Liquid-Liquid Coalescing

KOCH-OTTO YORK®

SEPARATIONS TECHNOLOGY

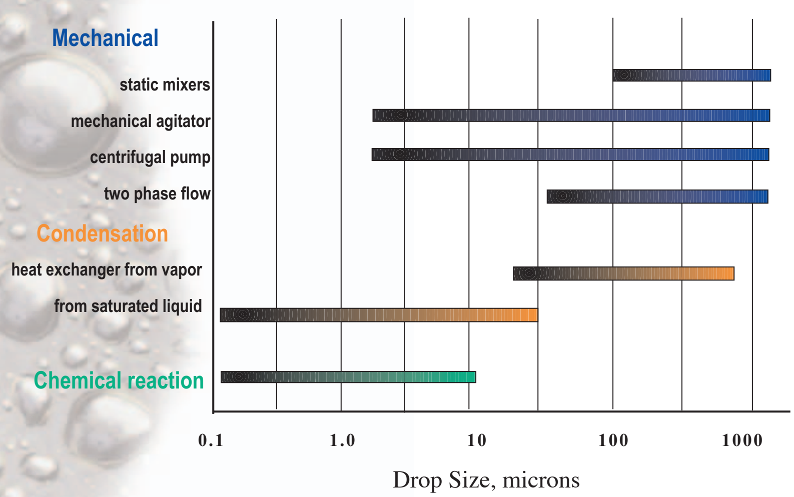
OTTO YORK™

A Koch-Glitsch business group

Liquid-Liquid Dispersions-Why They Occur

Mixtures of two immiscible liquids occur throughout the process industries. Often this is an unavoidable result of the process. In other cases, the mixing of two liquids is necessary to obtain mass transfer between the phases or to promote a chemical reaction. Almost always, a full separation of the liquids will be important for efficient and cost effective performance of the downstream process.

The size of the resulting droplets (dispersed phase), and the ease of their separation from the continuous phase are partially dependent on how the dispersion is created, as shown in the chart below:



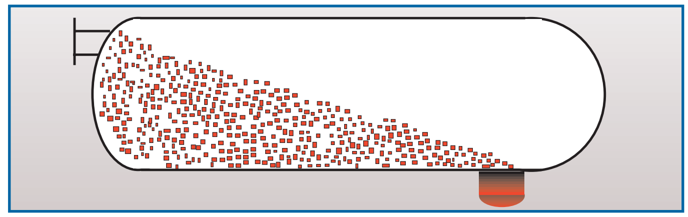
Equally important are the physical properties of the two liquids, including interfacial tension, density difference and viscosity. The presence of solids and trace impurities, as well as pH and temperature changes can completely alter the characteristics and ease of separation. For example, it is quite possible for even a few ppm of impurities to change an easy separation to a difficult emulsion.

Because of this complexity, a theoretical calculation describing the separation of two liquids can only be done based on assumptions of pure liquids, which never occurs in the real world. Therefore, the selection and design of liquid separation equipment is based on a combination of basic principles, experience and trial testing.

Design of Coalescer Vessels

Many separators consist merely of a horizontal vessel, as shown in the diagram below, where the separation occurs by allowing the droplets to settle by gravity.

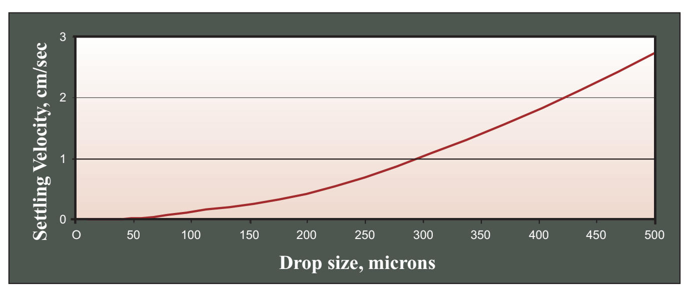
Droplets rise (when they are the lighter phase liquid) or fall (when the heavier phase) based on the following equation, which is derived from Stoke's Law:



$$V = g\,(\rho_H - \rho_L)\,D^2 / 18\mu$$

V = Settling velocity (cm/sec)
g = Gravitational constant (98/cm/sec^2)
μ = Viscosity of continuous phase (poise)
ρ_H = Density of heavy liquid (g/cm^3)
ρ_L = Density of light liquid (g/cm^3)
D = Droplet diameter (cm)

For a water droplet falling in an oil with a density of 800 Kg/m3 (50 lb./cu. ft.), the settling rates are shown in graph 1 below. These traditional separators are not economical because they require long residence times to achieve separation of even 150 - 200 micron droplets. They are rarely justified in new designs unless large surge capacity is required for process reasons, or because of very heavy solids loadings or high viscosity liquids in the process.



