Liquid - Liquid Coalescer

Moize Turkey
Manager - Applications Engineering
AMACS Process Tower Internals

Safety Moment

CHOOSING AND USING LADDERS

When you're in a hurry to reach a high place, it's tempting to climb on a chair, table, or anything handy to get there.

But is it worth the risk?

A major cause of ladder injuries is improper set-up. The good news is that most ladder accidents are preventable. All it takes is the right ladder in a good working condition along with solid placement of that ladder before climbing on it.

Outline

- Liquid-Liquid Separation
- Coalescer and Operating Principle
- Design Considerations
- Typical Configuration: *Vertical and Horizontal*
- Pictures
- Future Path …… Possible Options
- Conclusions

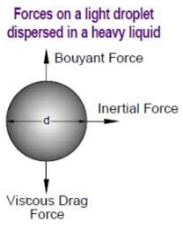
Liquid-Liquid Separation

- Gravity Settling
- De-Emulsifiers & Deoilers
- Coalescers
- Centrifugal
- Electrostatic

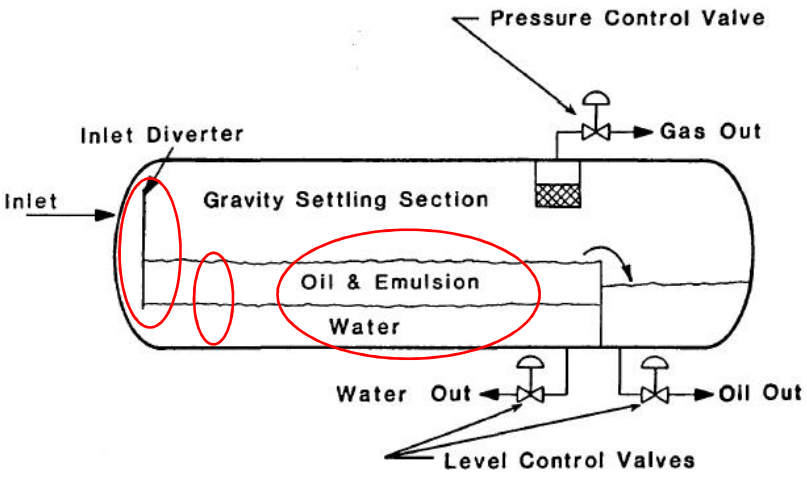
Stokes Settling - Gravity

- Developed in 1800's and is still valid today
- Differences in densities causes droplets to rise or fall
- Viscosity of continuous phase acts in opposite direction

$$V = \frac{g\,\Delta\rho\,d_p^{\,2}}{18\mu_c}$$



Gravity Separator



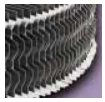
Coalescers

- Mechanical equipment to accelerate liquid liquid separation.
- Coalescers are used to increase the rate of Gravity Separation of a mixture of two liquid that are immiscible or non-soluble in one another.
- A media to merge dispersed droplets entrained in process stream.

