

Liquid-Liquid Separation Technology



Introduction

In industrial process equipments liquid-liquid mixtures are produced by essentially two different mechanisms.

- Mixing of the phases in either purpose-built equipment, mechanical mixers, static mixers where pressure energy is applied to increase the surface free energy of the fluids to produce droplets, or in shear flow of the fluid mixture in pipes.
- The cooling of a saturated liquid below the solution point so that the solute phase condenses out of solution resulting in the formation of a second liquid phase. This takes place frequently in storage tanks and in processes downstream of condensers or coolers

When two phases are formed, this mixture is most often in the form of a dispersion (droplets of one phase distributed in the second or continuous phase). The mixture is thermodynamically unstable, meaning that given time, the droplets will separate out to form two bulk liquid phases. This takes place by droplets coalescing both with “near neighbor” droplets (drop-drop

coalescence) and with the bulk phase as this forms and settles from the mixture (drop-interface coalescence). The kinetics, or rate at which these processes take place, determine the selection and design of equipment. The driving force promoting coalescence is gravity and in a given system is proportional to $\Delta\rho \cdot g$, $\Delta\rho$ being the density difference between the two liquid phases. The diameter of the droplets is a critical parameter. In determining the settling velocity in a liquid-liquid dispersion the droplet size combined with $\Delta\rho \cdot g$ will define the “settling” force on a droplet. This separation principle is governed by the Stokes Law which is defined as:

$$v_d = \frac{g \cdot |\Delta\rho| \cdot d^2}{18 \cdot \mu_c}$$

Where:

- v_d Settling velocity of a dispersed droplet
- $\Delta\rho$ Density difference between the two liquid phases
- d Drop size diameter
- μ_c Dynamic viscosity of continuous phase
- g Gravitational acceleration

The Brownian force additionally acts on smaller droplets in a fluid. An everyday example is seen in a beam of sunlight where dust particles in the air are seen to “shimmer”, the random motion being due to the bombardment of the small dust particles by air molecules. The dust particles affected in this way are in the size range of 0.1~2 μm . Larger particles are not affected in this way. In a similar manner smaller liquid droplets in a liquid continuum are so affected and since the settling velocity due to gravity of such droplets is very low, the random motion imparted on the droplets by Brownian motion turns out to be of the order of the settling velocity. The net result is that droplets in this range of sizes will not settle out and therefore are not amenable to gravity settling methods. Such dispersions are called secondary dispersions. Technically they are still thermodynamically unstable but the kinetics of separation by gravity only is so low that for most purposes they appear stable. Secondary dispersions cannot be separated effectively in gravity or primary separation equipment and require different techniques for separation.

Content	Page
Introduction	2
Product Summary	4
Mellaplate	6
Feed Inlets and Calming Baffles	9
DC Coalescer	10
Dusec Coalescer	11
Wash Tank Distributor	14
Testing and New Developments	15

The simplest forms of equipment used to separate dispersions are horizontal or vertical gravity settling tanks. The capacity of such vessels decreases as the rate of coalescence and separation decreases. Therefore, there will be circumstances where the dimensions of such vessels are uneconomical for some applications and methods to improve the separation kinetics need to be applied. This can be achieved by increasing the driving force to accelerate the steps in the mechanism of coalescence.

Sulzer offers a range of equipment designed to accelerate the separation of either primary or secondary immiscible liquid dispersions. Coalescers - and their inherent benefits - are today often considered preferable to conventional gravity separators. Figure 1 gives a simple overview of how primary and secondary dispersions are usually formed and which Sulzer coalescers are suitable to separate these dispersions.

