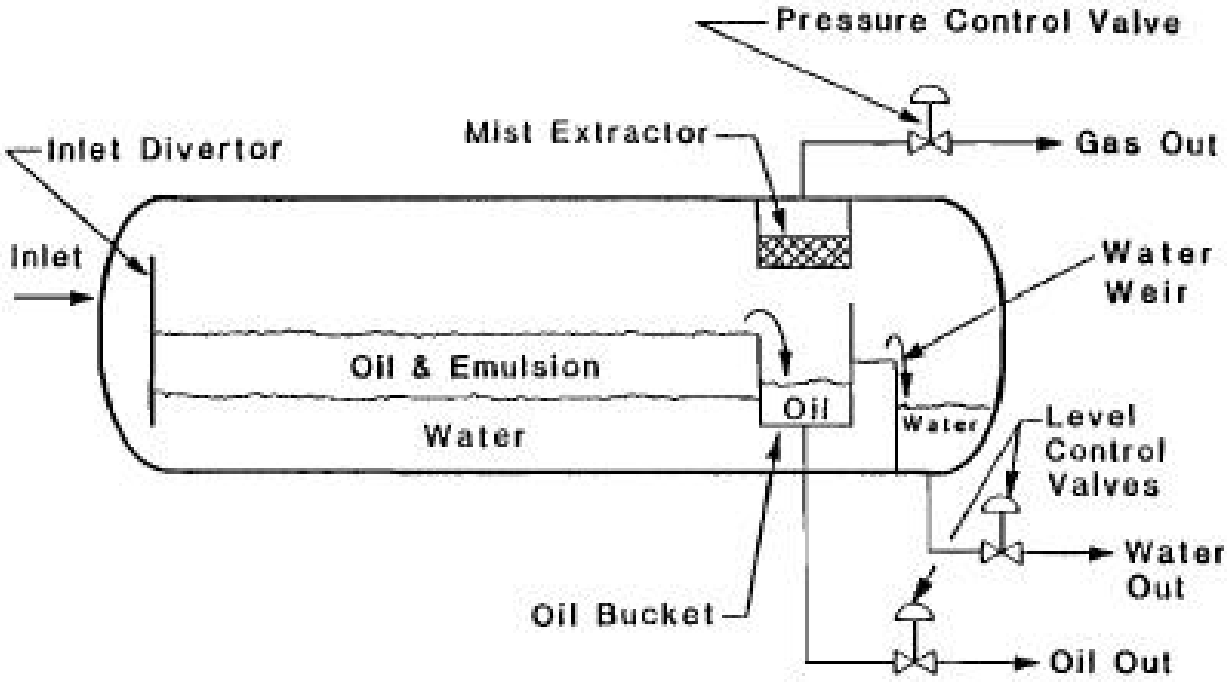
Source: International Training & Development, M. Stewart

Horizontal (3-P) Separator – Interface level controller design



Source: International Training & Development, M. Stewart

Horizontal (3-P) Separator – “Bucket-and-Weir” design



Source: International Training & Development, M. Stewart

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

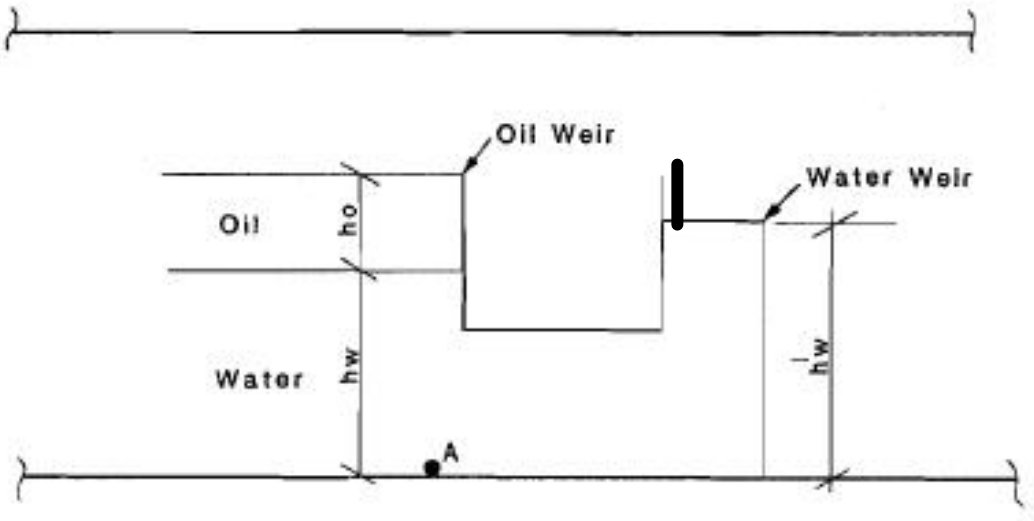
Source: International Training & Development, M. Stewart

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



$$\Delta h = h_o \left[1 - \frac{r_o}{r_w} \right]$$

Remember the derivation of the equation!