Types of Coalesing Media

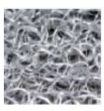
- Parallel Plate Pack

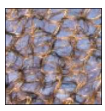
- Corrugated: Metal



- Mesh: Metal or Plastic

- Co-Knit:
  - Wire/Fibreglass
  - Wire/Polymer





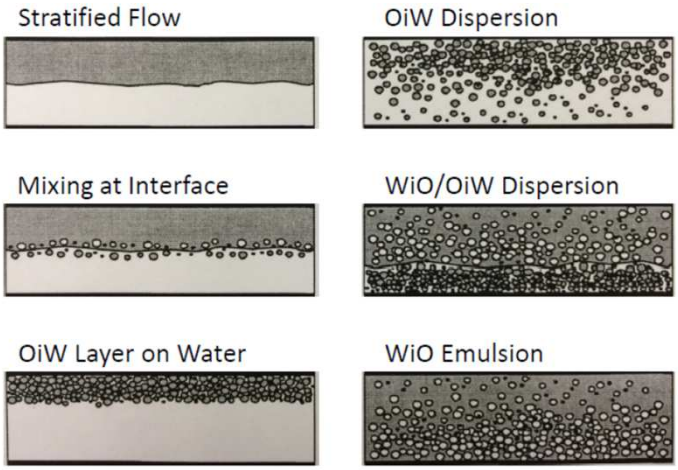
Advantages of Coalescer

- Improves product purity
- Reduction of vessel size on a new build project
- Increases capacity of existing unit on a revamp project
- Increases separation efficiency of existing unit
- Reduces downstream corrosion
- Provides wide operational range

Emulsion

- An Emulsion is a mixture of two immiscible or non-soluble liquids
- Dispersed phase forms droplets in continuous phase
  - Droplet size is generally greater than 1 micron
- The two phases are held apart by their interfacial surface tensions
- Examples:
  - Water in Oil -- *Water is the dispersed phase*
  - Oil in Water -- *Oil is the dispersed phase*
  - *Water-in-Oil-in-Water*

Emulsion



Emulsion Stability

Source	Stability	Droplet Size Range
Flash Drum Emulsions with >5 % Dispersed Phase, Static Mixers	Weak	100-1000 microns
Flash Drum Emulsions with <5 % Dispersed Phase, Impellor Mixers, Extraction Columns	Moderate	50-400 microns
Centrifugal Pump Discharges, Caustic Wash Drums, Low Interfacial Tension Emulsions	Strong	10-200 microns
Haze from Condensing in Bulk Liquid Phases, Surfactants Giving Emulsions With Very Low Interfacial Tensions	Very Strong	0.1-25 microns

Separation Time	Emulsion Stability	Droplet Size, Microns
< 1 minute	Very Weak	>500
< 10 minutes	Weak	100-500
Hours	Moderate	40-100
Days	Strong	1-40
Weeks	Very Strong	<1 (Colloidal)

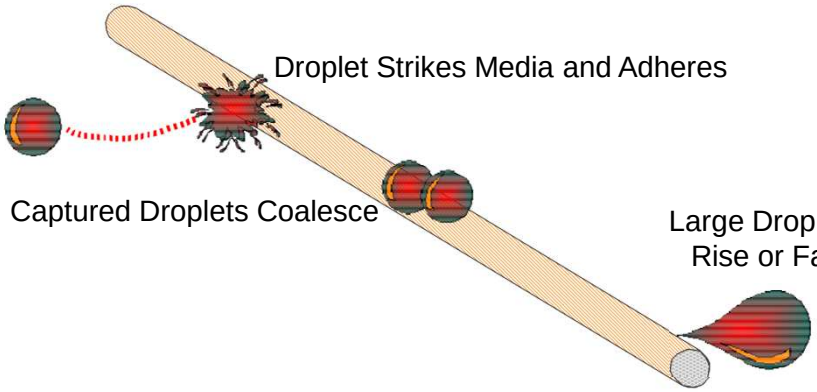
Emulsion Stability

- pH Value
- Salt Content
- Temperature
- Density Difference
- Viscosity of Continuous Phase
- Surface Tension & Interfacial Tension

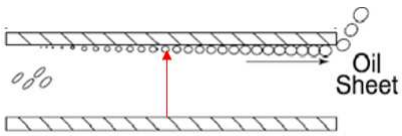
Operating Principle of Coalescer

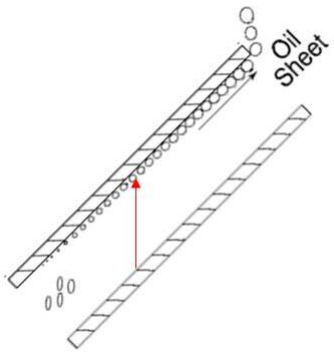
- Droplet Capture
  - Intra-Media Stokes Settling
  - Direct Interception
- Droplet Coalescence
  - Combine, aggregate, or coalesce captured droplets.
  - Droplets collected on fiber, wire or plate, will combine and subsequently minimize interfacial energy
- Stokes Settling with Coalesced Droplets
  - Settling length available.
  - Location of outlet nozzles/weir/interface level