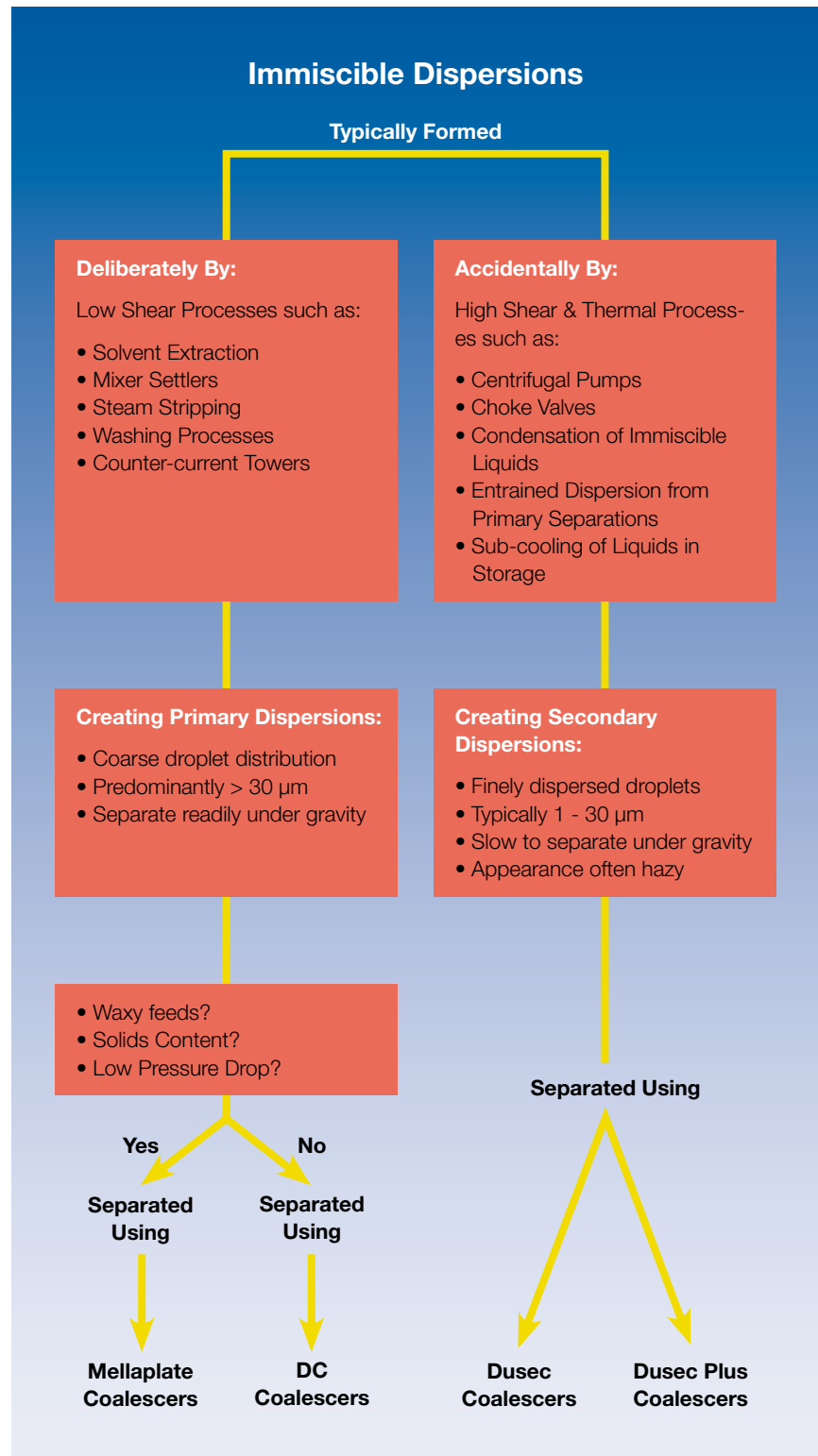
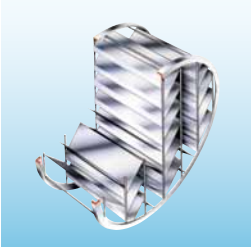
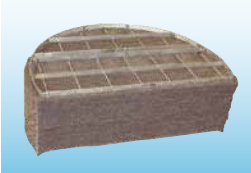





Fig. 1: Overview about Formation of Dispersion and suitable Sulzer Coalescer Types

Product Summary

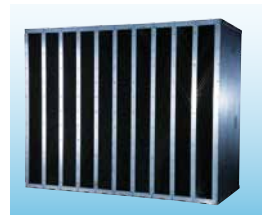
	Type of Separator	Materials	Applications
	Mellaplate™	Stainless steels Alloy 625, 825	Improved separation efficiency. Two phases disengage continuously along the plate or sheets. Improved flow stability. Reduced risk of droplet re-entrainment. Very suitable in systems susceptible to fouling with increased plate angle and plate spacing. Efficiency maintained even with phase inversion of dispersed liquid. Suitable for operation with a gas phase.
	DC Coalescer™	These are produced by two dissimilar filaments knitted together to form the mesh. One filament is a metallic wire made of stainless steel or alloy C22, C276, 400, 625 or 800 and the other is made of PP, FEP, ETFE, PTFE, or glass fibers	Improved separation efficiency. Higher capacities allow de-bottlenecking of conventional separators. Large cost savings in pressure vessels. Efficiency maintained even with phase inversion of dispersed liquid. High free volume means smaller pressure drop.
	Dusec™ Dusec Plus™	In cartridge form with the liquid flowing from the center radially outwards, the Dusec and Dusec Plus Coalescer consist of a selection of fiber materials.	Fiber topology and surface properties combined with optimized layer compositions mean higher efficiency. Separation efficiency down to 10 ppm entrainment of free droplets. Higher loadings and absence of jetting from outer layers mean higher packing densities. Smaller vessel size means capital cost reduction. Pressure drop minimized. Quick performance recovery following feed condition changes.
	Shell Schoepentoeter™ and Schoepentoeter Plus™ Inlet Device	Stainless steels, Alloy 625, 825	The Schoepentoeter is the most commonly used vane inlet device for introducing gas/liquid mixtures into columns. The Schoepentoeter Plus is an advanced feed inlet vane device with considerably increased de-entrainment efficiency. Both devices suppress and minimize the turbulence in the inlet compartment of the separator. Entry of gas into the liquid phase is low.
	GIRZ Cyclone Inlet Device	Stainless steels, Alloy 625, 825	The GIRZ is used as a defoaming cyclonic inlet device to suppress and break many types of process foams. Some typical applications include free water knockout drums, flash drums, test separators, 2 and 3-phase production separators.

Typical Operational Range

Characteristics

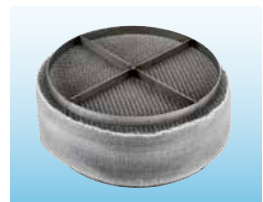
Applicable for primary dispersions. Depending on the type used, Mellaplate coalescers can operate at separation fluxes of up to $100 \text{ m}^3/\text{m}^2 \text{ h}$. Compared to empty settlers improved "cut-off" diameters are achieved due to shorter settling distance between plates.