Graph 1: Droplet settling velocity

Some Typical Solutions

Benefits from Modern Coalescer Technology

- Reduce size and cost of new liquid-liquid separators
- Improve product purity in existing installations
- Debottleneck existing reflux drums
- Reduce downstream corrosion caused by corrosive liquid carryover
- Reduce losses of glycol, amine and other valuable chemicals
- Improve fractionation tower operation and reduce maintenance
- Reduce fugitive VOC emissions

Refinery & Chemical Applications

Hazy Distillates occur when dissolved water condenses from solution while the product cools in storage tanks. This can result in tying up product in inventory for days or weeks while the water settles to allow meeting haze specifications. Proper coalescers have allowed almost immediate use of the product in blending and final product sale, reducing carrying costs.

Caustic Treaters often allow carryover of sodium into the product, making it difficult to meet final product specification in this regard. Subsequent water washing of the product can be virtually eliminated by installation of proper caustic coalescers.

Fractionator Overhead Reflux Drums often become a bottleneck when distillation towers are retrofitted with higher capacity internals. In most reflux drums, capacity can be at least doubled with the installation of the proper liquid-liquid separation media to prevent carryover of water condensate in the reflux or product.

Acid Alkylation Plants have multiple locations where feeds and alkylates are mixed with aqueous, acid and caustic streams as part of the process. Each location has unique operating properties demanding careful choice of media and a strong knowledge of the process implications.

MTBE and ***TAME*** plants have been retrofitted with the KOCH-OTTO YORK® vertical flow COALEX™ liquid-liquid separator in both the main and methanol wash columns.

LPG Treaters routinely add KOCH-OTTO YORK® coalescers to debottleneck towers for additional capacity.

Natural Gas Purification

Glycol and amine systems both suffer from foaming problems caused by liquid hydrocarbon carryover in the natural gas or light ends. Excessive chemical losses generally occur with traditional skimmers, and immediate payback is obtained by retrofitting with high efficiency coalescer media.

Waste Water Treatment

Reducing loads on existing water treatment facilities, by treating specific sources within the plant, reduces total investment.

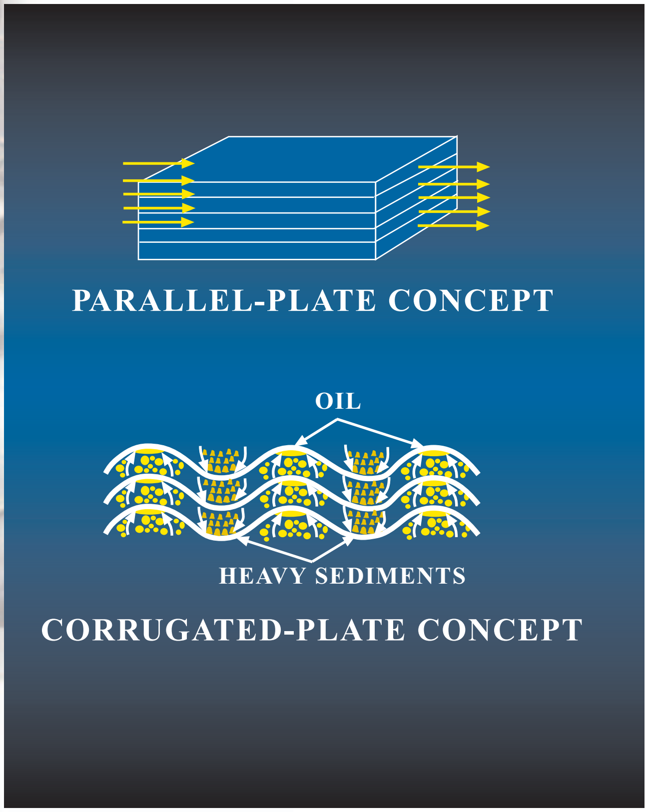
For ground water runoff, underground clarifiers and coalescer vaults are often used to remove unwanted oils or sediment. Improvement in performance, service life and capacity has been shown for many installations using KOCH-OTTO YORK® products. Performance below 10 ppm residual oil in the water discharge is routinely obtained.

