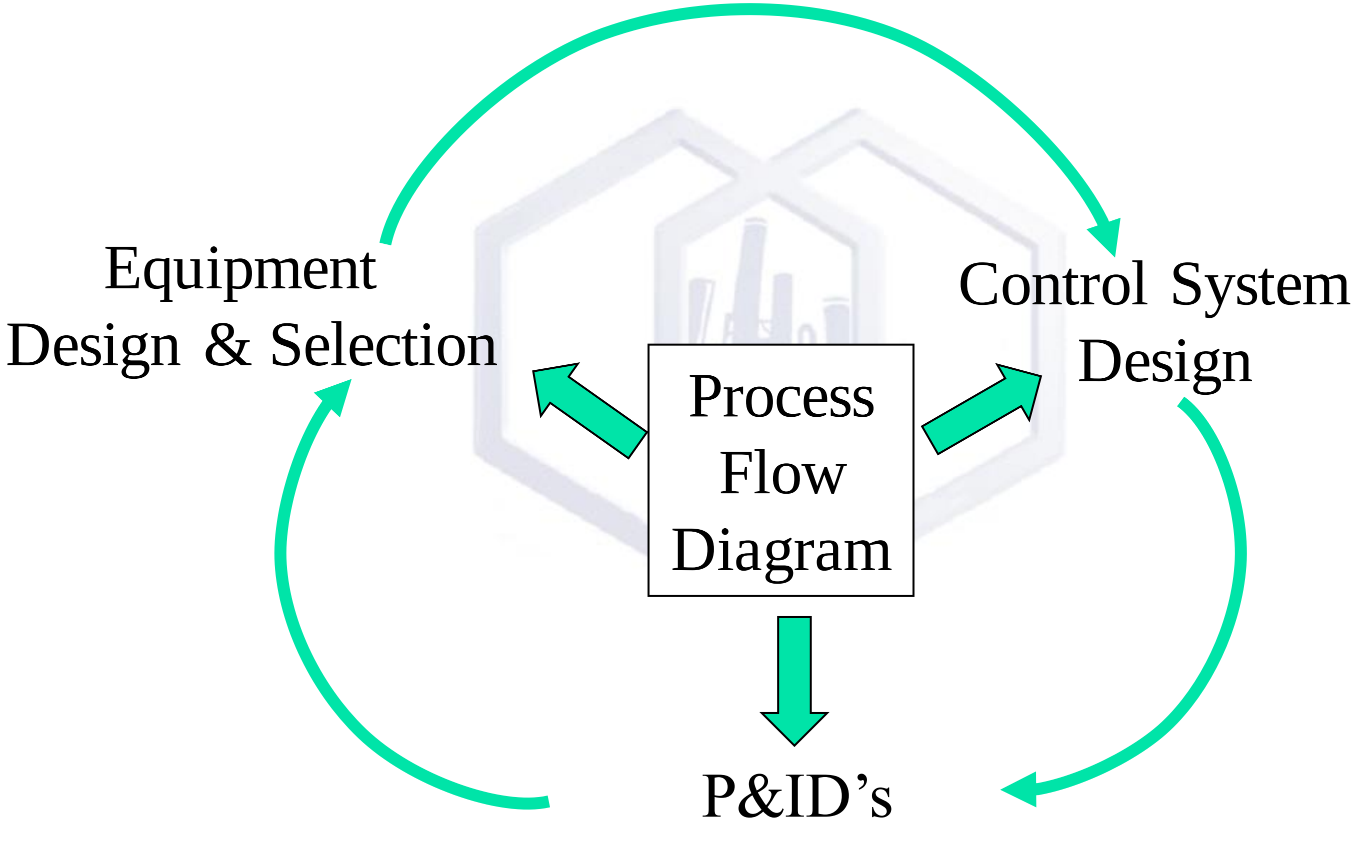
P&ID Design and Equipment Selection

Intro

- What:
  - Evolution of PFD to P&ID's and equipment
- Who:
  - Process Engineer
- How:
  - Understanding appropriate equipment for the task at hand

From PFD to ...



Equipment
Design & Selection
Process
Flow
Diagram
Control System
Design
P&ID’s

What’s a P&ID?

- P.. Piping &
- I.. Instrumentation
- D.. Diagram

- Sometimes called a Mechanical Flow Diagram

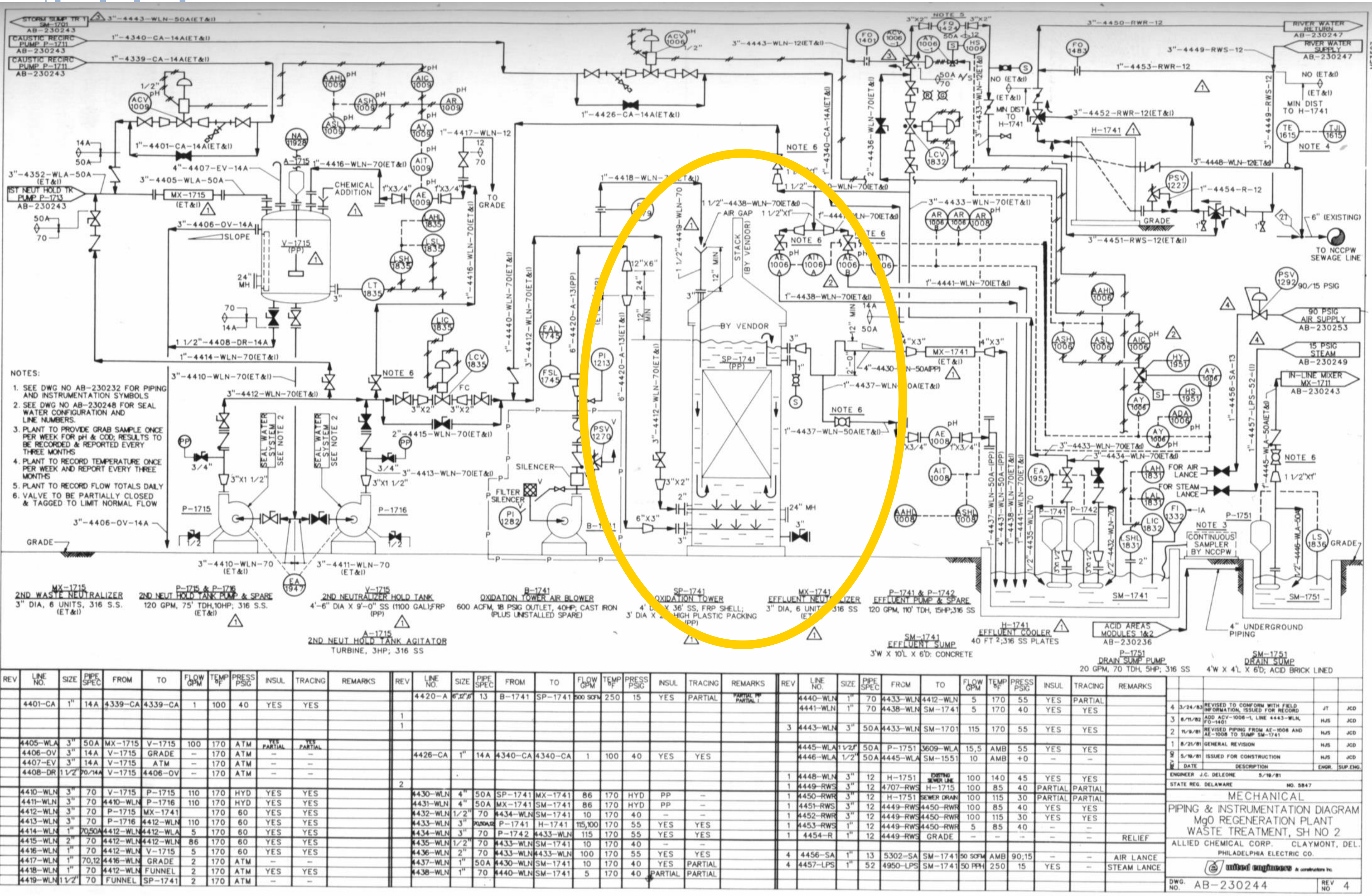
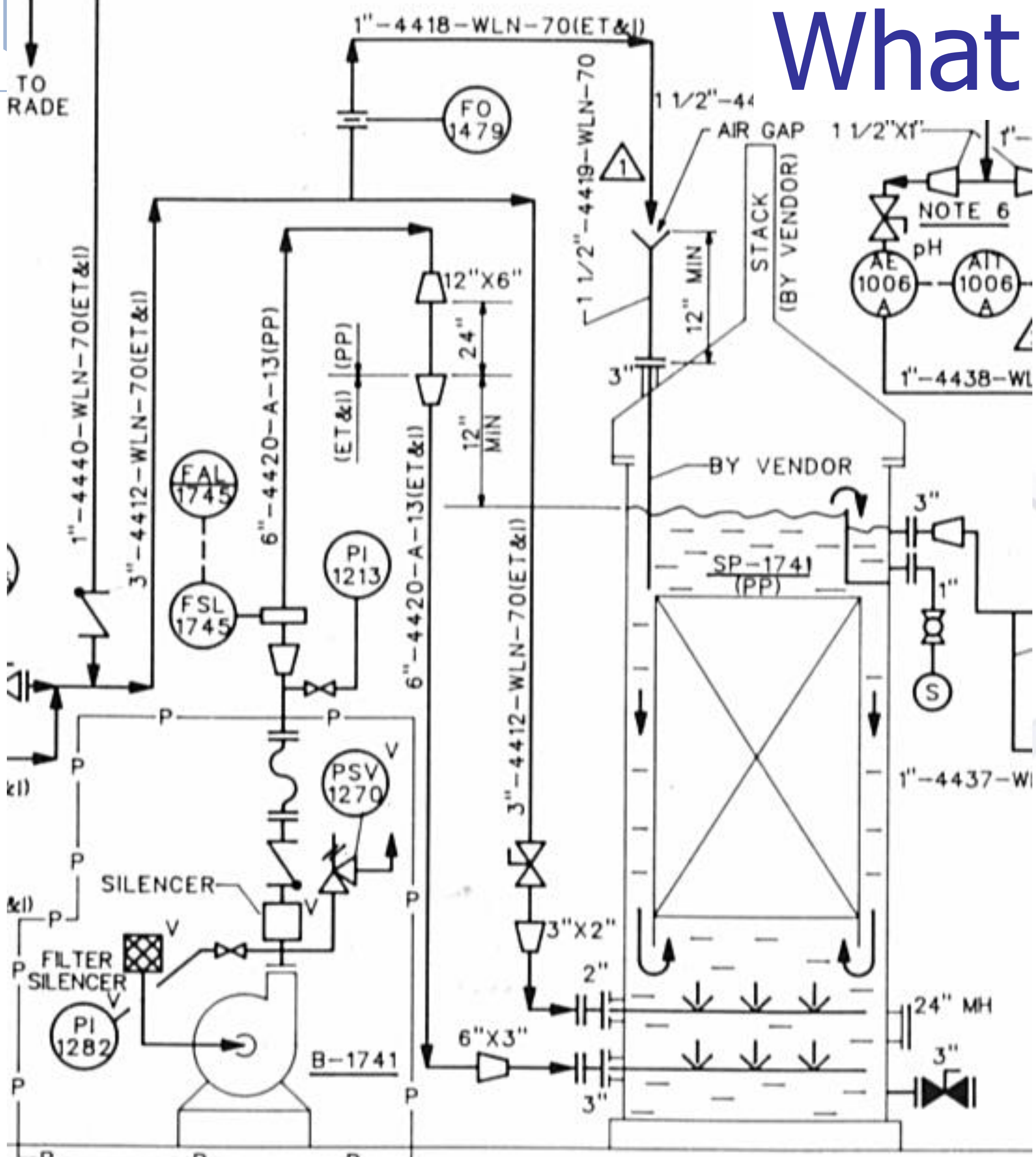


Figure 3.2 Typical piping and instrumentation drawing. Equipment shown in the foreground

What a P&ID is..