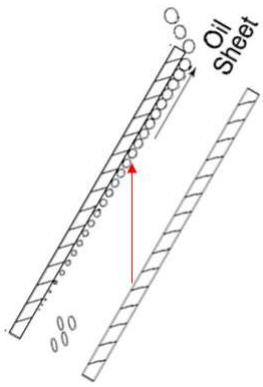
Operating Principles of Coalescer



Intra-Media Stokes Settling







Distance = d_p x cos θ
Where,
d_p = Plate Spacing
θ = Angle of Inclination

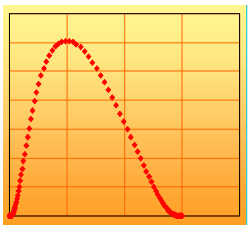
Direct Interception

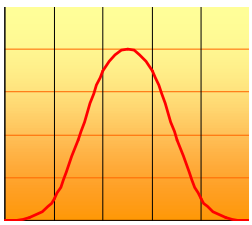
$$\eta_D = \frac{E(1-\alpha)}{K}\,\frac{\left(d/D\right)^2}{1+\left(d/D\right)} \qquad O.E. = 1-\exp\left(\frac{(-4\eta_D \alpha L)}{\pi D(1-\alpha)}\right)$$

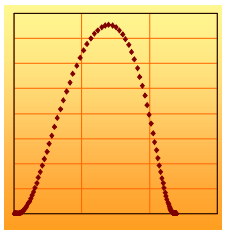
η_D = Collection Efficiency of a Single Target by Direct Interception
E = Available Length Multiplier
α = Volume Fraction of Fibers or Wires
D = Target Diameter
K = Kuwabara's Hydrodynamic Factor
L = Element Length

Design Consideration - DSD

- Inlet droplet size distribution is characterized by maximum droplet size and shape of distribution curve.
- Distribution curve is seldom Gaussian *(bell shaped with peak at ½ max diameter)*
- Usually skewed to right or left