Mellaplate W is made up of a set of parallel plates that is fitted into a vessel in the separation section such that the plane of the plates is arranged in the axial direction of the vessel. The plates are normally inclined to the axis at an angle of 45° or 60° . The plate spacing is of the order of 15 to 100 mm. Mellaplate M, MG and N are made up of structured corrugated metal or plastic sheets. High packing density means more sheets in a given vessel volume.



Applicable for primary dispersions. Low "cut-off" diameters, therefore extended range of operation. The lower limit is at or near the transition region from primary to secondary dispersion i.e., cut-off droplet size $\sim 30 - 40 \mu\text{m}$. Depending on the DC Coalescer type and application, high separation fluxes of up to $120 \text{ m}^3/\text{m}^2 \text{ h}$ can be achieved.

Manufactured as a knitted wire mesh packing. Can be easily customized to suit most vessel shapes and sizes. DC Coalescers are sensitive to the presence of solids in the feed. Typically, particle sizes below $\sim 50 \mu\text{m}$ do not cause excessive blockage.



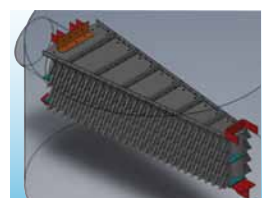
Applicable for secondary dispersions where the droplets are so small they do not readily wet a surface or settle under gravity – typical drop sizes are in the range of 1 to 30 microns. Designed to achieve high performance with minimum pressure drop, the Dusec Plus model provides a high capacity alternative to conventional Dusec cartridges. The smaller diameter and increased packing density make it suitable for maximizing the effective area of the coalescer media in a given size of vessel.

Dusec and Dusec Plus coalescers are supplied as cartridges. Scope of supply usually includes supports and mounting plate suitable for direct installation in a vessel of either horizontal or vertical orientation. Cartridges are available for highly aggressive chemical environments and high temperature applications.



Generally designed at dynamic pressures $< 8000 \text{ Pa}$, but can perform well at higher values. Is typically used for feeds having a gas volume fraction of $> 70 \text{ vol}\%$. Suitable for installation in horizontal or vertical separators. Suitable for liquid slugs.

Constructed from banks of swept vanes. Designs available for operation in most gas/liquid flow regimes. The Schoepentoeter Plus is equipped with sophisticated catching rims to minimize entrainment.



The GIRZ cyclonic inlet device utilizes the momentum of the feed stream inlet in order to generate high g-forces. Defoaming is achieved as gas bubbles are separated from the liquid phase by the centripetal forces in the cyclone tubes. Gas is released from the top of the device and the bottom opening of the cyclones is submerged below the liquid in the separator in order to avoid a gas 'blowout'.

The GIRZ consists of an arrangement of two or more cyclones symmetrically arranged off a common, centrally located header. The device can be installed in vertical or horizontal vessels. If required, mixing elements at the cyclone gas outlet will improve the distribution to the downstream device.



Mellaplate

Sulzer offers Mellaplate™ coalescers, which enhance the separation process by allowing the reducing the droplet settling distance, thus aiding the coalescence of the droplets.


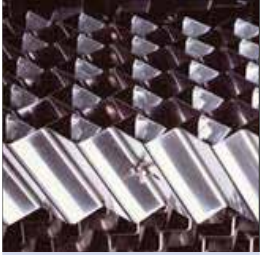


Sulzer Mellaplate coalescers are available in four different types:	Mellaplate W	Mellaplate MG	Mellaplate M	Mellaplate N
				
Construction Form	Flat parallel plates	Structured corrugated flat plates	Structured corrugated metal sheets	Structured corrugated plastic sheets
Relative Capacity ¹⁾	1	1.5	1.5	1.5
Typical droplet cut-off size	≥ 50 μm	≥ 100 μm	≥ 50 μm	≥ 50 μm
Pressure drop	Negligible	0.5 – 4 mbar	1 – 10 mbar	1.5 – 15 mbar
Solids Handling	High fouling resistance	Good to high fouling resistance	Moderate to good fouling resistance	Moderate to good fouling resistance
Remarks			Also used as wave and foam breaker elements	More suited for de-oiling due to the plastic surface

Table A

1) Values are relative to Mellaplate W type

Sulzer Mellaplate™ Type W

This type of coalescer consists of a combination of inclined parallel plates, with fixed spacing, so that droplet settling distance is reduced significantly and this enhances the coalescence process. The inclined arrangement of plates allows the liquid phases to disengage diagonally towards the liquid interface. The flow is normally kept in the laminar region for better separation performance. The inclination and the spacing between the plates is deter-

mined by the application, the nature of contaminants present in the mixture and the degree of separation needed. Typically, the angle is either 45 or 60° with plate spacing from 15 to 100 mm. Due to the high fouling resistance, the Mellaplate W (Fig. 2) is, for example, used in crude oil production separators. It is also ideal for retrofitting an existing gravity settler to operate at a higher throughput and improve the separation performance.

From the construction aspect, the Mellaplate W can be made in modular frame arrangement or boxes (Fig. 3). Alternatively, it can also be constructed in one piece (Fig. 4) for vessels with access through the body flange. Experienced engineers at Sulzer can assist you in designing this separator to ensure trouble-free installation and operation.