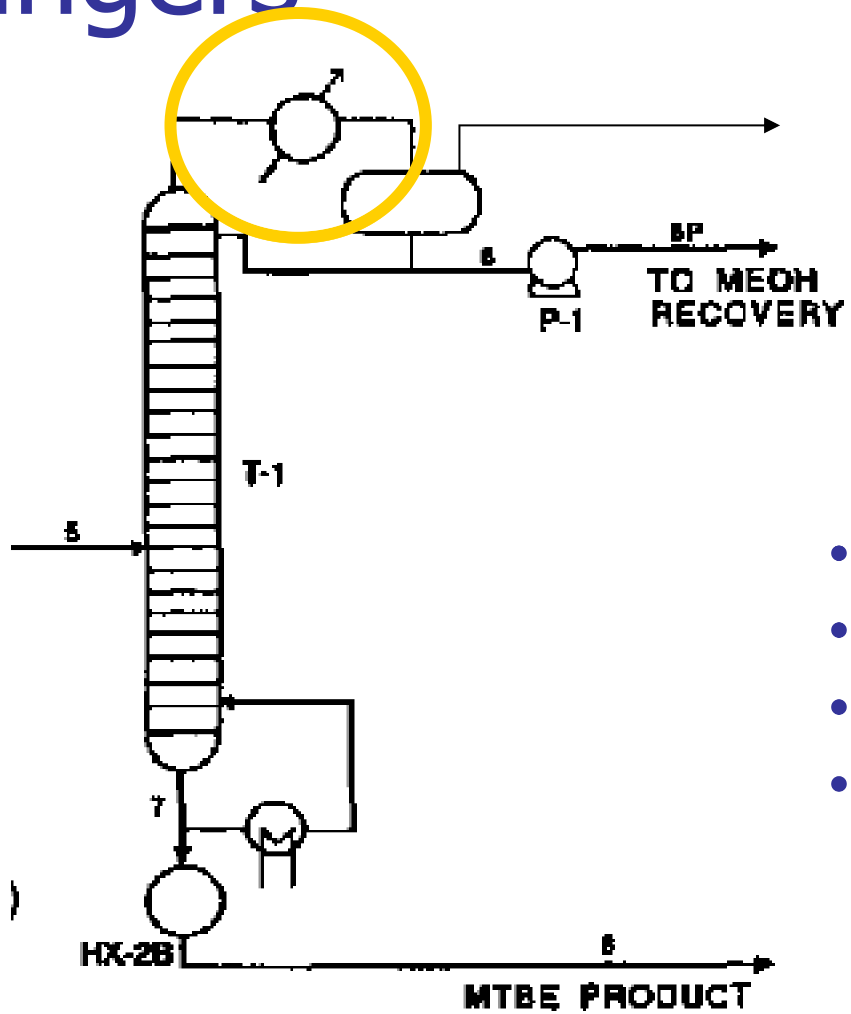


- All Equipment & Some details
- Major Flows
- All Piping and relative locn of branches
- Piping “spec” & diameters
- Manual valves
- Motors
- Liquid Levels
- Instrumentation
- Control Scheme

What a P&ID is NOT

- Not to scale (but relative elevations are shown)
- Does not explain/show complicated control schemes
- Does not show timing dependencies of controls
- Does not show Details of Instruments
- Does not show exact routing of pipes
- Does not show pipe supports

Exchangers



- Full Condenser
- Partial Condenser
- Cooler / Heater
- Boiling

Exchanger Types

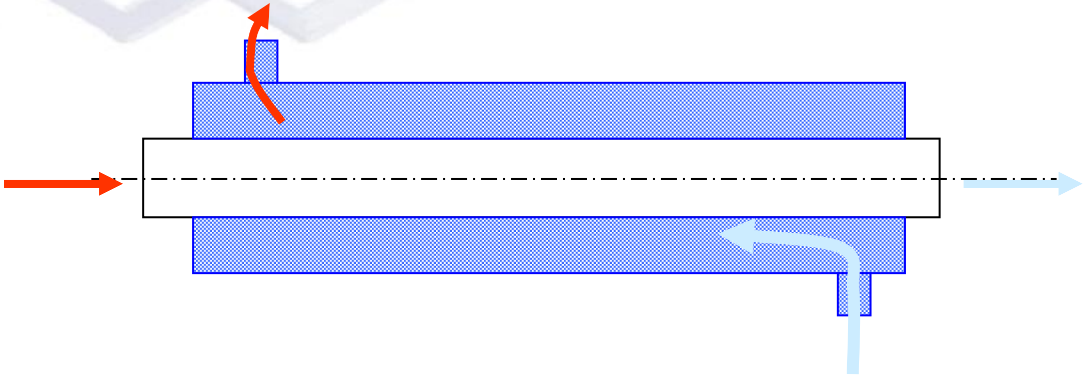
- Double Pipe
- Shell & Tube
- Plate & Frame
- Pipe Coil
- Finned (air cooled)
- Fired
- Direct Contact

- Simple and inexpensive

- Small heat x-fer areas

- suitable for high pressures

- suitable for minimal leakage applications



Exchanger Types

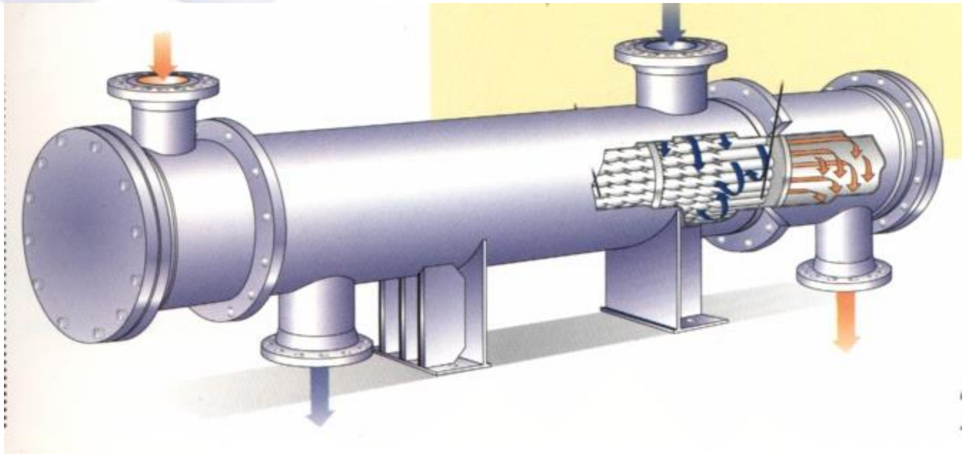
- Double Pipe
- Shell & Tube
- Plate & Frame
- Pipe Coil
- Finned (air cooled)
- Fired
- Direct Contact

- Most Commonly used

- High heat transfer area in small volume

- Easily cleaned

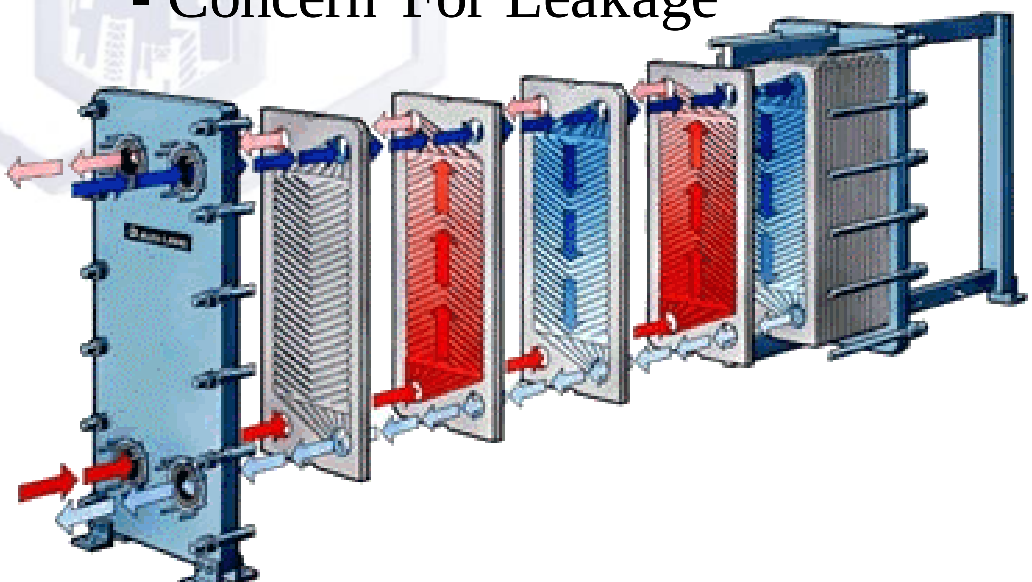
- Well established design methods



Exchanger Types

- Double Pipe
- Shell & Tube
- Plate & Frame
- Pipe Coil
- Finned (air cooled)
- Fired
- Direct Contact

- High Heat x-fer coeficients
- Small Space Requirements
- Easy Expansion
- Concern For Leakage



Exchanger Types

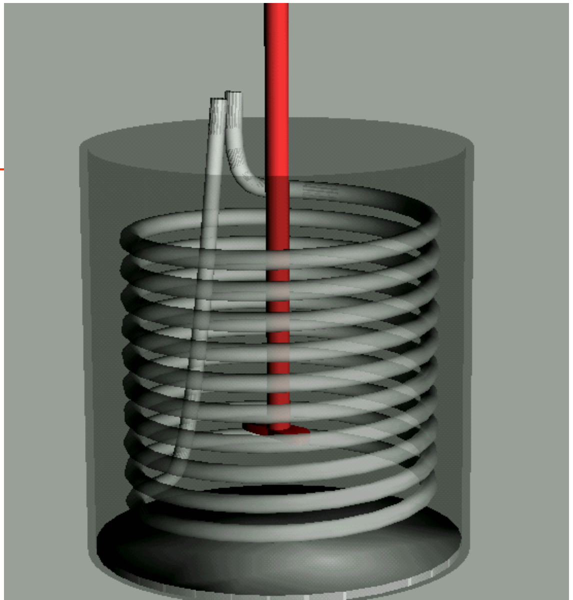
- Double Pipe
- Shell & Tube
- Plate & Frame
- Pipe Coil
- Finned (air cooled)
- Fired
- Direct Contact

- Mainly used submerged in tanks

- Commonly used with agitators

- Low Cost (combines tank & exch)

-Large Space

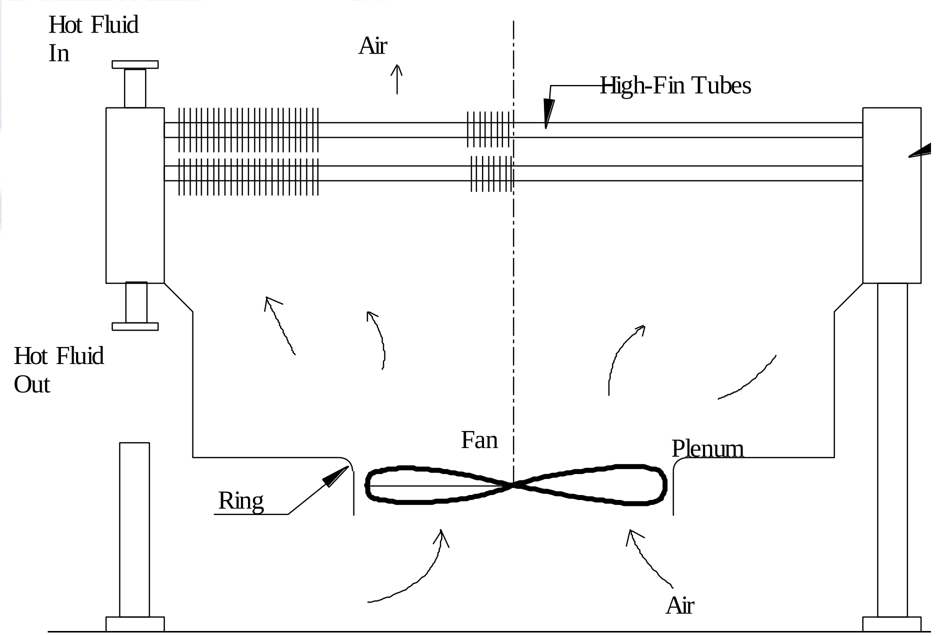


Exchanger Types

- Double Pipe
- Shell & Tube
- Plate & Frame
- Pipe Coil
- Finned (air cooled)
- Fired
- Direct Contact