Skewed Left

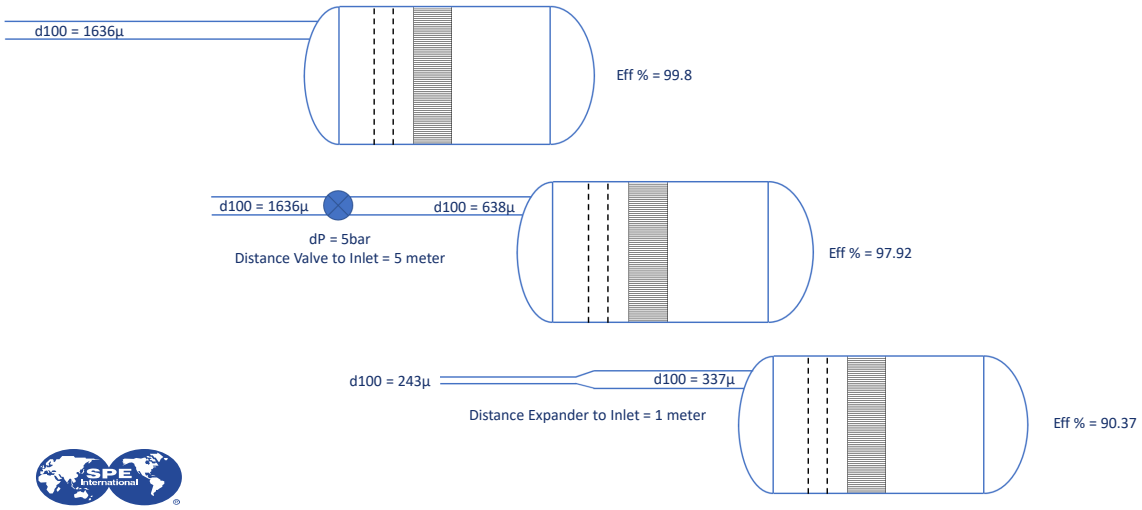

Gaussian


Skewed Right

Design Consideration - Droplet Size

Media	Source	Max Droplet Diameter, µ	Flow Range gpm/ft^2
Plate Pack Corrugated Sheets	Separations with Coarse Emulsions & Static Mixers	40-1000	15-75 (35-180 m^3/hr/m^2)
Wire Mesh	Overhead Drums, Extraction Columns, Distillation Tower Feeds, Impeller Mixers	20-300	7.5-45 (20-110 m^3/hr/m^2)
Co-Knits of Wire & Polymer	Steam Stripper Bottoms, Caustic Wash Drums, High Pressure Drop Mixing Valves	10-200	7.5-45 (20-110 m^3/hr/m^2)
Glass Mat, Co-Knits of Wire & Fiberglass	Haze from Cooling in Bulk Liquid Phase, Surfactants Giving Emulsions with Very Low Interfacial Tension	1.0-25	7.5-45 (20-110 m^3/hr/m^2)

Design Consideration - Upstream



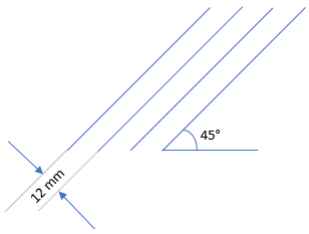
Design Consideration - Fouling

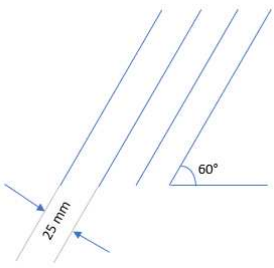
- Fouling can significantly diminish the performance of the unit.

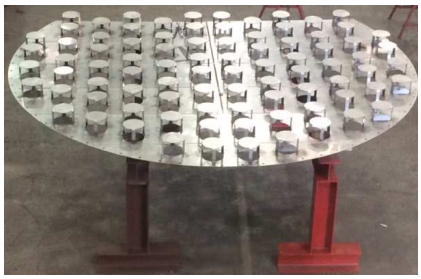



Design Consideration - Fouling

- Plate design with steep angle and larger plate spacing.
- Distribution baffle with caps and large hole sizes.

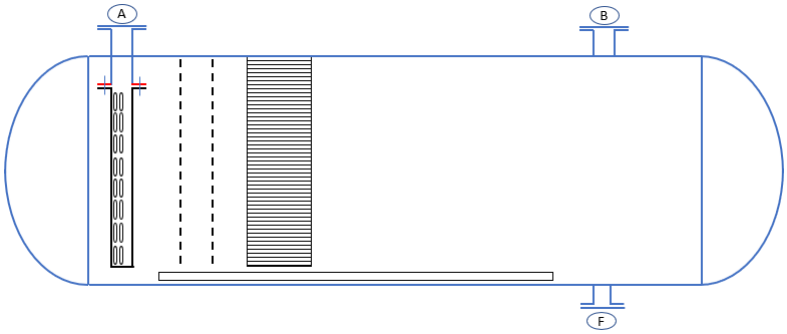






Design Consideration - Fouling

- Cut back at the bottom of distribution baffle & plate pack coalescer
- Installation of Sand-Jet Systems



Design Consideration - Inversion Point

- Phase Inversion refers to a phenomenon where with a small change in the operating conditions, the continuous and dispersed phase spontaneously inverts.
- Parameters influencing Phase Inversion
  - Physical parameters (density, viscosity)
  - Chemical properties: presence of surfactants
  - Change in flow conditions: dispersed phase fraction is increasing.