Fig. 2a: Sulzer Mellaplate W

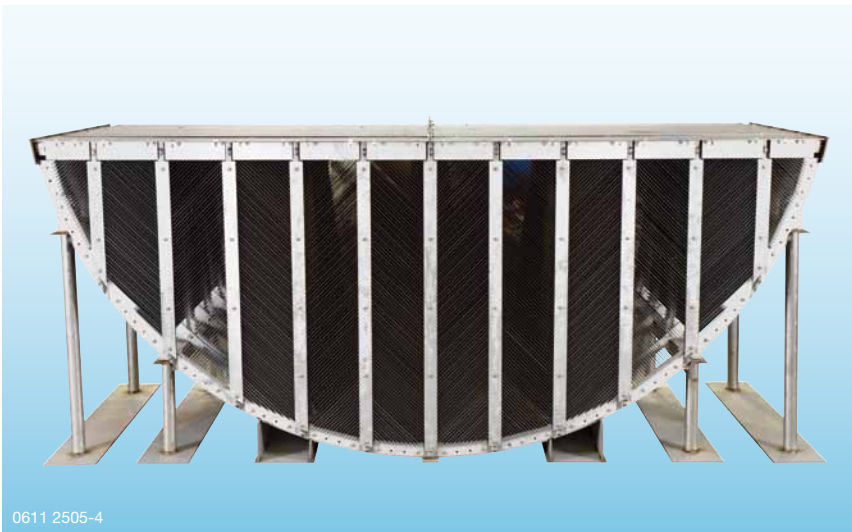


Fig. 2b: Sulzer Mellaplate W

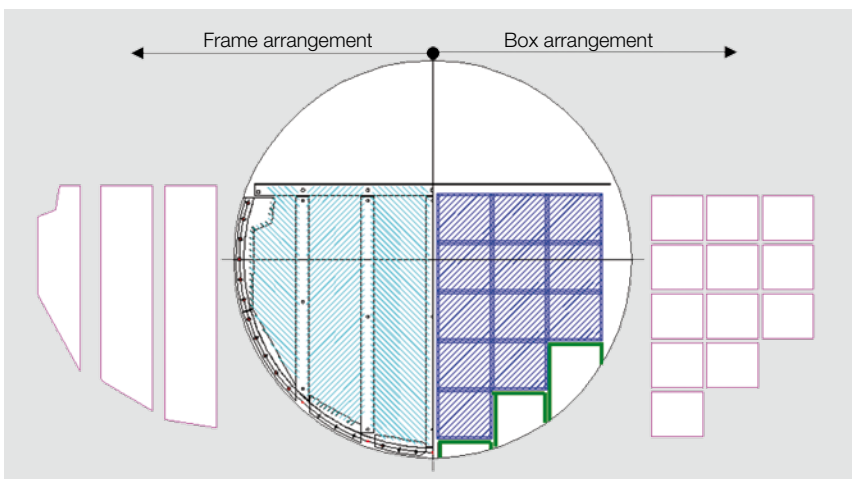


Fig. 3: Frame and Box Arrangement

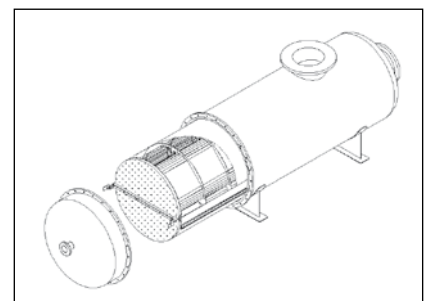


Fig. 4: One Piece Sulzer Mellaplate W

Sulzer Mellaplate™ Type M, MG and N

This type of coalescer is made of structured corrugated metal or plastic sheets (Fig. 5). Various universities and oil companies have tested Mellaplate M, MG and N types in oil/water separators also under moving conditions. Sulzer supplied the first Mellaplate in 1988 for the Hutton Tension Leg Platform (TLP) in UK. Since then hundreds of oil/water separators have been equipped with various Mellaplate M, MG and N styles. Some have been used as wave breakers or dampers in oil/water separators on TLPs and FPSOs (Floating Production Storage and Offloading).

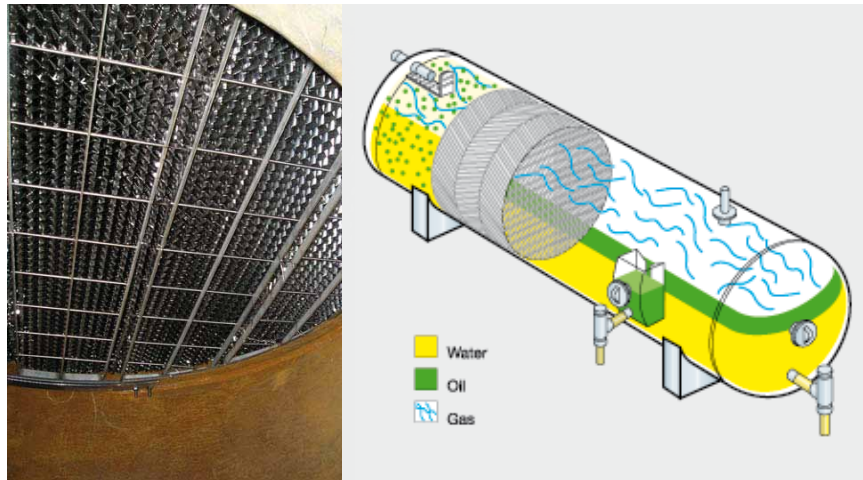


Fig. 5: Sulzer Mellaplate - M

Vessel Arrangement with Sulzer Mellaplate™ Coalescer

The Sulzer Mellaplate Coalescer types W, M, MG and N can be used flexibly in either horizontal or vertical vessels. A typical sketch of a 3-phase separator is shown

below (Fig. 6) which shows the Sulzer Mellaplate W as coalescer and the Mellaplate M as wave breaking device.

