Coalescing Technology

General considerations in the separation of immiscible liquids

Using coalescers to separate two immiscible liquids will provide...

- *Capital cost savings due to smaller separators*
- *Increases in capacity for existing separators*
- *Savings due to recovery of solvents*
- *Improved product quality*
- *Reduced tank inventory*
- *Compliance with Environmental Regulations*

Why does coalescing occur?

In an emulsion of two immiscible liquids, coalescence is the process by which very fine droplets physically join together to form larger droplets which then settles naturally by gravity. The most common method for this phenomenon to occur is to simply allow the mixture to flow at low rates (m/sec) in large vessels and/or sit over time in storage tanks (days sometime weeks) to separate. Gravity and buoyance forces will sooner or later form two distinct layers. In most cases this is not the most economical method. In the case of very stable emulsions consisting of droplets less than 10 microns in size a natural coalescing and separation by gravity might never occur.

The theory of coalescence

The separation of a dispersion of immiscible liquids has been considered more of an art than a science. Theoretical investigations are based on calculations of droplet size of pure components. Most predictions are based on a mean droplet size, but since the extent of separation is a function of small droplets, a droplet size distribution is a more accurate method. This approach is quite costly, so most designs are not based on theoretical assumptions, but rather from experimental investigation of the pertinent mixture. Practical experience by EIT process engineers is essential in order to reach an effective and economical solution to most industrial coalescer problems.

There will be two major steps involved in this kind of separation. The first is truly coalescence, the physical process of very fine droplets joining on another and forming larger droplets (Figure 1). The second step is the natural separation of the two phases by gravity and bouyancy (Figure 2). Each of the two steps occur simultaneously and can be enhanced by proper design of the vessel and appropriate internals with special emphasis in coalescer media.

Mechanisms of coalescense – Stokes Settling

We have stated that the simplest mechanism for all liquid/liquid separators is the gravity settler which works solely on the principal of Stokes Law. It predicts the rise and fall of one liquid dispersed in another.

The equation George Stokes developed in 1851 for the terminal settling velocity is still used today:

$$vt = 1.78 \times 10^{-6} (\Delta S.G.) (d)^2 / \mu$$

vt = Terminal Settling Velocity, ft/s
d = Droplet Diameter, microns
ΔS.G. = Specific Gravity Difference between the Continuous and Dispersed Phases
μ = Continuous Phase Viscosity, centipoise

The key parameters are:

- **Density difference between liquids; difficult to separate if low**
- **Viscosity of fluids; difficult to separate if high**
- **Interfacial tension; coalescense difficult if low (can be affected by additives such as corrosion inhibitors)**
- **Gas and/or solids content in the feed**
- **Pressure and/or temperature**
- **Aggressiveness of liquids; material selection varies**

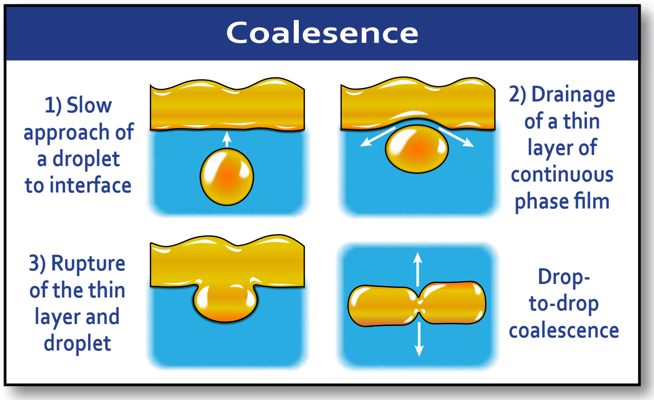

Figure 1 *Coalescence of droplets (1-3) and drop-to-drop.*

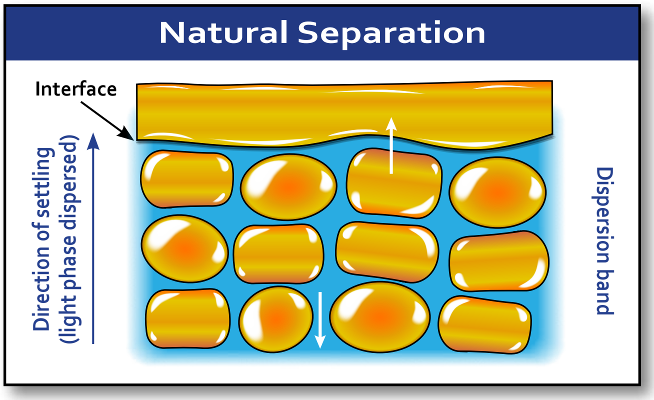

Figure 2 *Dispersion band of coalescing droplets.*

These designs assume that droplets are truly spherical and flow is laminar not turbulent. When the Reynolds number (the ratio of inertial forces to viscous forces) is high, droplets shapes are deformed and eddy currents are produced which re-disperse them before reaching proper size and weight. How can this mechanism be improved?