Design Consideration - Velocity

- Effective separation occurs when flow is laminar.
  - Turbulence increases the drag forces and can cause re-entrainment
- Vertical liquid-liquid separator velocity with coaleascer should be limited to 2 ft/min (0.6 m/min) or less.
  - Coalesced droplets flow countercurrent to continuous flow
- Horizontal liquid-liquid separator velocity with “mesh” coaleascer should be limited to 3.5 ft/min (1.06 m/min) or less.
  - Further velocity reduction is recommended for co-knits

Design Consideration – Residence Time

Typical Retention Times for Liquid-Liquid Separation

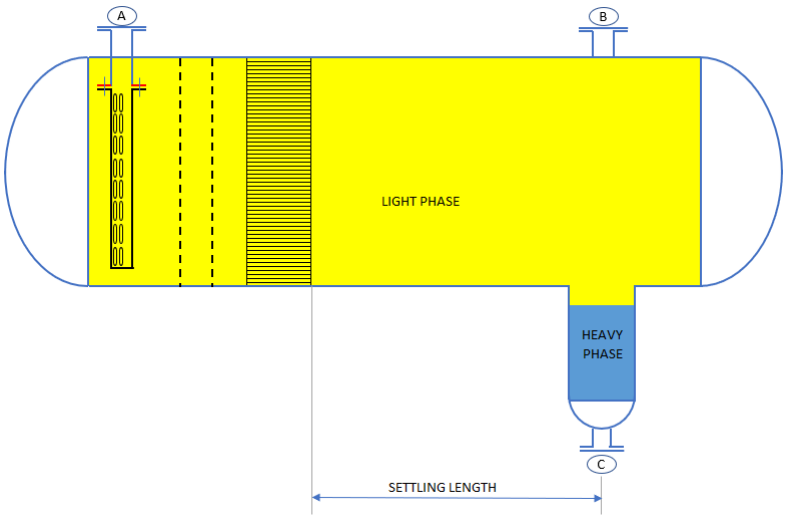
Type of Separation	Retention Time, minutes
Hydrocarbon/Water Separators[7]	
Above 35° API hydrocarbon	3 – 5
Below 35° API hydrocarbon	
100°F and above	5 – 10
80°F	10 – 20
60°F	20 – 30
Ethylene Glycol/Hydrocarbon[8] Separators (Cold Separators)	20 – 60
Amine/Hydrocarbon Separators[9]	20 – 30
Coalescer, Hydrocarbon/Water Separators[9]	
100°F and above	5 – 10
80°F	10 – 20
60°F	20 – 30
Caustic/Propane	30 – 45
Caustic/Heavy Gasoline	30 – 90

Source: GPSA

Design Consideration - Boot

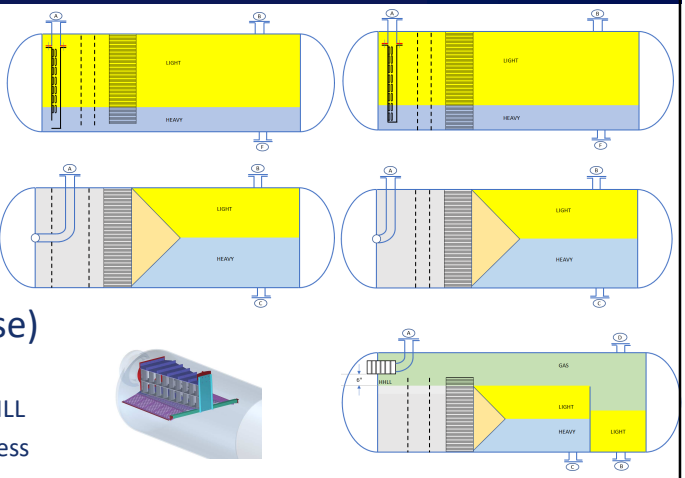
- Boot is recommended if the heavy dispersed phase volume fraction is less then 10%.
  - Maintaining a decent interface level in a vessel is a challenge.
- Interface level to be maintained in the boot.
- Recommended velocity in boot should less than 1.5 ft/min.
- Every effort should be made to make sure there is sufficient settling length available after the coalescer.
  - Often mechanical constraints like saddle location overpowers process.