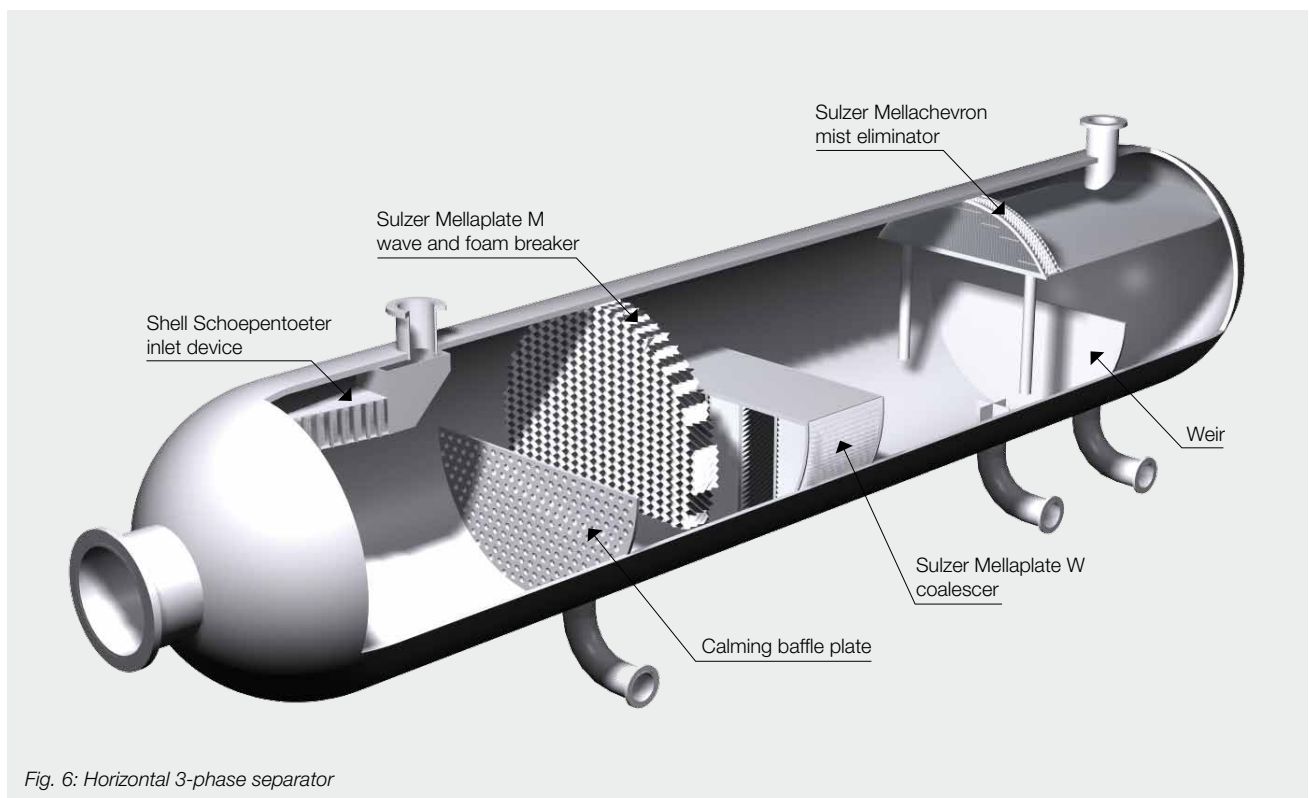


Fig. 6: Horizontal 3-phase separator

Feed Inlets

For two phase liquid/liquid separators or three phase separators, it is important that the flow in the vessel is equalized.

Any turbulence or disturbances such as flow variations, surges or external motion may significantly compromise the separation efficiency. Separators in an upstream oil and gas environment are particularly exposed to such problems. Sulzer inlet devices help to significantly improve the flow distribution across the vessel without causing droplets to shatter.

For a 3-phase separator, depending on the characteristic and inlet momentum of the feed mixture, different types of inlets are suitable:

	Suitability for large gas vol. fraction	Inlet Momentum	Defoaming	Degassing	Relative Cost of Device
Elbow pipe	–	–	–	–	\$
Half open pipe	+	+	–	–	\$\$
Shell Schoepentoeter™ vane type inlet	+++	++	+	++	\$\$\$
Sulzer GIRZ cyclonic inlet	+++	+++	+++	+++	\$\$\$\$

Table B

Calming Baffles

Sulzer recommends using the calming baffle in all liquid/liquid and gas/liquid/liquid separators, either operated as simple gravity settler or equipped with Sulzer Mellaplate or DC Coalescer. These baffles are provided with uniform holes which are optimized to achieve good flow distribution and minimize any turbulence in the liquid phases towards the coalescer internals. Depending on the type of applications, two calming baffles may be used.