Improving the Process

Droplet settling is strongly affected by both the droplet size and the distance the droplet must settle before it reaches the interface between the two liquid phases. Both of these factors can be influenced through the intelligent selection of internals to accelerate the separation.

Parallel Plate Separators

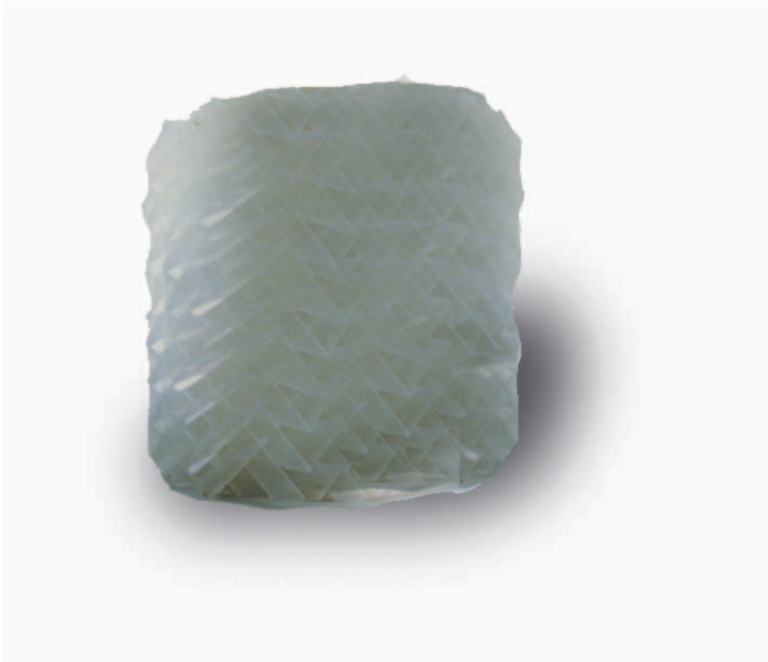
While droplets larger than 200 - 300 microns diameter will settle quickly, as shown in graph 1 on page 1, smaller droplet dispersions require excessive settling times, when they must travel long distances to the interface. By the use of multiple horizontal, parallel plates, the designer can create many interfaces within the same vessel, as can be seen below, allowing significant reductions in



separator vessel sizes.
For dispersions down to 50 - 100 microns it is possible to achieve efficient separation with this technique, and it is the preferred equipment design where the potential for solids or tarry liquids exists.

KY-FLEX™ Media

These corrugated plate separators are an improvement over the parallel plate separators except where severe solids loadings require the extra large spaces that the parallel plates allow. Properly structured, the corrugations provide superior collection and drainage channels for liquids and solids. A variety of corrugation geometries and spacings are available to optimize the fouling resistance and efficiency to the needs of each process.



YORKMESH™ Media

The second approach focuses on increasing the size of droplets, by coalescing them into the easily separated drops larger than 200 microns, so they will quickly separate by gravitational force. Generally, this technique is aimed at the smaller droplets, from 100 microns down to a few microns diameter, which settle very slowly or not at all. Often referred to as secondary dispersions, haze or emulsions, these applications present the biggest challenge, and are solved with high performance coalescing media, often custom engineered for the properties of the specific chemicals involved.

They consist of mixtures of metal and non-metallic wires and fibers. The internal geometry promotes droplet size growth and maximizes liquid throughput velocities for minimum vessel sizes.

Fiber Media

These specially engineered elements are applied to the most difficult separation applications, where even long settling times do not allow complete emulsion separation. Although more expensive by themselves, their cylindrical geometry allows efficient use of the internal vessel space, making them a popular choice to minimize separator vessel size, or to maximize throughput in existing vessels.

These elements commonly use glass fiber, polypropylene, carbon or ceramic fiber depending on the chemical corrosion and wettability.

Choosing the Best Media

With over 40 years experience providing coalescers, KOCH-OTTO YORK® has developed a large library of knowledge based on successful applications, which is the best starting point for selecting the right solution the first time.