An enhancement such as reducing the distance droplet needs to reach interface is one such way. EIT provides coalescing elements with channels. These channels introduce surface area where droplets meet more readily other droplets. Coalescing elements such as the Enhanced Cross-Flow™ and Enhanced Corrugated Plate Interceptor™ will significantly increase the coalescing process over empty vessels which results in much shorter length, smaller in diameter, lower in weight and with a much smaller footprint. New high power software programs model these advantages.

Mechanisms of coalescense – Direct Interception

When gravity forces with enhancements alone do not produce the desired separation, Direct Interception can be deployed with the use of fibrous media. Fine droplets are drawn to or contact a filament. The finer the filament the finer the droplet captured. Liquid now begins to cover surface as other fine drops contact filament do the same. The thin film of dispersed liquid covers the surface where a much larger droplet begins to grow in size. In Figure 3, surface energy holds a droplet to a filament. The total force of adherence is a function of the contact angle. As the velocity of flow through the media increases. a point will be reached at which the droplets are swept off the filament. This process continues through the element to the drainage zone settling to bottom of vessel or rising to interface. EIT offers a variety of fibrous media including various polymeric materials, glass mats, stainless steel meshes and glass fiber to create that effect. Fine targets of wire, monofilaments, and multifilament are geometrically placed in flow path to capture, coalesce, and drain fine dispersed droplets from continuous phase.

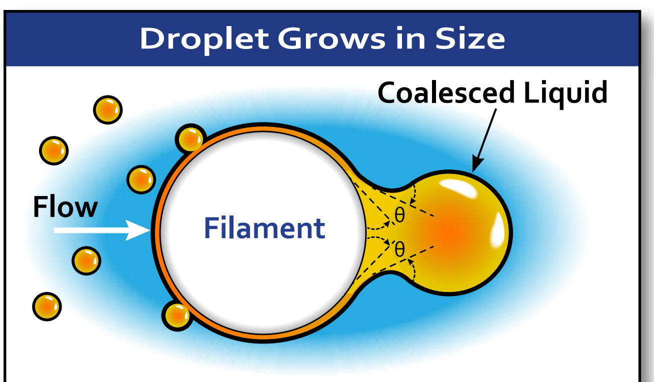

Figure 3 *Assisting coalescence by use of fibrous material.*

Coalescer Type	Source of Dispersions	Mechanism	Min/Max Droplet Diameter	Flow Range m³/hr/m²	Solids Handling
Enhanced Cross-Flow™	Separators with Coarse Emulsions and Static Mixers	Stokes Law Settling	50-1000µ	42-216 (18-90 gpm/ft²)	Good
Enhanced Corrugated Plate Interceptor™	Overhead Drums, Extraction Columns, Distillations Tower Feeds, Impeller Mixers	Stokes Law Settling	40-1000µ	35-180 (15-75 gpm/ft²)	Fair
Enhanced DC™	Haze from Cooling in Bulk Liquid Phase, Surfactants Giving Emulsions with Very Low Interfacial Tension	Direct Interception Preferential Wetting and Interstitial Effect	5-300µ	20-110 (7.5-45 gpm/ft²)	Filter may be required

Design Consideration for Coalescer vessels

For new vessels, typically the settling theory or retention time for the liquid phase is the method used by many. With the use of enhanced coalescers and advanced computer software programs, EIT can offer state-of art design (sizing) or evaluate (rating) separators and scrubbers in detail, right down to the selection of all suitable separation internals. This includes the design layout for the inlet section, coalescing section, demisting sections, and liquid levels, determining optimum vessel sizes, properly select internals and assess the overall performance of each vessel.

Furthermore, EIT can also evaluate an existing design and determine its theoretical performance based on actual operating data and propose improvements to boost capacity, increase operating ranges and provide sharper separation efficiencies.

The EIT optimization capabilities provide an excellent opportunity for equipment cost saving. Vessels designed based on actual performance predictions can often be made smaller than vessels designed solely based on common engineering standards. A reduction in vessel size not only reduces the cost for the vessel, but it can also have a significant effect on lowering the overall project cost.

EIT Coalescence Technical Bulletins

Enhanced Corrugated Plate Interceptor

Enhanced Cross-Flow

Enhanced DC

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