Δh = distance below oil weir (in)

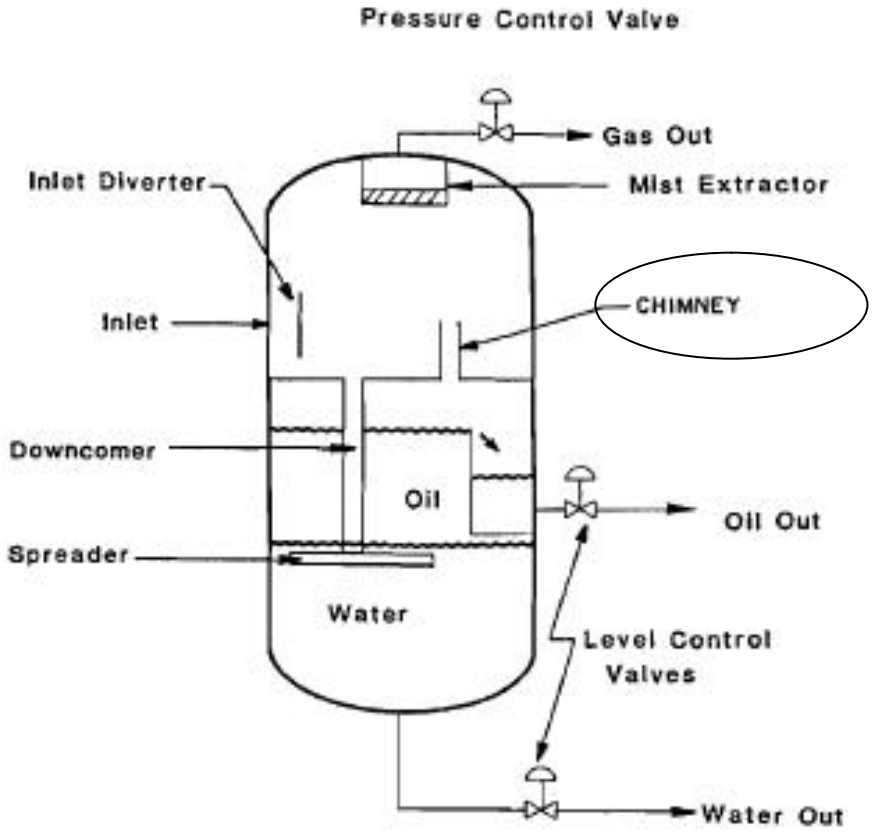
h_o = desired oil pad height (in)