	Parallel Plate	KY-FLEX™	YORKMESH™	Fiber Media
Cost, w/o vessel*	3.0 – 5.0	1.5 – 2.5	1.0	1.5 – 3.0
Cost, incl. Vessel*	2.0 – 3.0	0.8 – 1.0	1.0	0.8 – 1.5
Capacity*	0.75 – 1.0	1.25 – 1.5	1.0	0.8 – 1.25
Efficient performance range	≥ 75 microns	≥ 25 microns	2 – 25 microns	≤ 2 microns
Pressure Drop, WC	≤ 25 mm (1")	25 – 100 mm (1" – 4")	50 – 1000 mm (2" – 40")	50 – 1000 mm (2" – 40")
Solids Handling	Designed for fouling service	Good fouling resistance	Limited solids capability	Non-fouling service only

** Values are relative to YORKMESH™ media*

Converting Experience into Solutions

The best solution to every liquid-liquid separation application requires evaluating a variety of design factors before the most cost effective solution is selected. While the design can not be reduced to a series of equations, as already discussed, a systematic approach will lead to the right selection.

Collect Data on the Process

As already noted, the method of droplet creation will often give a good indication about the difficulty of separation. Physical properties of each phase and other data need to be collected:

- density differences and viscosity determine how fast the droplets will disengage,
- flowrates will determine the ultimate size of the required separation equipment,
- desired separation performance must be defined,
- interfacial tension, which is a measure of the ease of droplet coalescing and how it is affected by pH and temperature, is very helpful when available,
- presence of impurities and solids will often create a more difficult separation, since they can collect at the interface between the liquids, making coalescing difficult and also limiting equipment choices,
- relative solubility at operating temperature will help the designer understand whether the desired separation is being prevented by solubility limits.

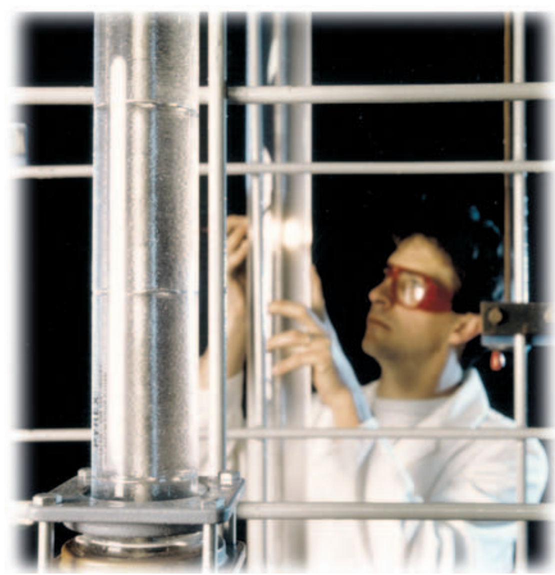
Qualifying Separation Difficulty

With this information, an experienced KOCH-OTTO YORK® engineer can begin to define the solution and foresee warning signals that should be considered. A simple bench-top test is often recommended at this point if the process operates near atmospheric conditions. By collecting an actual sample of the process stream and watching it settle, the time required for the liquids to separate will provide enough information to reach preliminary design conclusions. When separation occurs within minutes, it is generally possible to provide a straightforward solution. If the main separation occurs quickly, but a haze remains in one or both liquids long after the primary separation, a more difficult problem exists. If the phases are still partially or completely mixed after several days of settling an emulsion is present which can only be solved with high performance designs.

Field or Laboratory Testing

For assurance of coalescer performance, testing of the actual process stream under actual operating conditions gives the highest level of confidence that performance objectives will be met. In the most difficult applications involving stable emulsions, it is the only true way of assuring a satisfying solution.

The KOCH-OTTO YORK® pilot plant facility in Houston, Texas regularly conducts tests on customer feed samples which closely replicates the actual plant process conditions. Tests run in a 100 mm (4 inch) diameter unit, with run times of several days, produce data that can be reliably scaled up to commercial solutions. Samples of 400 - 500 litres (100 - 150 gallons) of actual plant material are required.