- Should be considered if water supply is limited

-Better economics than using water when min temp is > 150 °F



Exchanger Types

- Double Pipe
- Shell & Tube
- Plate & Frame
- Pipe Coil
- Finned (air cooled)
- Fired
- Direct Contact

- Typically for high temperature requirements

- Usually for utilities (steam gen)

Exchanger Types

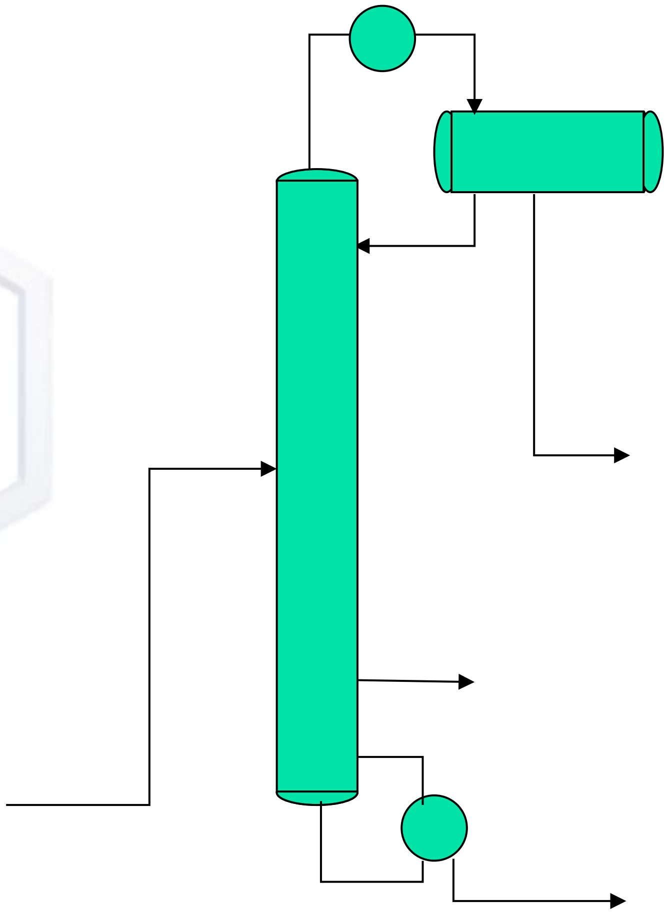
- Double Pipe
- Shell & Tube
- Plate & Frame
- Pipe Coil
- Finned (air cooled)
- Fired
- Direct Contact

- Very High Heat Transfer Coefficients

- Contamination of Streams

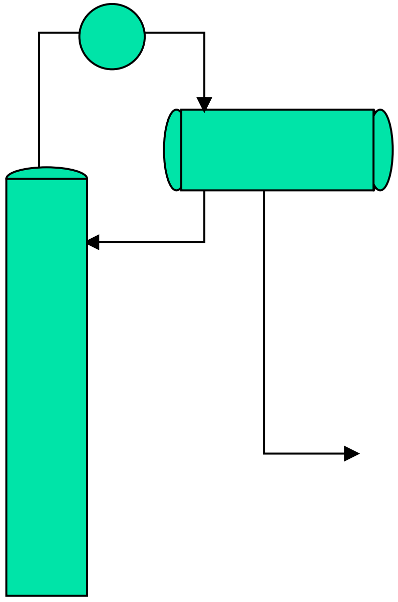
PFD - Column

- Design Notes
  - Full condenser
  - Reflux Drum
  - Reboiler
- Design Questions
  - Exchanger Types
  - Reflux pumps?
  - Bottoms pumps?

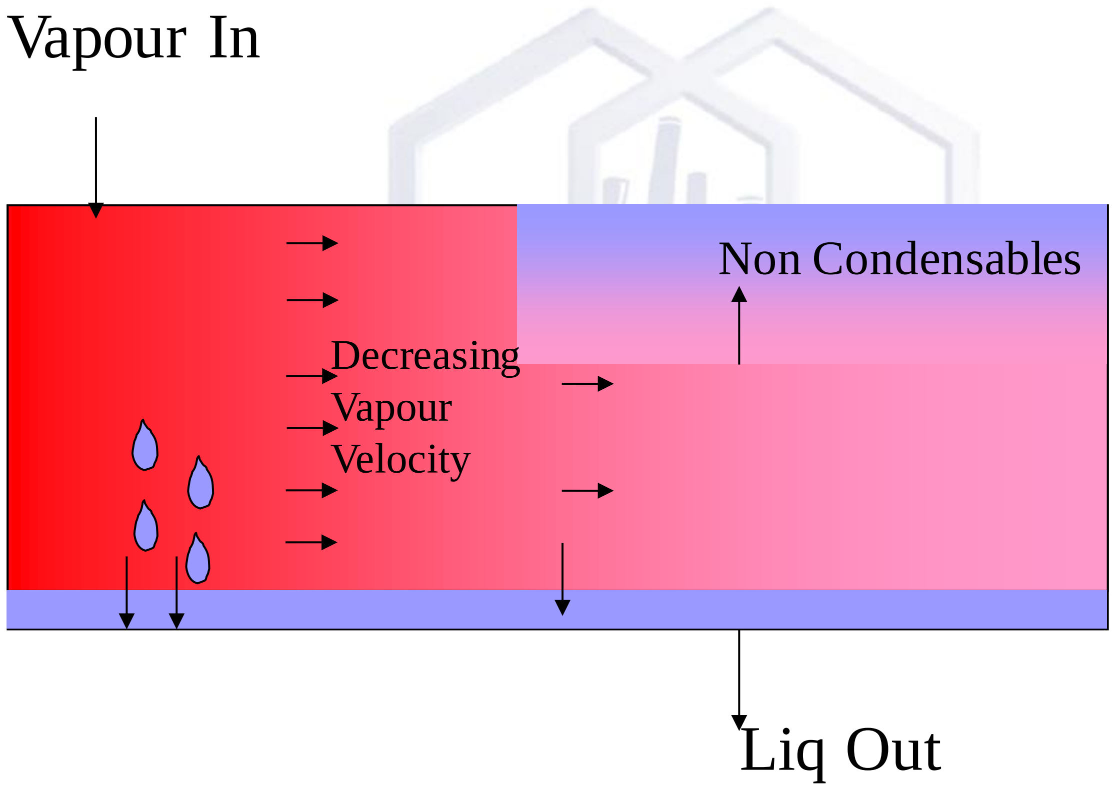


Column - Full Condenser

- Full Condenser
- Exchanger Orientation
  - Vertical / Horizontal
- Location
  - Elevated / Ground
- Process Shell Side/tube side