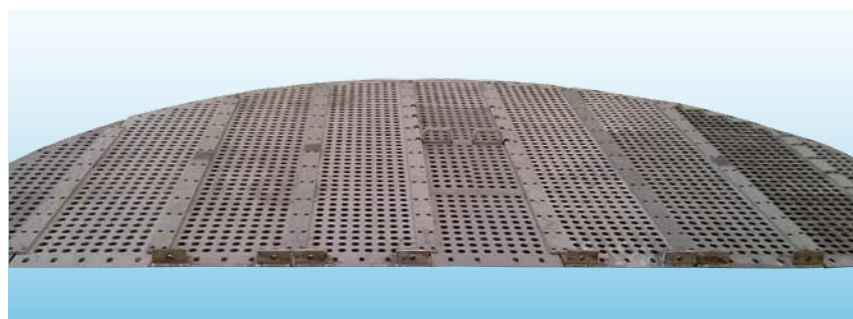


Fig. 8a: Calming baffle plate

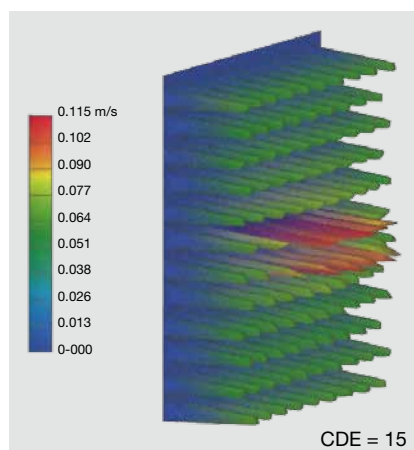


Fig. 7: CFD prediction of axial velocity distribution after the second baffle of a two calming baffle arrangement



Fig. 8b: Calming baffle boxes in front of a Mellaplate W

DC Coalescer

Sulzer DC Coalescer™

The Sulzer DC Coalescer Technology provides significantly lower settling times for primary dispersions with droplets as small as 30 microns.

While the droplets pass through the coalescer, they grow in size through a continuous process of coalescing and draining. The faster settling velocity of coalesced droplets leads to minimized vessel dimensions as opposed to gravity separation alone.

The coalescer uses a combination of two materials with different surface free energy – typically metal and plastic – to enhance the droplet coalescence of both phases (Figure 9).

The co-knitted Sulzer DC Coalescer outperforms single medium alternatives providing an improved draining at the junction points of the two dissimilar materials. (Table C). The separation performance is maintained regardless of which phase is dispersed.

The Sulzer DC Coalescer can be installed both vertically and horizontally. Shape and fixing method can be customized for the vessel or housing into which it will be installed. A broad variety of materials and knitting types offer a tailor-made solution wherever efficient liquid-liquid separation is required.

Key Benefits

- Debottlenecking of existing settlers
- Reduced size of 2- and 3-phase separators
- Improved phase separation efficiency
- Low “cut-off” diameters provide extended range of operation. The lower limit is at or near the transition region from primary to secondary dispersions i.e., cut-off droplet diameter ~ 30-40 µm.
- Depending on the DC Coalescer type and application, high separation fluxes of up to 120 m³/m²h are possible (Figure 10)
- Applicable for primary dispersions
- Equal performance regardless of which phase is dispersed

Typical applications of Sulzer DC Coalescer

- Separation of dispersion following water washing stages
- Entrainment reduction of either phase for liquid-liquid extraction columns as LPG Amine Treaters, Hydrogen Peroxide Extraction Columns and Caustic Washers
- Separation of dispersions formed by condensation following azeotropic distillation as in Butanol / Water Distillation
- Separation of liquids following steam stripping

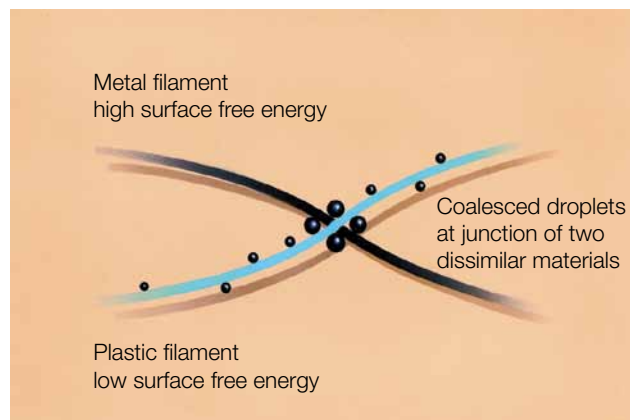


Fig. 9: Preferential Wetting & Junction Effect

Packing	Dispersed phase	Relative Flux ¹⁾
Stainless Steel	Kerosene	0.10
	Water	1.00
Polypropylene	Kerosene	1.10
	Water	0.05
Sulzer DC Coalescer Stainless Steel/ Polypropylene	Kerosene	1.45
	Water	1.45