Design Consideration - Boot



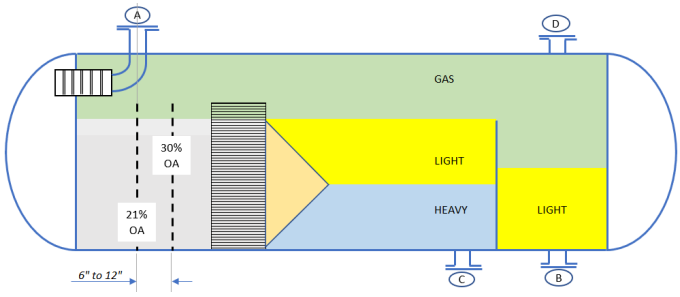
Internals - Inlet Section

- Slotted Feed Pipe (2-Phase)
  - Min slot size should be ½" x 2"
  - Slots to face towards head of the vessel
- T-Type Feed Pipe (2-Phase)
  - Min hole size should be ½"
  - Holes to face towards head of the vessel
- Vane Type Inlet Device (3-Phase)
  - Located in head or Shell
  - 6" space between bottom of inlet and HHLL
  - Anti-Re-Entrainment baffle if distance is less



Internals - Distribution Section

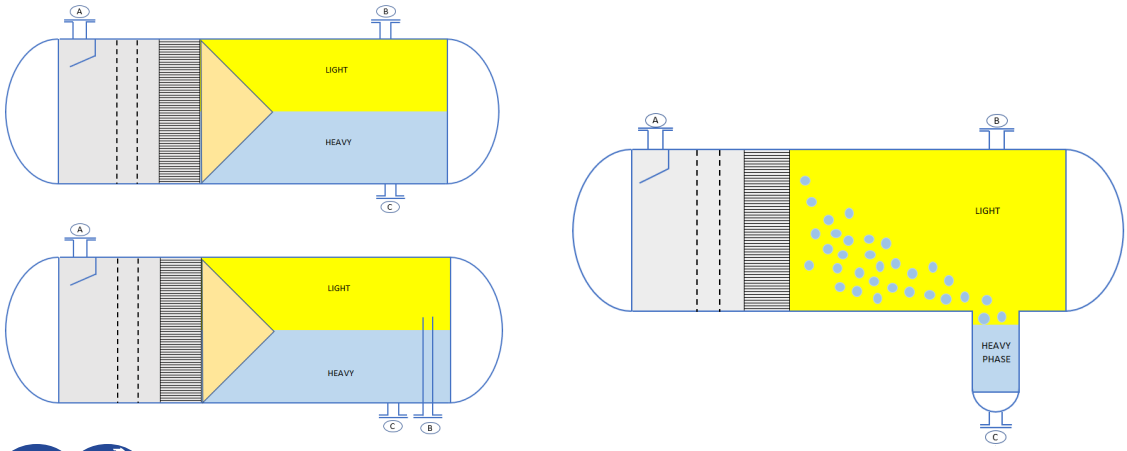
- Minimum two (2) recommended
  - Open area ranges from 21% to 50%
  - Extend 4" (100 mm) above HHLL.
  - Spacing ranges between 6" (150 mm) to 12" (300 mm)
  - Min hole size to be ½" (12 mm)
  - Fouling ……. Sand / Paraffin……etc