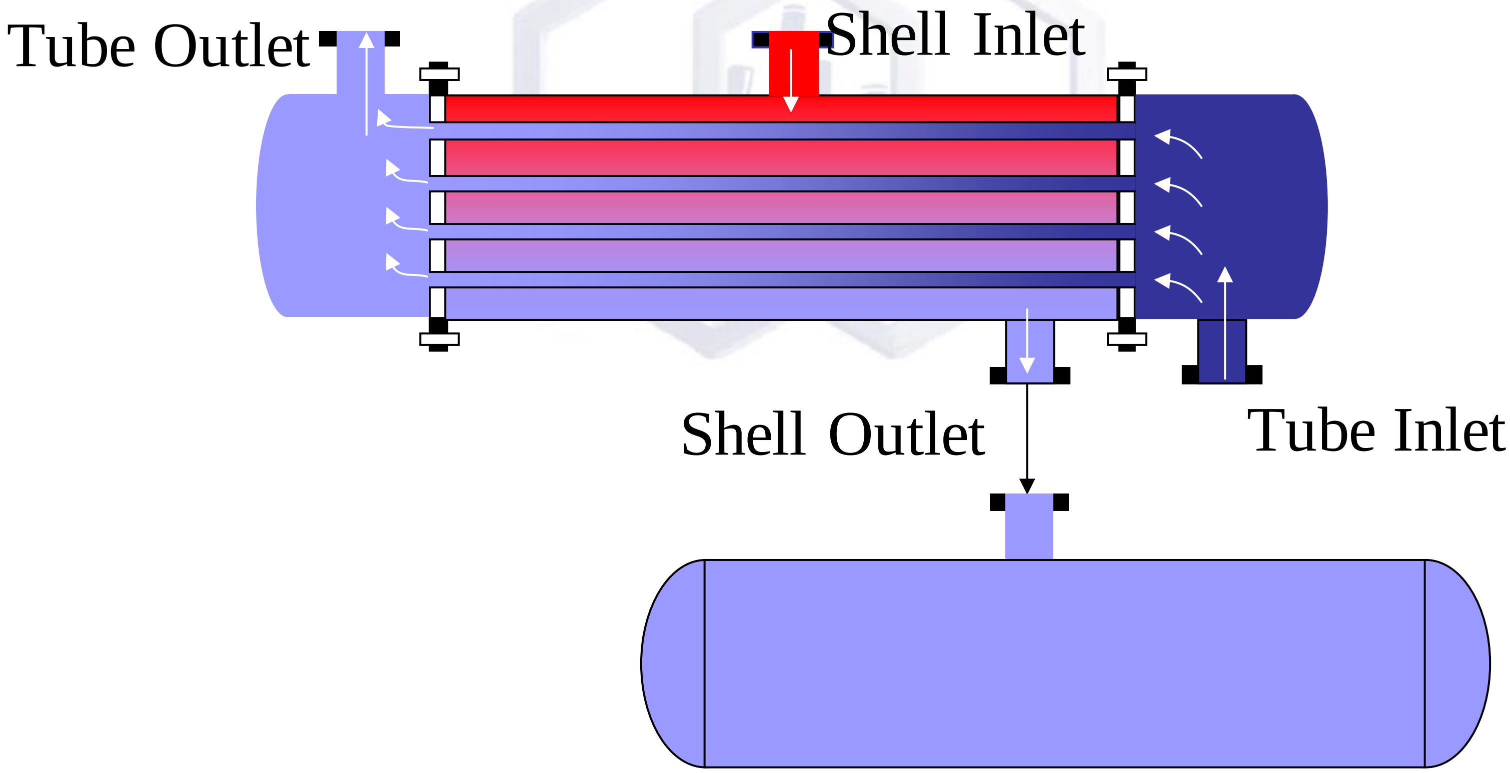


Condenser - Operation

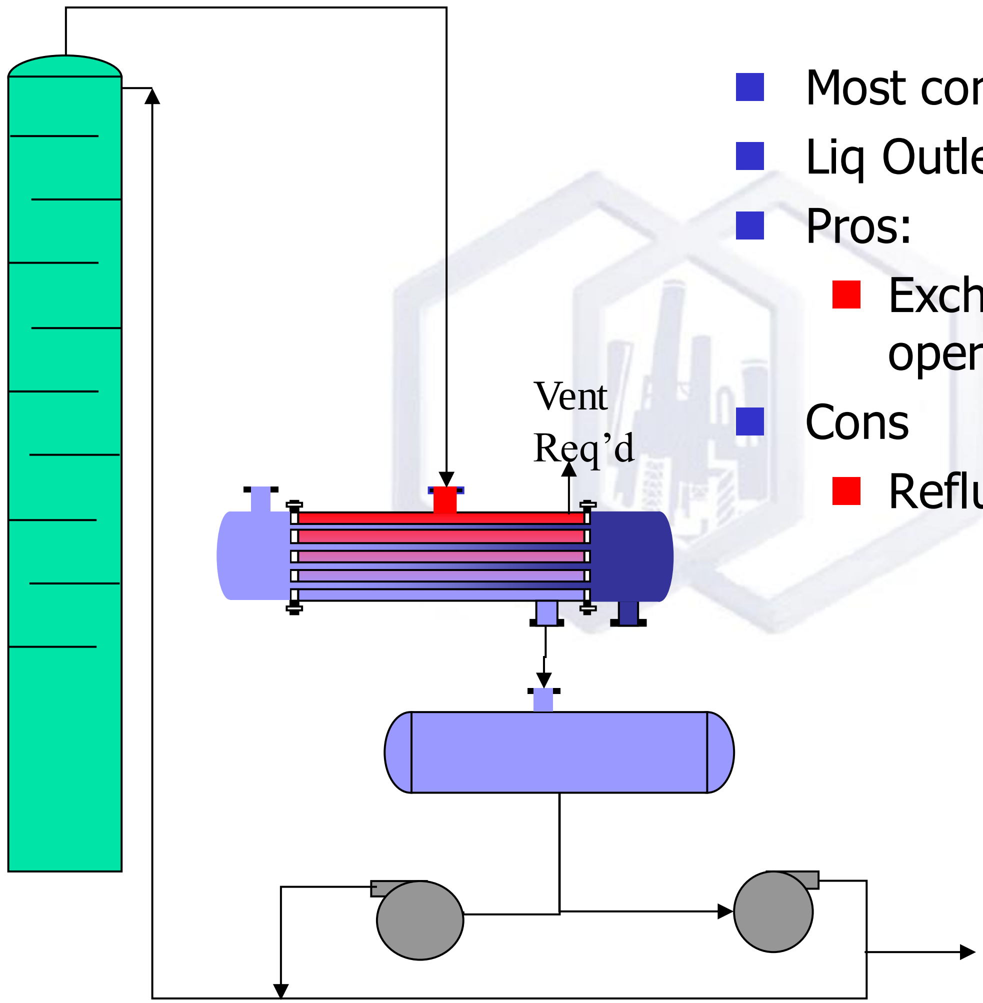


Column Ovhd - Full Condenser

- Process In Shell Side
- Gravity Drain on bottom to Reflux Tank

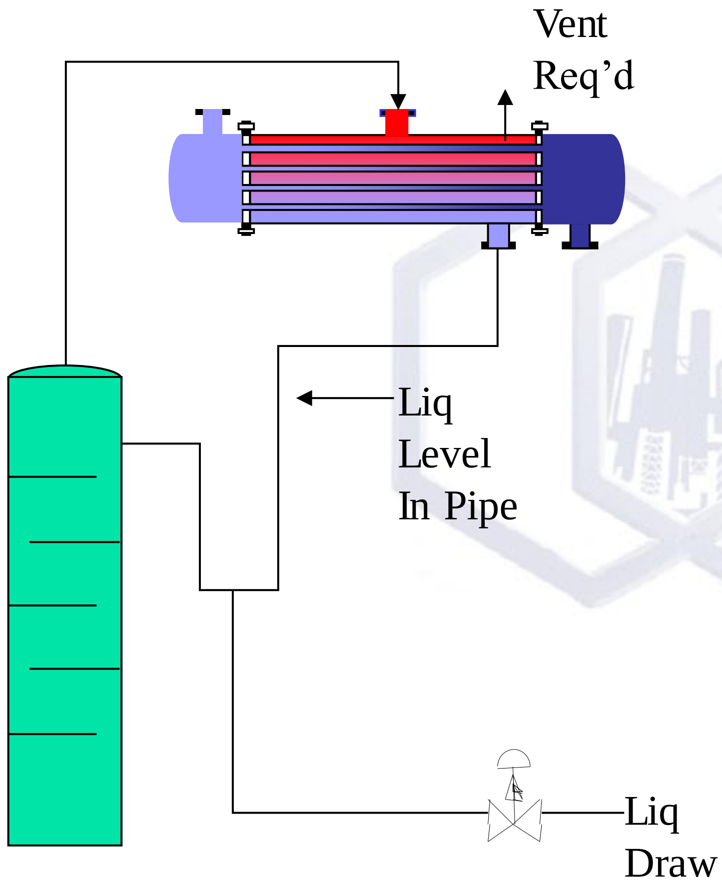


Full Condenser, Horiz, Ground Level



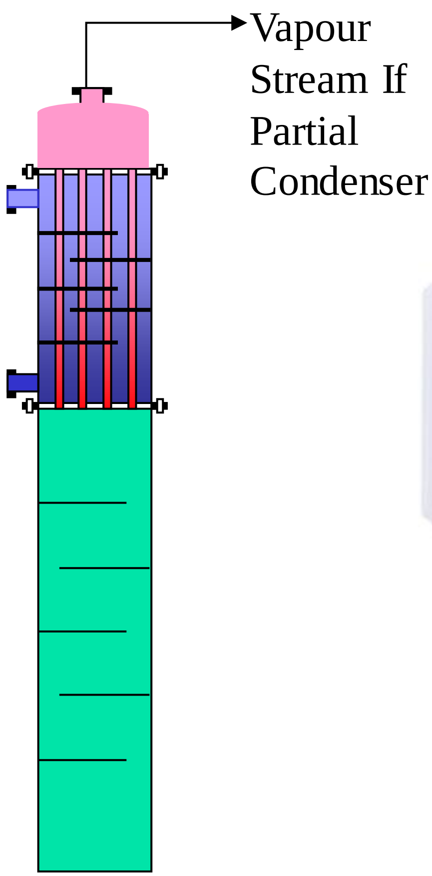
- Most commonly used
- Liq Outlet on pump disch
- Pros:
  - Exch close to ground - maint. / operability
- Cons
  - Reflux pumps req’d

Full Condenser, Horiz, Elevated



- No Liq Draw
- Pros:
  - No Pumps
  - few controls
- Cons
  - Appropriate when no liq draw is present
  - Structure larger / more expensive to accommodate exch
  - Monitoring more difficult
  - Little hold-up - smoothing of concentrations
  - reflux flow not controlled well

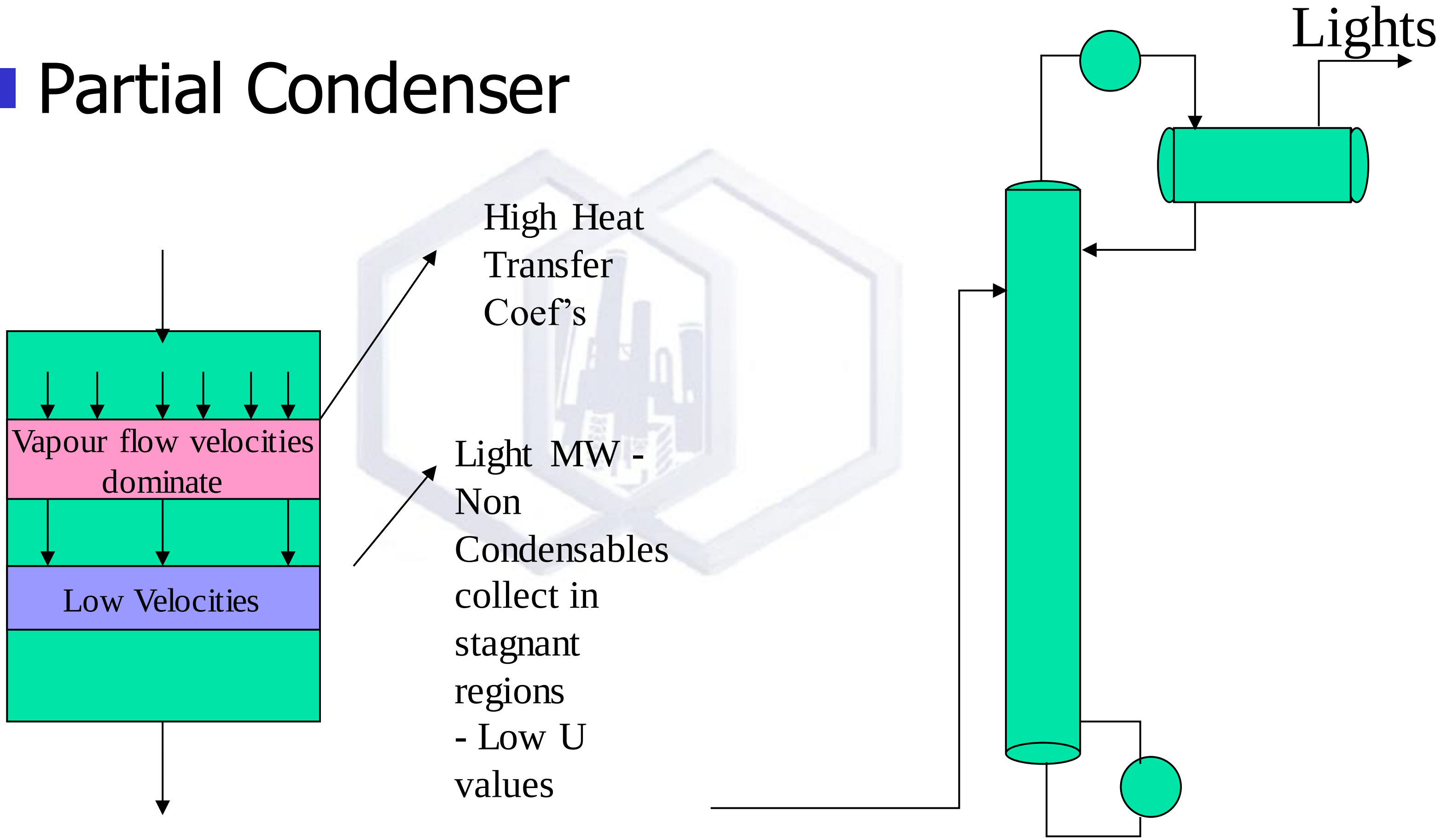
Full or Partial Condenser, Vertical, Elevated



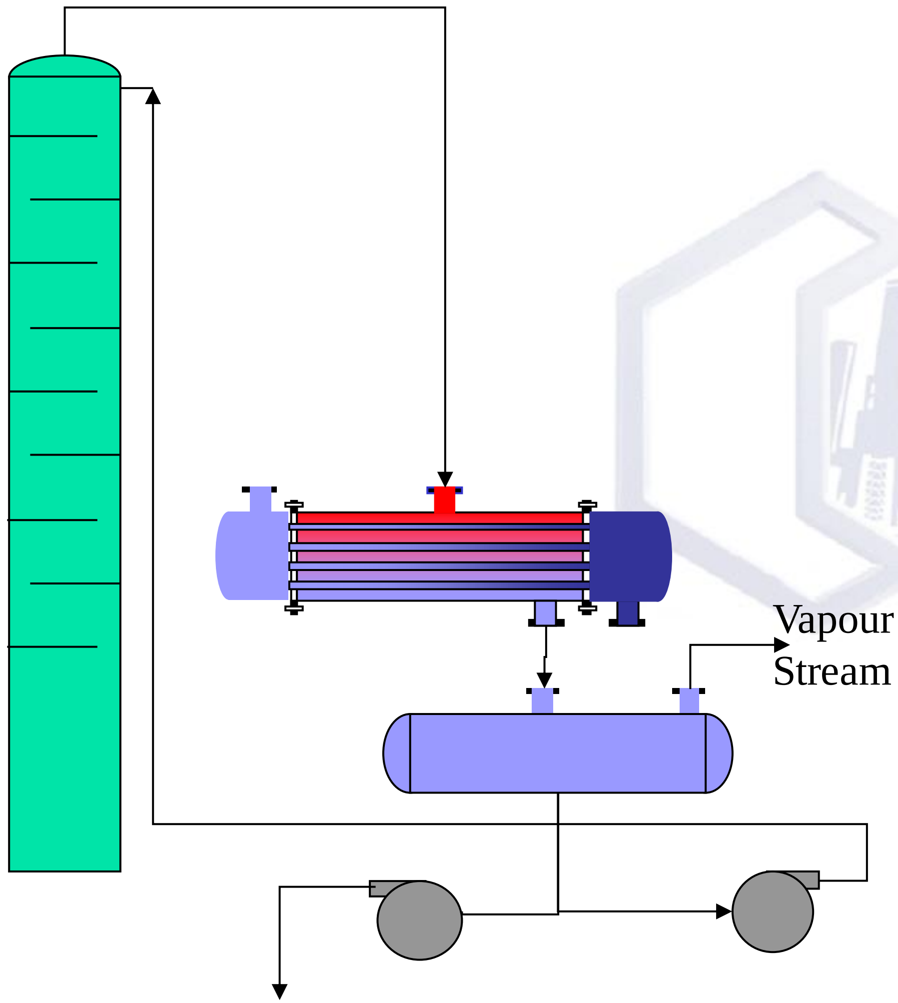
- Pros:
  - No Pumps
  - few controls
  - little piping
- Cons
  - Appropriate when no liq draw is present
  - Column & Structure larger / more expensive to accommodate exch
  - Monitoring more difficult
  - Limited Surface Area / exch dia
  - Little hold-up - smoothing of concentrations
  - reflux flow not controlled well