1) where entrainment exceeds limit

Table C: Comparison of conventional and Sulzer DC Coalescer



Fig. 11: Sulzer DC Coalescer

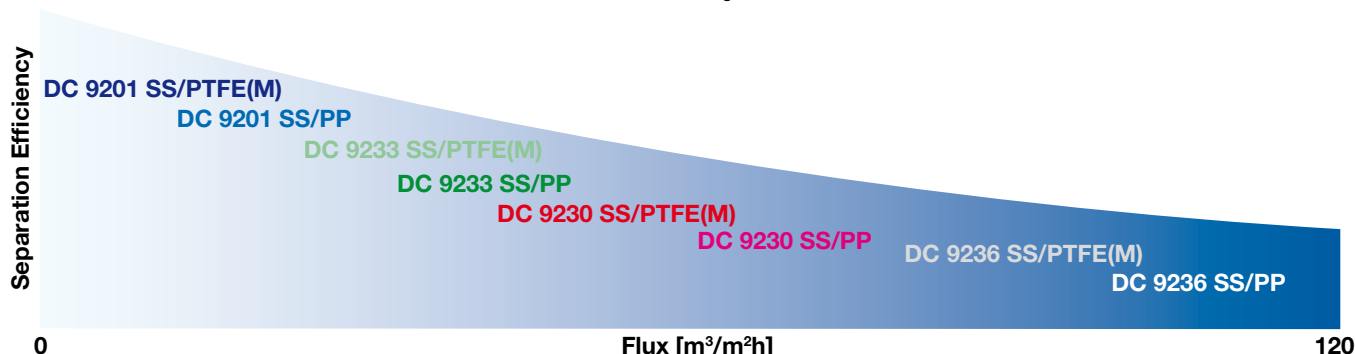


Fig. 10: Performance chart of Sulzer DC Coalescers

Dusec™ and Dusec Plus™ Cartridge Coalescer

In secondary dispersions, the droplets are so small that they do not readily wet a surface or settle under gravity. Typical drop sizes are in the range of 1 to 30 microns. In cartridge form with the liquid flowing from the centre radially outwards, the coalescing process is improved as the liquid encounters a flow resistance. Due to adhesive forces, the intercepted droplets cling onto the fiber surface at selective points where clusters form until coalescence takes place and the droplet grows. Viscous drag forces increase until they exceed the adhesion forces, causing the droplets to separate from the fiber and move further into the coalescer fiber bed, where the process is repeated. Finally the droplets reach primary dispersion size >60 microns. This is the working principle of Sulzer Dusec cartridge coalescers (Fig.12). An important advantage is that the outer layer of the cartridge is of the same composite construction as the Sulzer DC Coalescer, which accelerates separation and avoids jetting & entrainment. Normally no droplets leave the outer surface and drainage takes place within the DC Coalescers layer. In principal the distance between the cartridges can theoretically be zero. In practice, however, a minimum practical space is necessary to allow the cartridges to be easily installed onto the plate within the vessel.

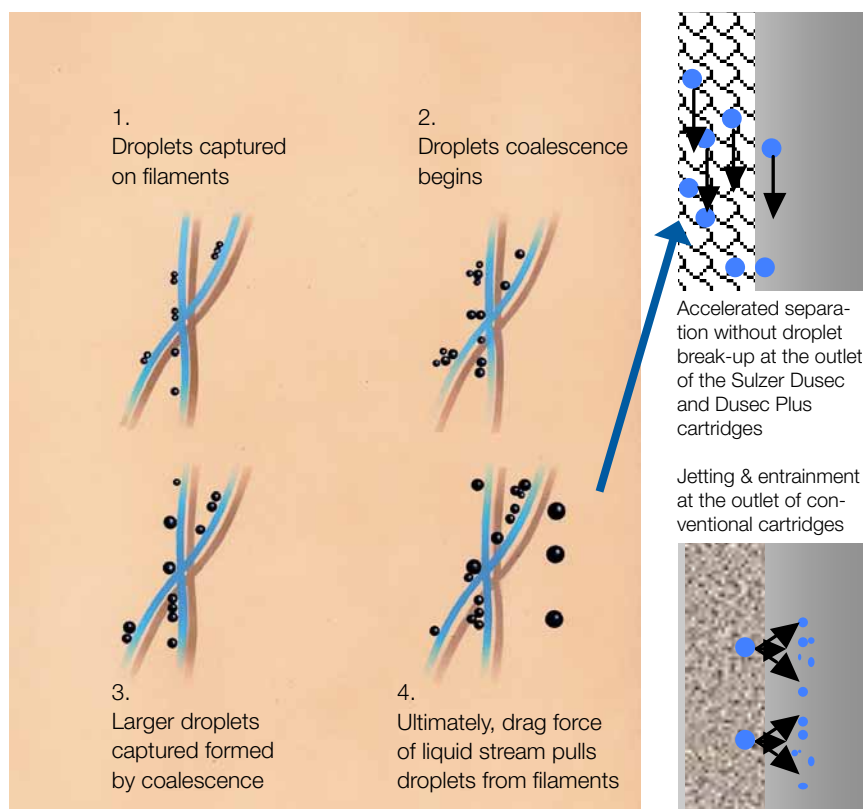


Fig. 12: Schematic representation of droplet coalescence in a Sulzer Dusec Coalescer

Another big advantage these coalescers offer is that they perform equally well independent which phase is dispersed. Dusec cartridge coalescers can be installed in both horizontal and vertical vessels (Fig. 13).