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

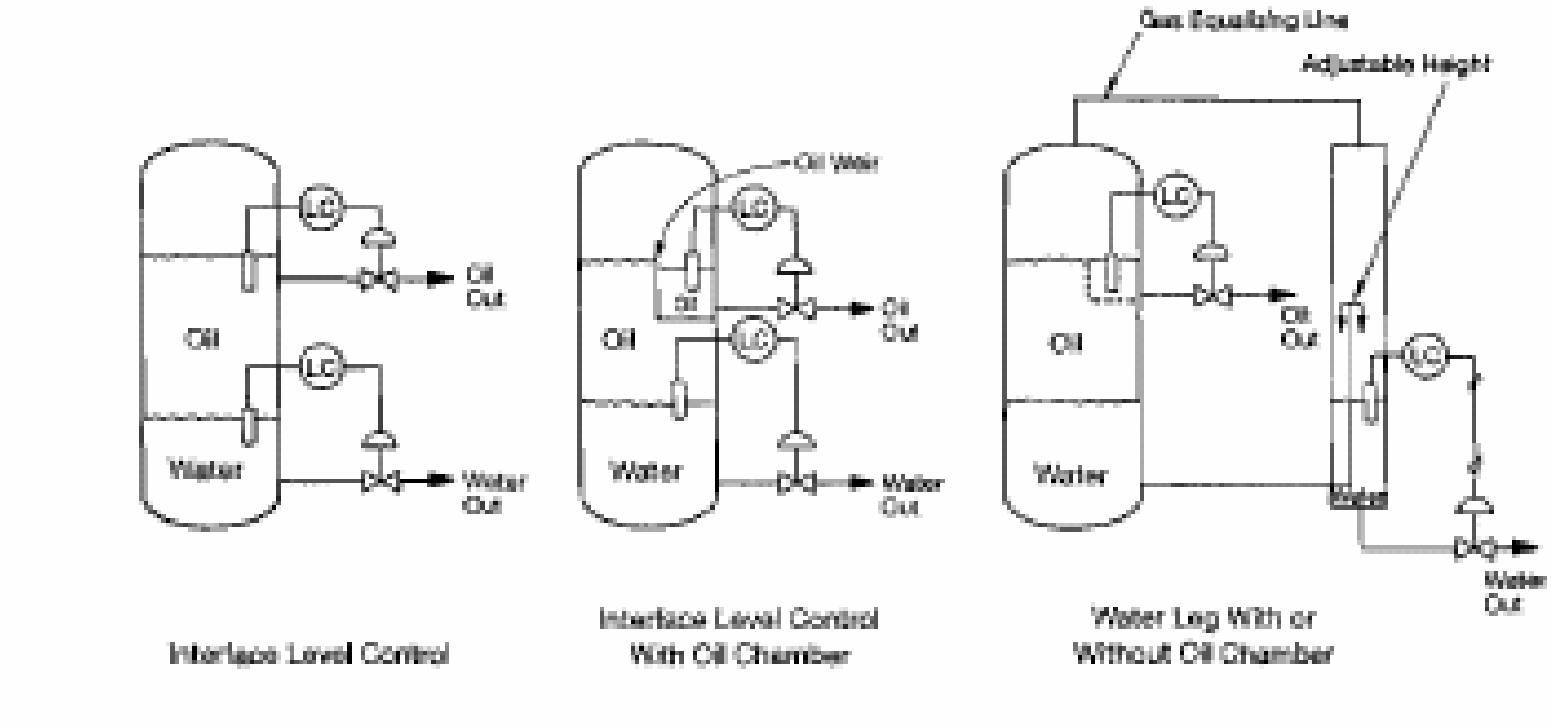
Source: International Training & Development, M. Stewart

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

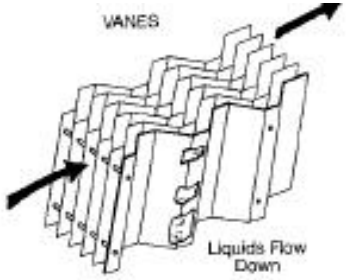
VESSEL INTERNALS

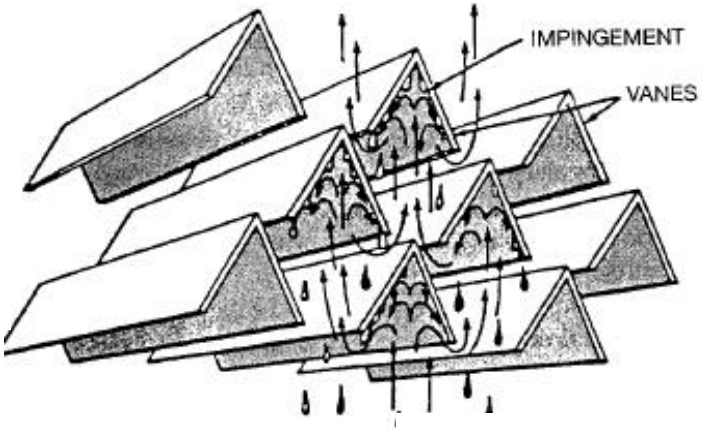
Main Vessel internals

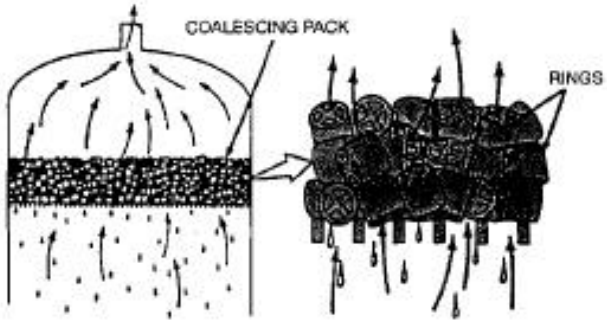
- Inlet diverter
  - Baffle plates or centrifugal diverters
  - Baffle plates → spherical dish, flat plate, cone etc
- Mist extractor
  - As gas flows through the vanes / wire mesh, it makes numerous directional changes
    - Due to greater mass, liquid droplets cannot follow the rapid change in flow 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

Source: International Training & Development, M. Stewart

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…