Column - Partial Condenser

- Partial Condenser

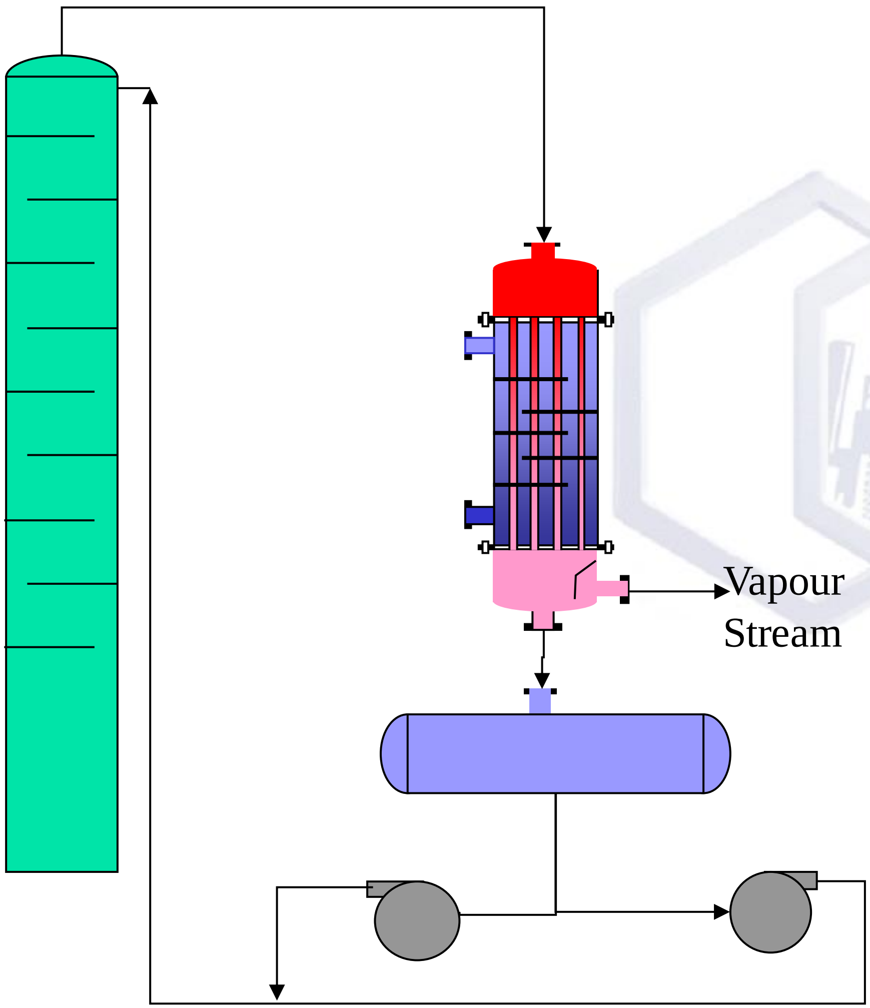


Partial Condenser, Horiz, Ground Level



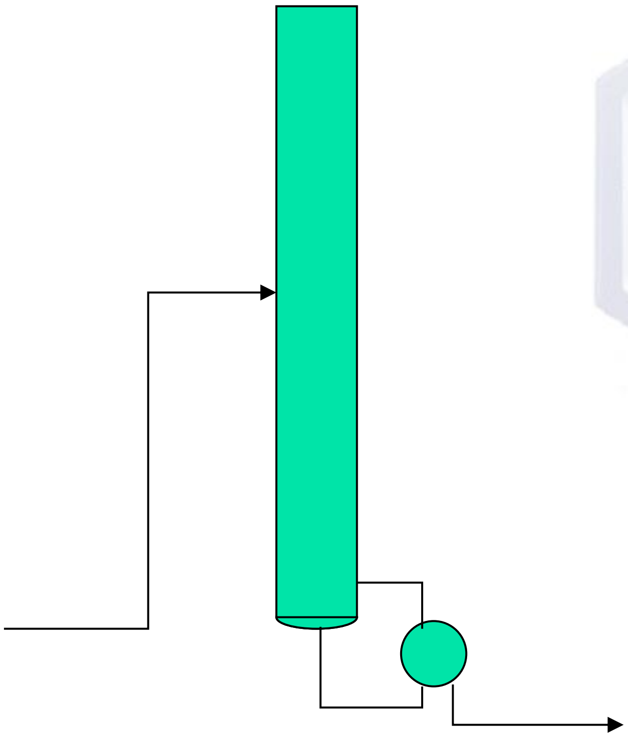
- Vapour flow through exchanger, exits from reflux drum
- Pros:
  - Exch close to ground - maint. / operability
  - sweeps non-condensables through exchanger
- Cons
  - Reflux pumps req'd

Partial Condenser, Vert, Ground Level



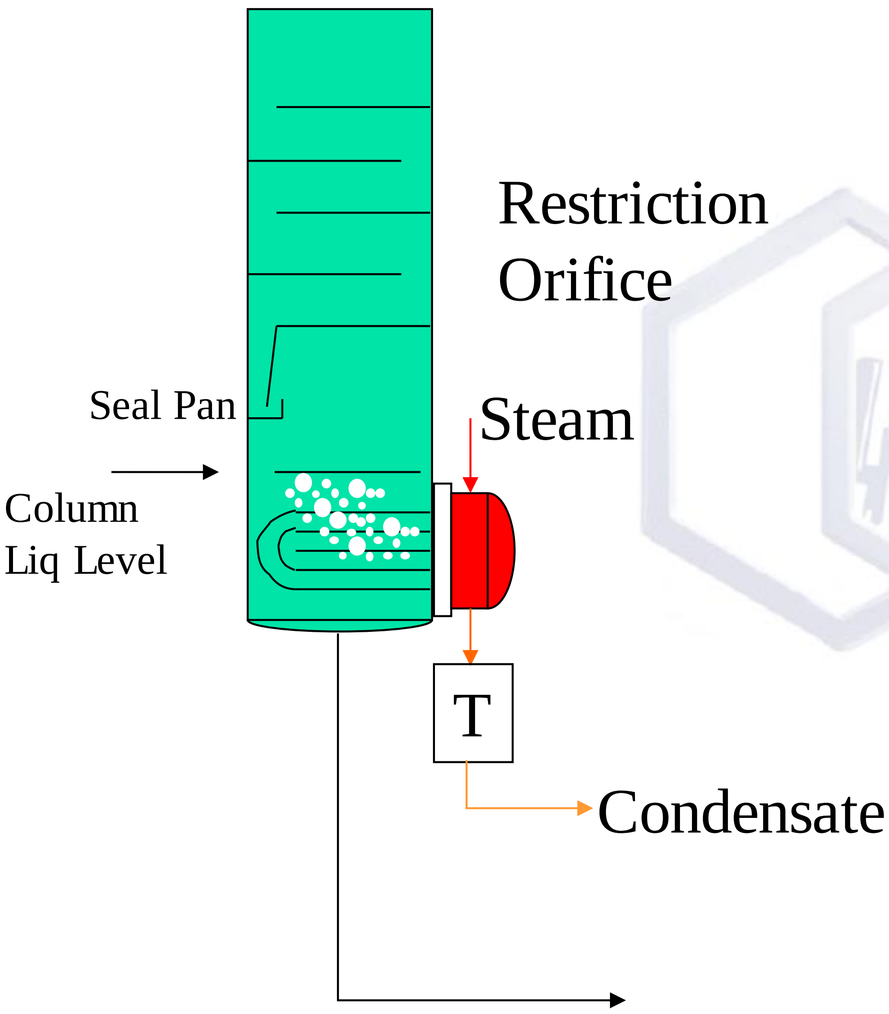
- Vapour flow exits from exchanger
- Pros:
  - Exch close to ground - maint. / operability
  - sweeps non-condensables through exchanger
  - Consideration to vapour flow entraining liquid off surface of reflux drum not required.
  - Non condensables removed more efficiently
- Cons
  - Reflux pumps req'd
  - Exchanger internal baffle required.

Column - Bottoms



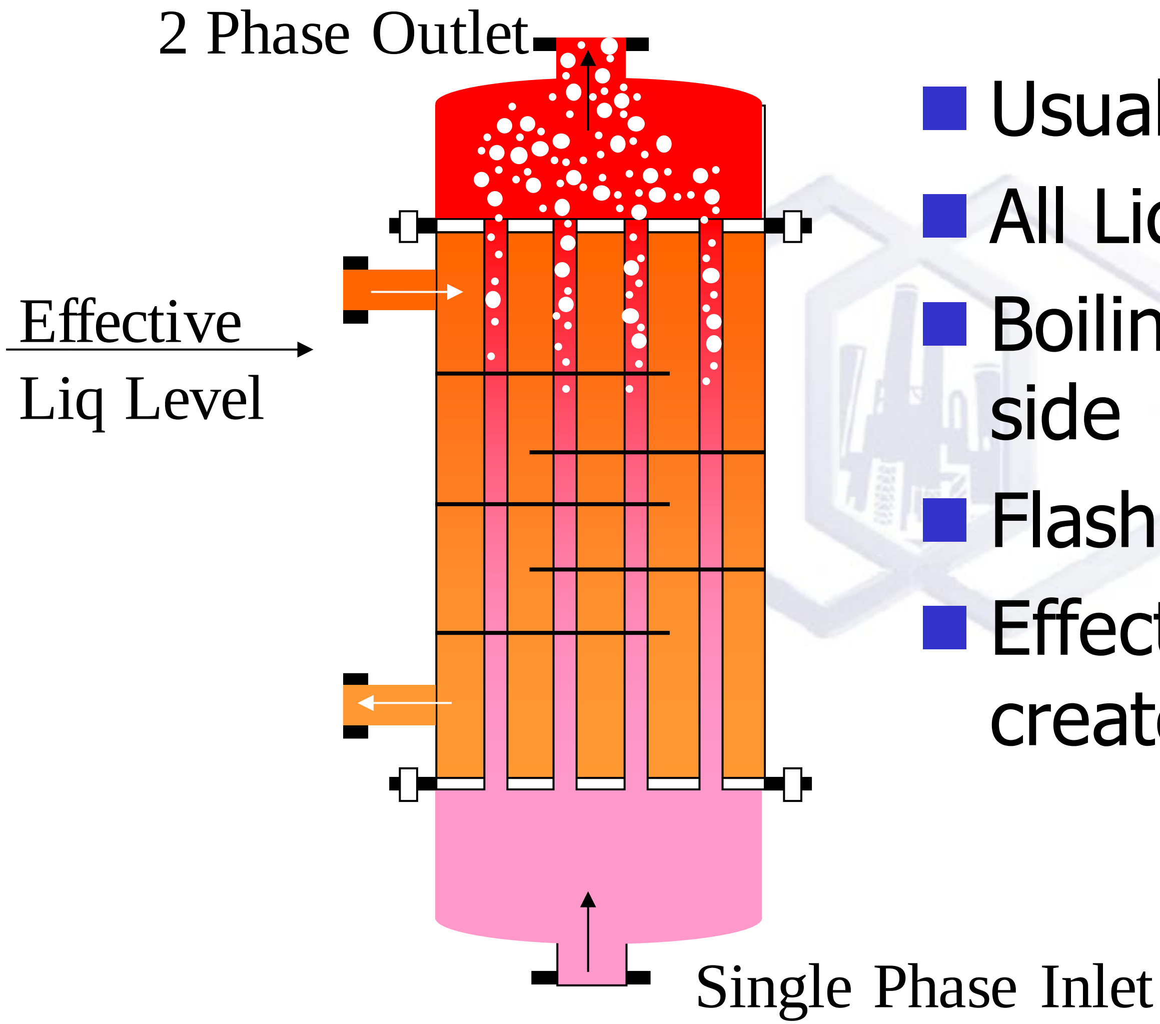
- Reboiler
  - Natural Circulation
  - Forced Circulation
  - Condensing Heating Medium
  - Non-condensing