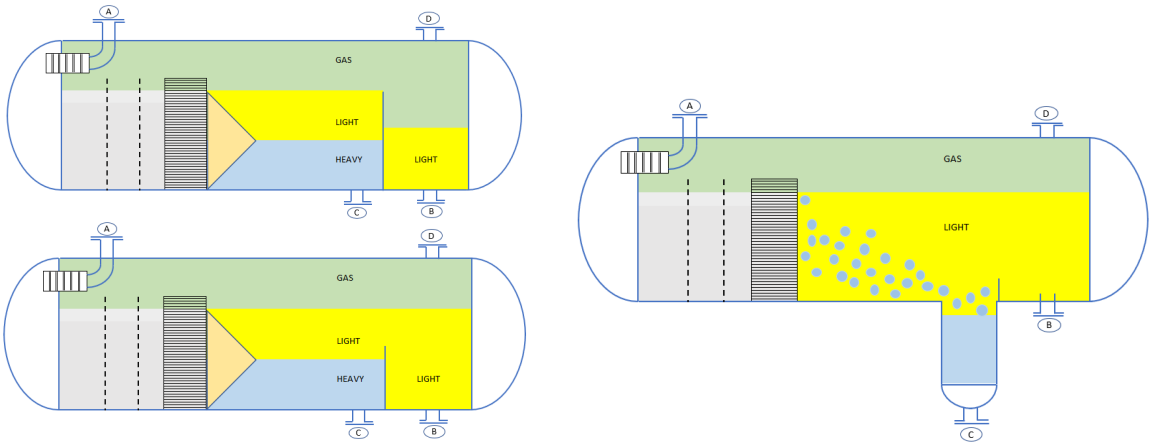
Internals - Coalescer Section

- Mesh Coalescer
  - Should not be used for fouling service
  - Mesh thickness varies from 12” (300mm) to 36” (900mm).
  - Material compatibility: Acid service / High temperature
- Plate Pack Coalescer
  - Trade off between plate spacing and angle of inclination Vs efficiency requirements.
  - Typical plate length is 1000mm
- Structured packing type Coalescer should possess smooth surface.
- High efficiency coalescing may require a two (2) stage approach.