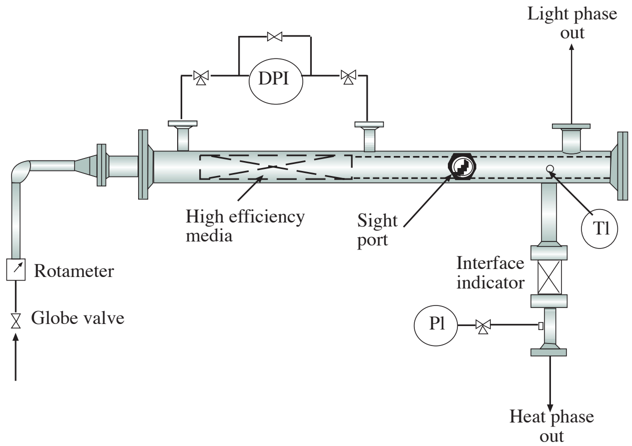


Since small uncertainties can still exist, because of possible changes in the emulsion during shipping and storage, the most reliable design data will always be obtained by onsite slipstream testing at actual process conditions.

Onsite Pilot Testing

For this purpose, KOCH-OTTO YORK® has specially designed rental testing units, available throughout the world, which can be shipped to the customer's plant. These units are capable of safely operating at high pressures and temperatures when necessary to evaluate the performance of various media.

Measurements of pressure drop, flow rates, and separation efficiency may be taken by the customer or experienced KOCH-OTTO YORK® engineers. The collected data give the best possible understanding for the tested stream, including the effects of contaminants, the potential for fouling or corrosion, and any other unforeseen complications. Performance guarantees to duplicate test unit performance are routinely given.



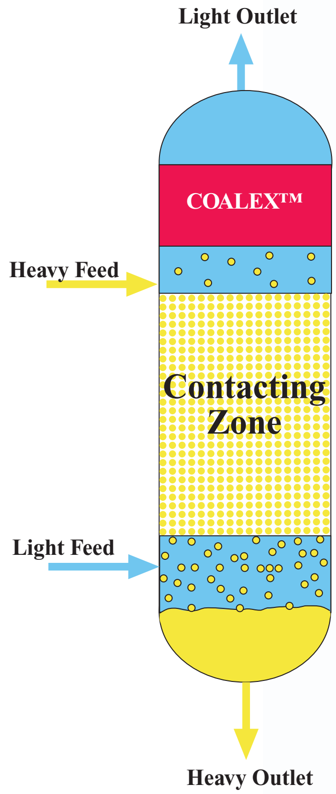
The testing units are fully operational, self-contained packages, consisting of pressure vessels (certified to such local codes as ASME, Stoomwezen, Codap and Ad-Merkblatt) with sight glasses to observe performance, instrumentation and piping.

Media Construction Materials

For these high performance coalescers, selection of the element's construction materials can be an important consideration. It is generally preferred that the dispersed phase preferentially wet the media. Sometimes this is absolutely critical to performance, while in other cases it makes no noticeable difference. Coalescer performance is generally based on the expectation that the droplets wet the coalescer media allowing collection and droplet growth, rather than bouncing off.

Vertical Towers

Coalescers are installed in both horizontal flow and in vertical vessels, and this strongly affects the coalescer media internal geometry requirements.



In vertical vessels, such as counter-current flow solvent extractors or wash columns, it has been common industry practice to install a horizontal flow coalescer in a separate, external vessel. By installation of a COALEX™ liquid-liquid separator within the extraction/wash column, as shown above, a separate vessel, with its instrumentation, plot plan space, foundations and installation costs, is eliminated.

KOCH-OTTO YORK®
Design & Service Leader in Separations Technology.

Members of the Koch-Glitsch Business Group

42 Intervale Road
P.O. Box 3100
Parsippany, NJ 07054-3100
TEL: 973-299-9200
800-524-1543
FAX: 973-299-9401

6611 Killough Road
Houston, TX 77086
TEL: 281-445-7026
800-736-7036
FAX: 281-445-7032

4111 E. 37th St. North
Wichita, KS 67220
TEL: 316-828-7181
FAX: 316-828-8018

Koch-Glitsch Italia S.r.l.
Via Tonale 50
P.O. Box 13
24061 Albano S. Alessandro
(Bergamo) Italy
TEL: 39-035-328611
FAX: 39-035-328601

Koch-Otto York BVBA
Bijkhoevelaan 12
B - 2110 Wijnegem, Belgium
TEL: 32-3-647-2847
FAX: 32-3-647-2879

Otto York Asia Pacific
260 Orchard Road, #11-01/09
The Heeren
Singapore 238855.
TEL: 65-831-6410
FAX: 65-835-2025

Visit us on the internet: www.koch-ottoyork.com

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