Stab In



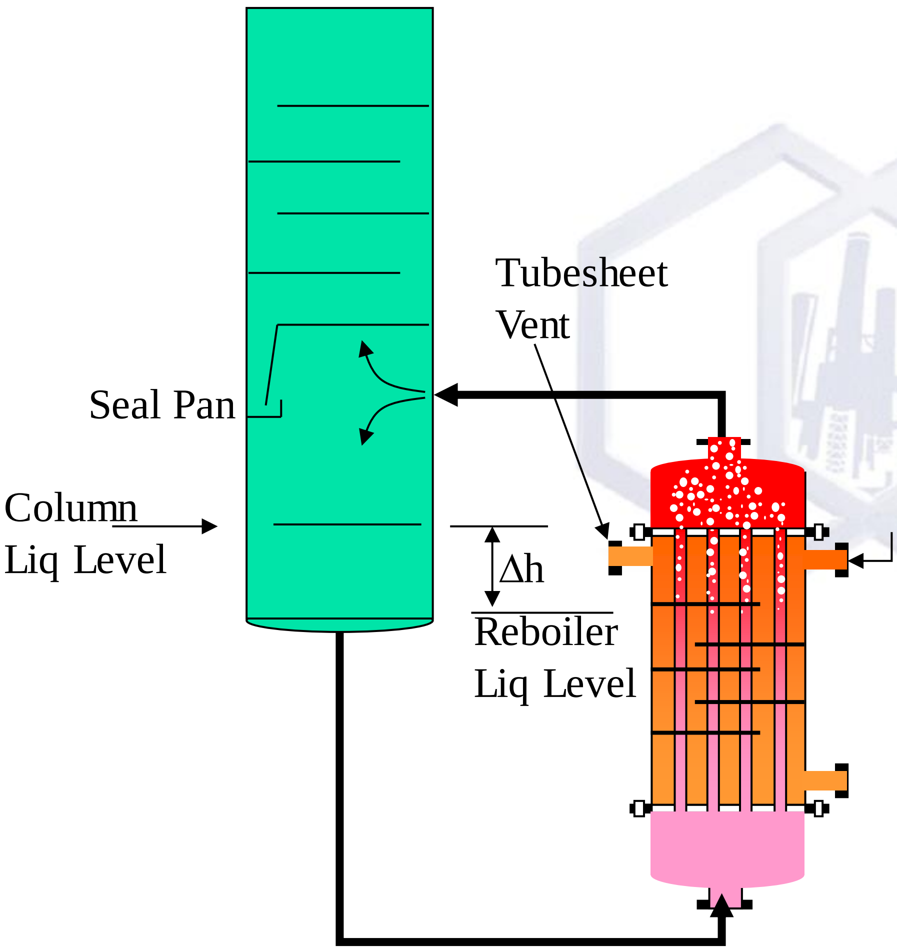
- Features:
  - Small U- tube exchanger inserted directly into column bottom
- Pros:
  - Cheap, no shell
  - compact, no plant space requirements
  - No pressure drop
- Cons:
  - Limited surface area allowed
  - Can't take exchanger off line for cleaning without taking entire column out of service

Natural Circulation - Thermosyphon Reboiler



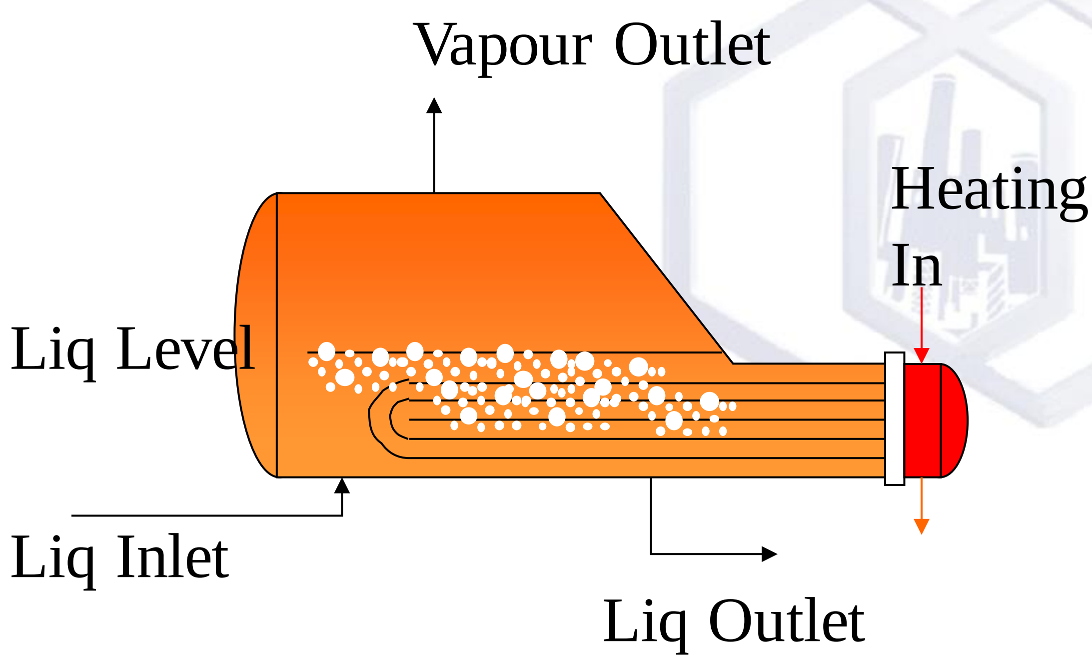
- Usually Vertical
- All Liq Inlet
- Boiling usually on tube side
- Flashing occurs
- Effective Liquid level is created

Natural Circulation - Thermosyphon Reboiler



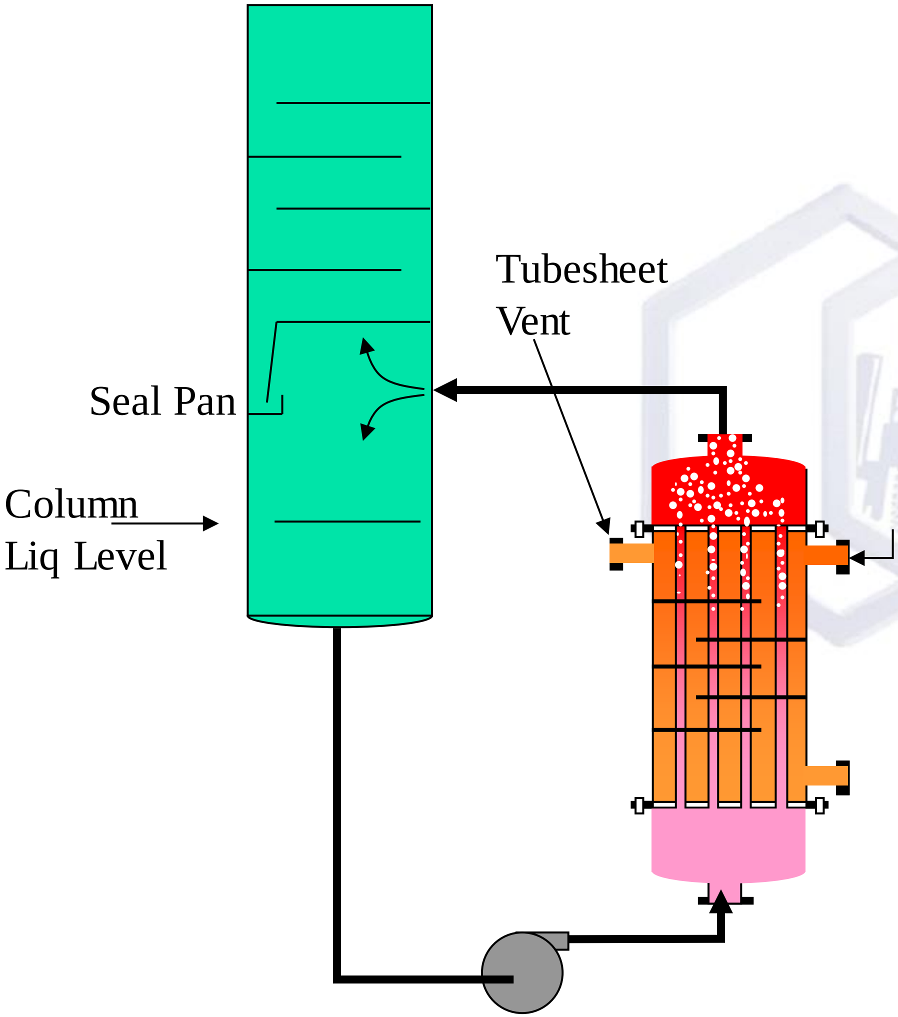
- Δh creates flow, offsets frictional flow losses (self limiting)
- Heating Medium ≈ 30 °C hotter than Process Temp
- Pros:
  - High Circulation Rate
  - High Heat x-fer Rate
- Cons
  - Difficult to design (programs)

Natural Circulation - Kettle Reboiler



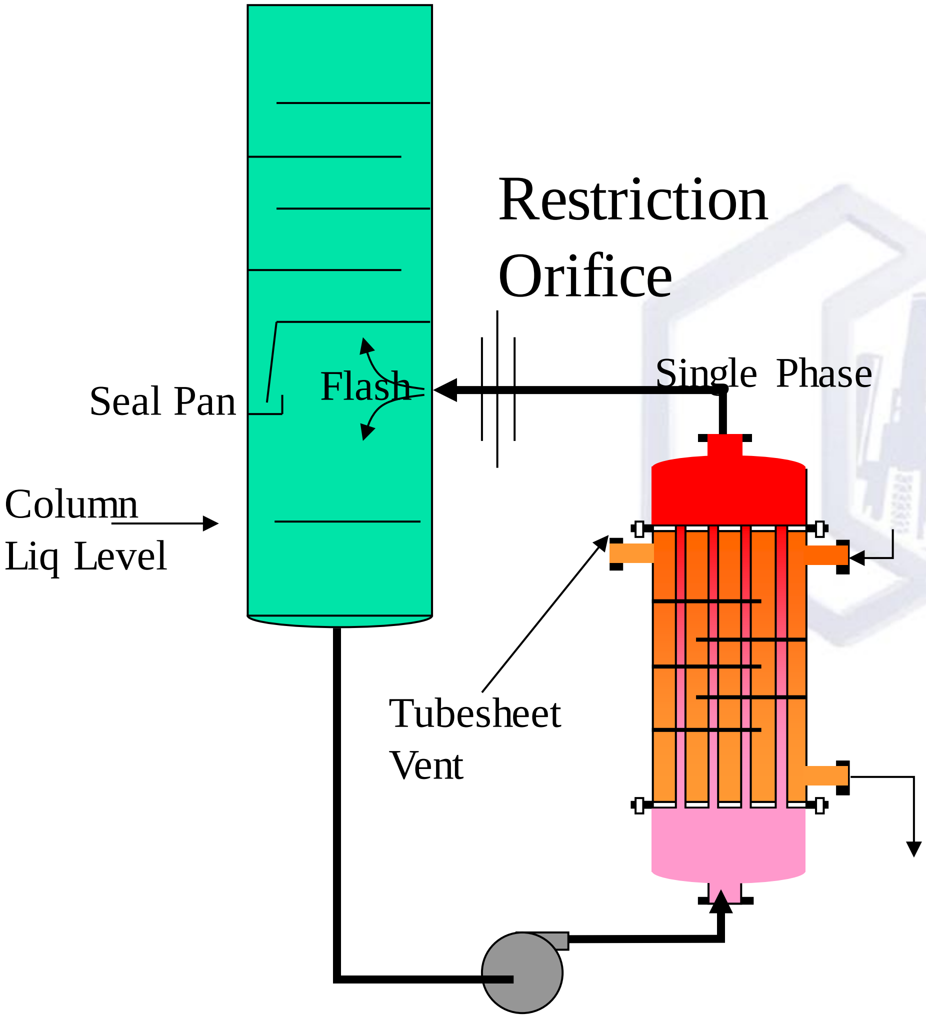
- Liquid boils as a pool
- Liquid draw off bottom
- Heating (condensing steam?) on tube side, must freely drain
- superheating of vapour is possible if liquid level is below top of tube bundle
- Pros:
  - Large Surface Areas are possible
- Cons:
  - Heat x-fer coeficients not as high