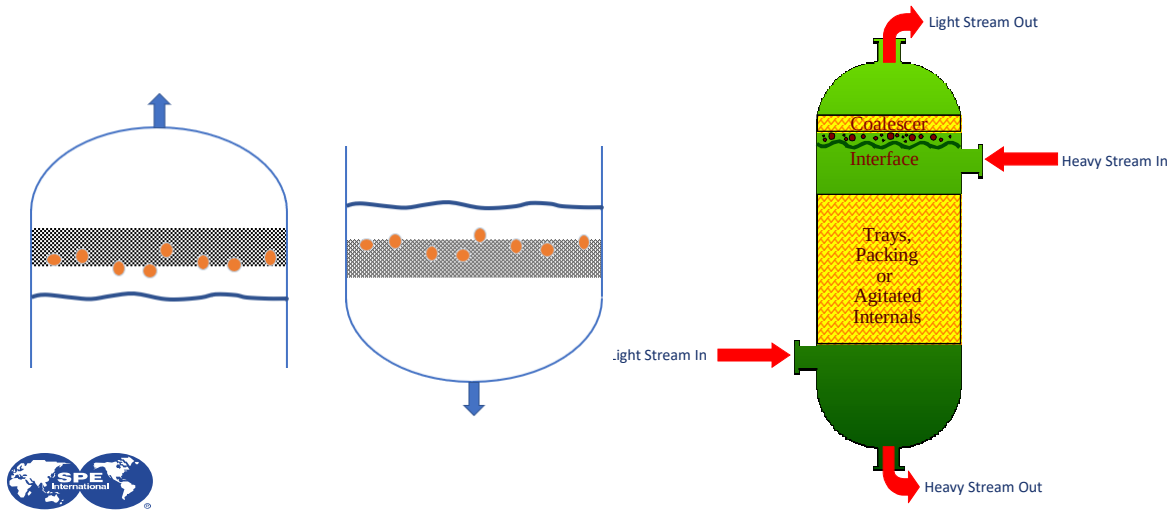
Liquid-Liquid Separator - Configuration



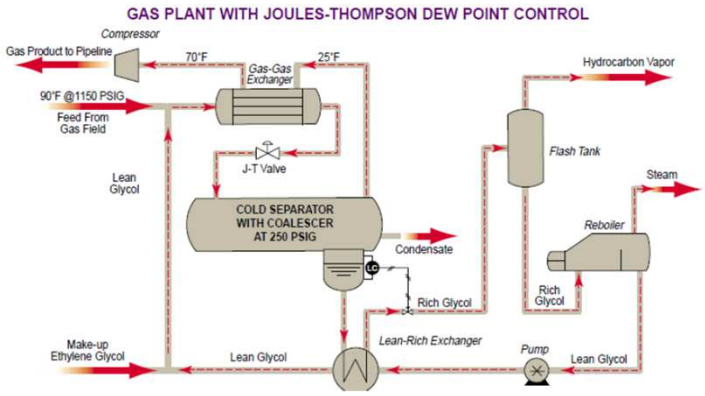
Liquid-Liquid Separator - Configuration



Liquid-Liquid Separator - Configuration



Case Study - Mesh Coalescer



NGL-EG Separation
Cut Off Diameter = 30 micron

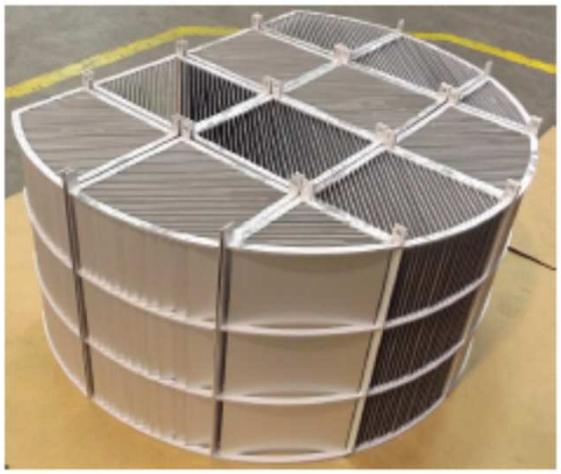
Gravity Separation

- Typical Residence Time = 30 min
- Gravity Separation: 5’-00” x 20’-00”
- 36” Height for L/L Section

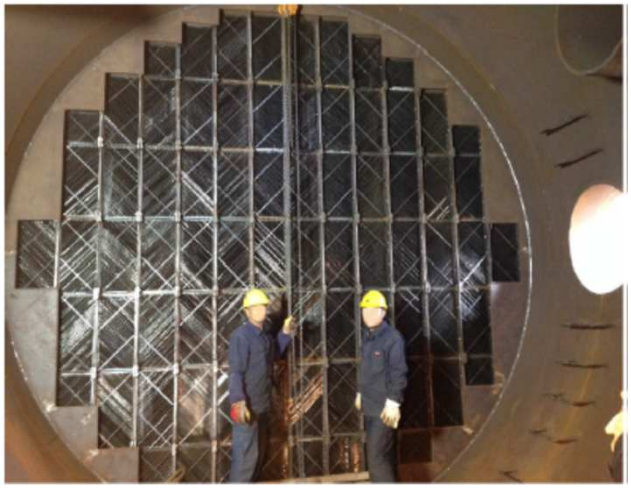
Interceptor Pak™ Coalescer (Mesh)

- 24” Thickness
- SS/Fiberglass Co-Knit
- Vessel Dimension: 36” x 12’-00”
- 24” Height for L/L Section

Picture – Plate Pack Coalescer



Picture – Plate Pack Coalescer



Picture – Mesh Coalescer

Picture – Mesh Coalescer

Future Path ……. Possible Options?

- Need an open dialogue between vendor and end client to achieve best results all around.
  - Possibility of sharing actual operating data
- A more definite approach and one that is often needed is testing on-site with pilot unit.
- "Joint Industry Program"
  - STAR is a great separation focus platform. With more members, there will be more ideas and more funding for testing.

Conclusions

- Although Coalescer operation still considered as “black box”, following basic design principle can/will mitigate some of the undesirable problems.
- Systemic/thoughtful design approach is needed to properly design and L/L or G/L/L separator
- More testing and knowledge sharing will help the industry.
- Liquid-Liquid separator design is

“Science with Art”

Thank You