Forced Circulation - 2 Phase



- Features:
  - Pump offsets frictional losses
  - 2 phase outlet
  - Heating Medium ≈ 30 °C hotter than Process Temp
- Pros:
  - Can heat viscous fluids
  - Can provide high velocity
    - **maximizing U value**
    - **minimize fouling**
  - Flow independent of heating
- Cons:
  - Energy requirements of pump

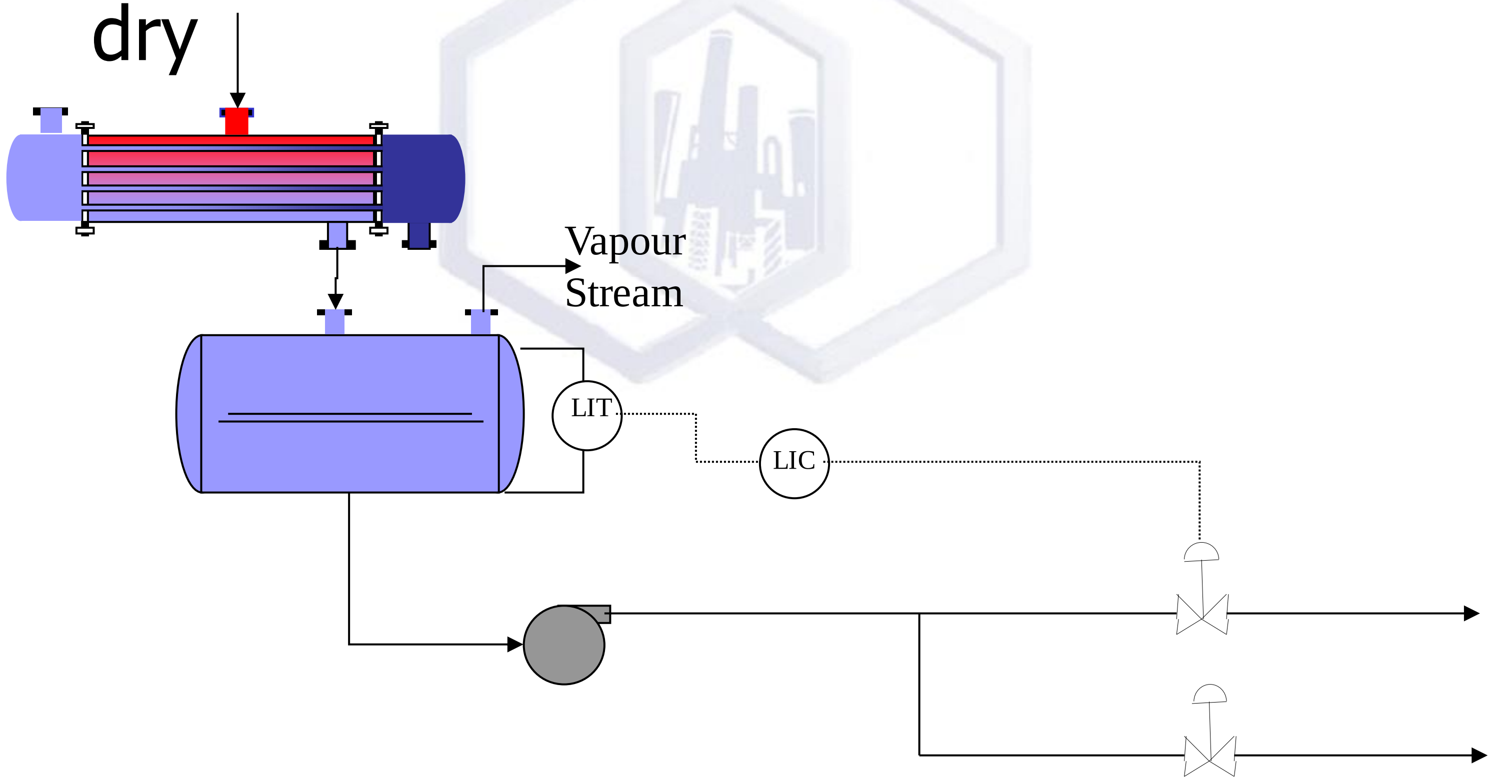
Forced Circulation - Single Phase



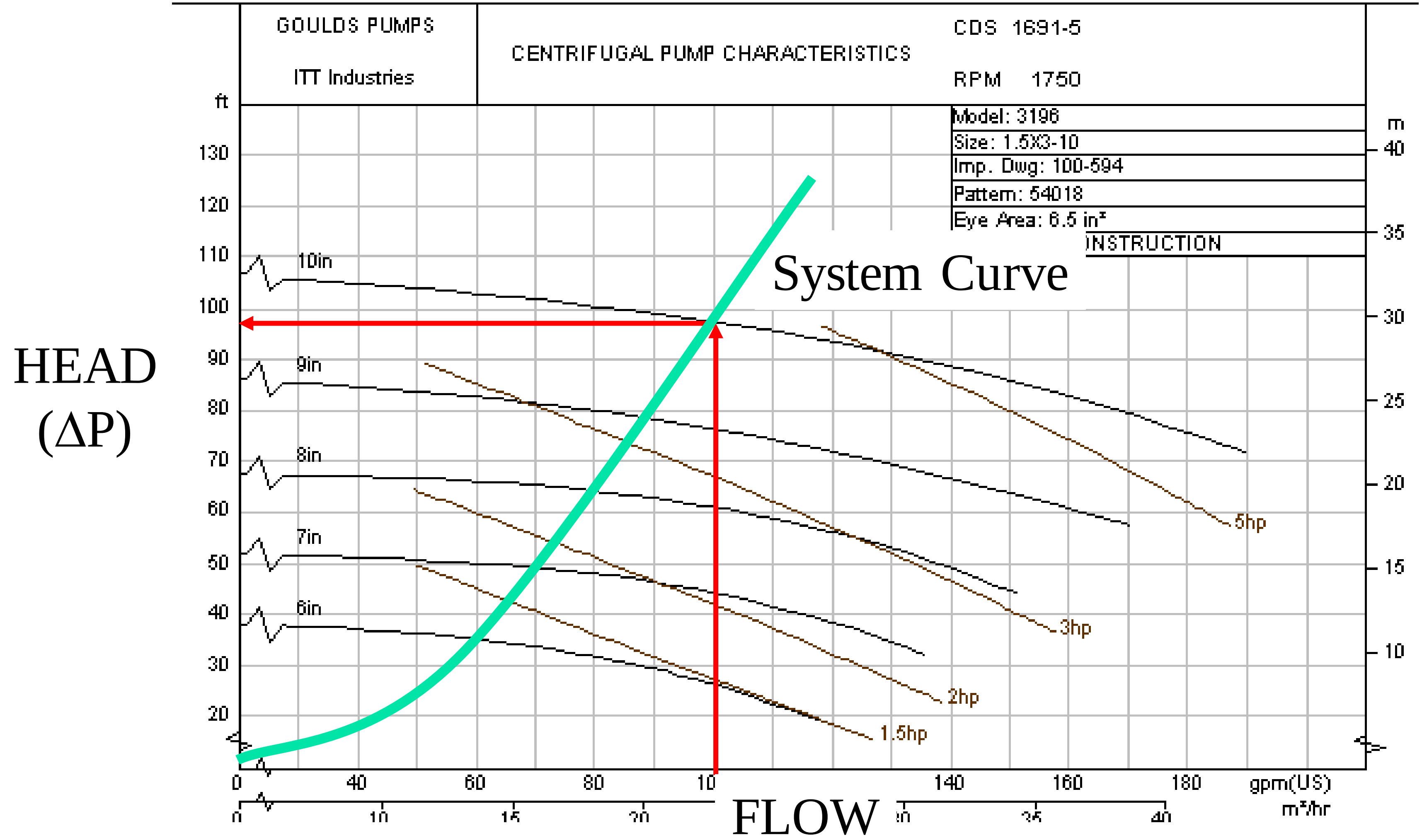
- Features:
  - Pump offsets frictional losses
  - Flashing occurs at Column
  - Heating Medium ≈ 30 °C hotter than Process Temp
- Pros:
  - Can heat viscous fluids
  - Can provide high velocity
    - maximizing U value
    - minimize fouling
  - Flow independent of heating
- Cons:
  - Energy requirements of pump (higher than 2 ϕ)
  - Fluid must be heated substantially more

Pumps

- Where pumps are required, tanks and controls are required to ensure they don’t run dry

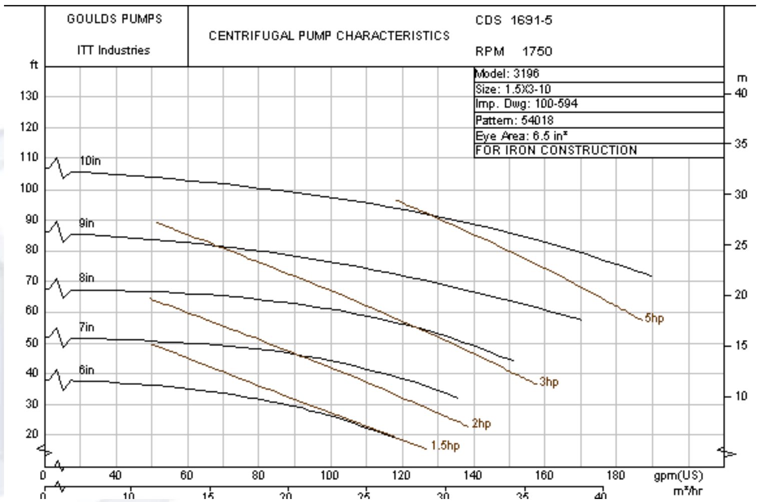


Centrifugal Pump - Flow vs Differential Pressure



Choosing one or two pumps

- High head, low flow
- Low head, high flow

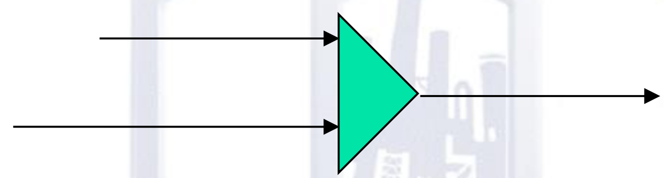


5 gal/min
3000 kPa

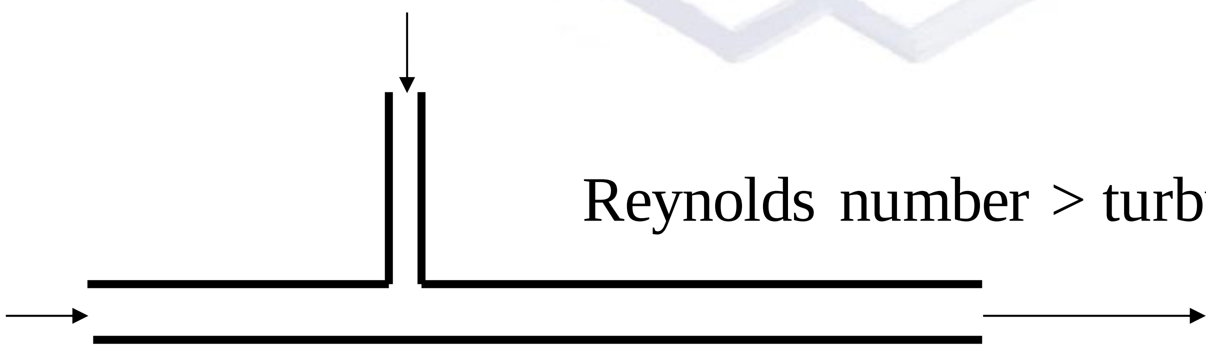
100 gal/min
200 kPa

Mixers

- Simulation Mixers usually have no corresponding equipment



- Piping



Reynolds number > turbulent = mixed

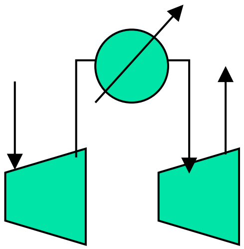
For high viscosity fluids (static mixers can be used)

Reactors

- Must satisfy the volume / time requirement of the simulation
- Usually a vessel / tank for volume
- Where temperature control is required may resemble a heat exchanger
- Consideration to loading catalyst must be given

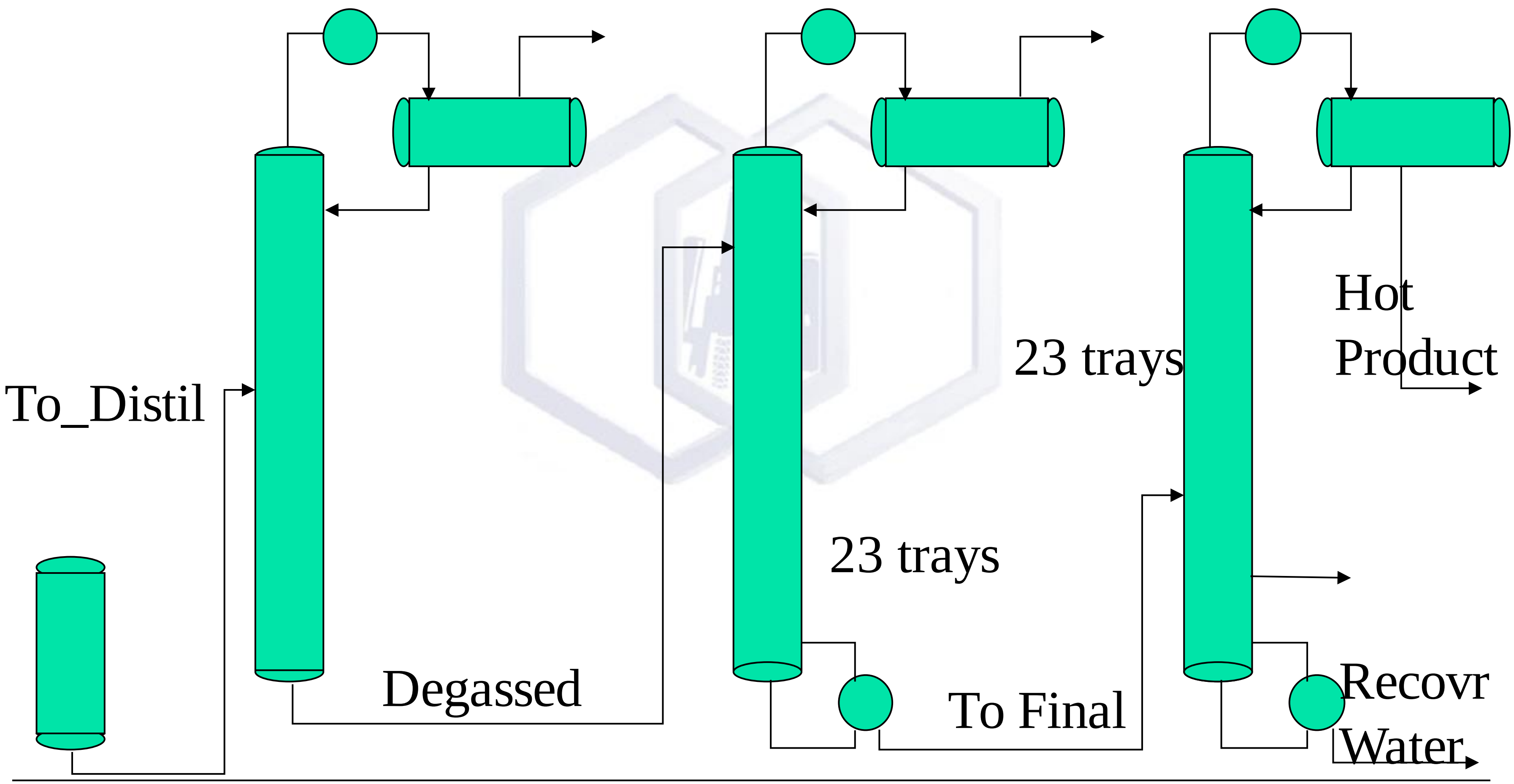
Compressors

- Simulations do not indicate any of the physical limitations real compressors exhibit.
  - Real compressors
    - need cooling
    - have discharge temperature limitations (350 °F) - may require multiple 'stages'
    - often require lubrication systems
    - have expensive controls to prevent physical damage from occurring (surge)
  - A typical compressor takes 2 to 3 P&ID sheets to represent



Our PFD

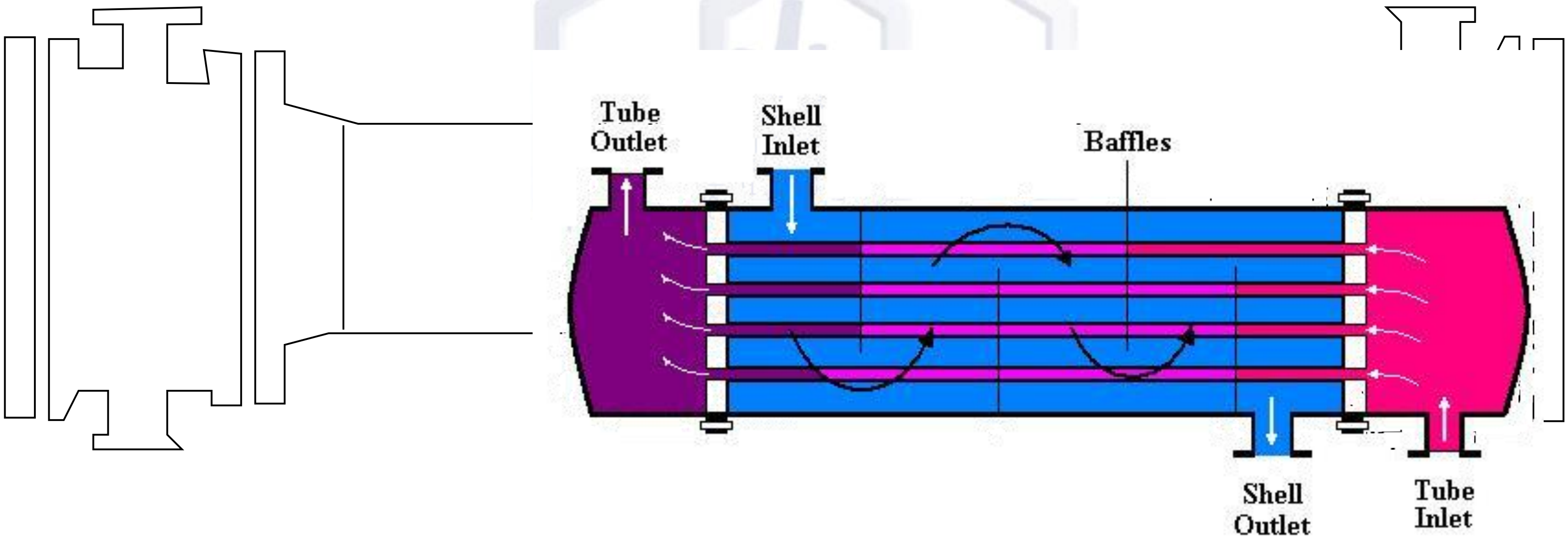
- Choose Exchangers
- Redraw with correct elev's



END

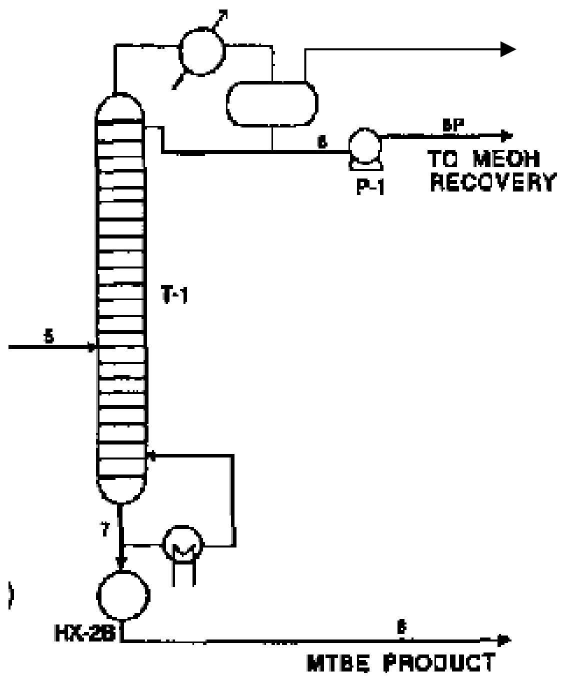
Shell And Tube

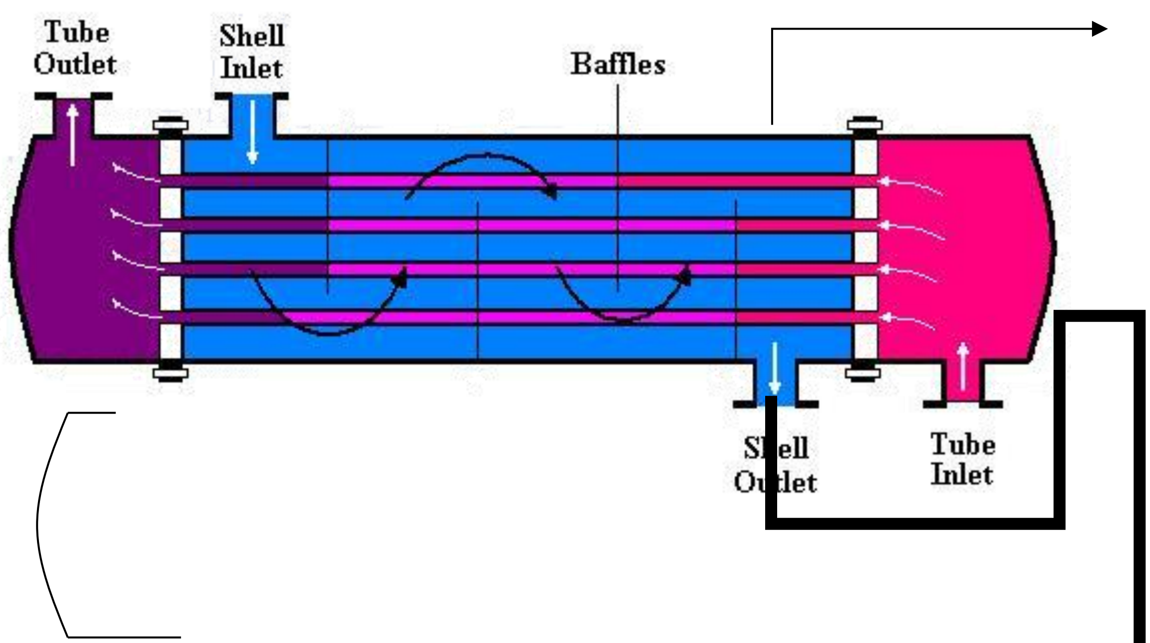
- Vertically Mounted



Shell And Tube

- Horizontally Mounted





Shell And Tube

- Vertically Mounted