A selection of high specific surface area fiber materials, arranged in a specific pattern in the cartridge, ensure high efficiency coalescence of droplets in a broad spectrum of applications. Depending on the arrangement & construction of layers in the cartridge, the Sulzer Dusec coalescers have been classified into different types (Table D). Qualified engineers at Sulzer can provide advice on coalescer design including specification of vessel dimensions, main process and interface control connections, and the number and type of Dusec cartridges. The cartridges are available in different length of 500 mm, 1000 mm and 1500 mm.

Cartridge designs are available for many applications including aggressive chemical environments, as for hydrogen peroxide and for high temperature duties.

Dusec Coalescer

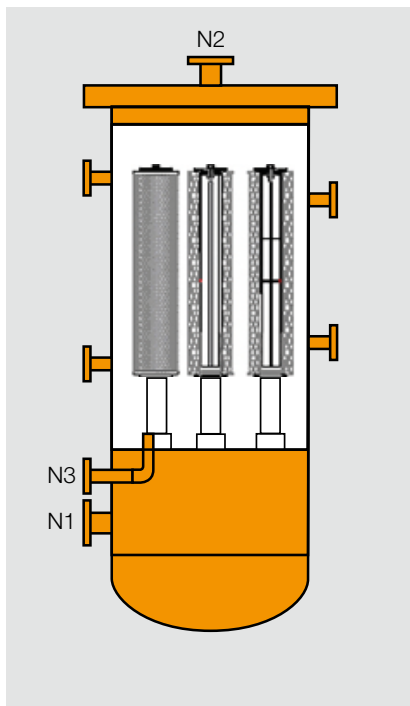


Fig. 13a: Heavy phase dispersed

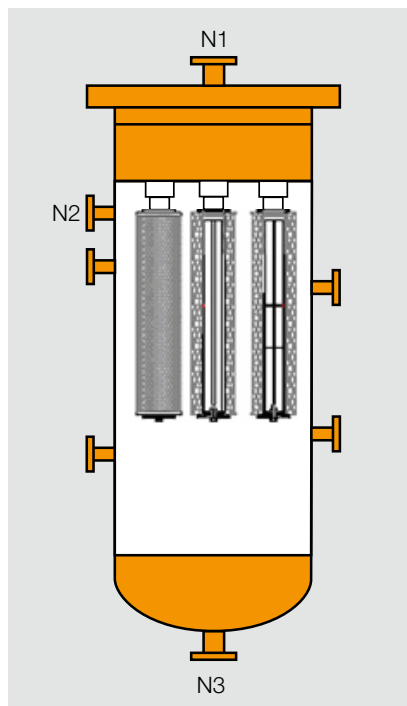


Fig. 13b: Light phase dispersed

Key Benefits

- Fiber topology and surface properties combined with optimized layer compositions mean higher efficiency
- Higher loadings and absence of jetting from outer layers mean higher packing densities.
- Works equally well independent which phase is dispersed
- Pressure drop minimized
- Separation down to 10 ppm free entrainment possible
- Suitable for interfacial tensions > 2 dyne/cm
- Quick performance recovery following feed condition changes

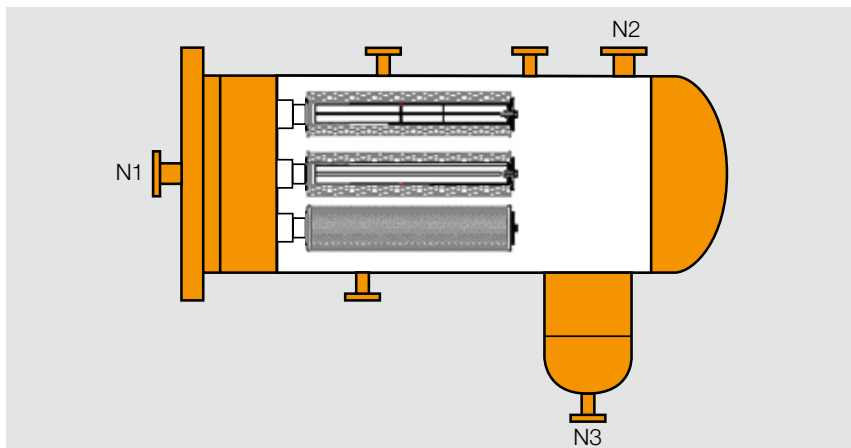


Fig. 13c: Heavy phase dispersed (horizontal layout). A dome is used if the light phase is dispersed.

Legend:

N1: Feed

N2: Light phase outlet

N3: Heavy phase outlet



Fig. 14: Sulzer Dusec with mounting plate



Fig. 15: Sulzer Dusec

	Resin bonded					Mechanically sealed				
Type	1/RB	2/RB	3/RB	4/RB	5/RB	1/MS	2/MS	3/MS	4/MS	5/MS
Max. Design Temperature	80	80	90	80	80	80	80	150	80	80
pH	<10	<10	<10	<10	<14	<10	<10	<10	<10	<14
If PP likely to be attacked use ☹			☹	☹				☹	☹	
If Epoxy resin likely to be attacked use ☹						☹	☹	☹	☹	☹
Applications										
Refining applications	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Amine extraction	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LPG Processing	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gas condensate	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Metal extraction	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Seawater	No	Yes	No	No	No	No	Yes	No	No	No
Produced water	No	Yes	Yes	No	No	No	Yes	Yes	No	No
Hydrogen peroxide	No	No	No	No	No	No	No	Yes	Yes	No
Aromatic solvents	No	No	No	No	No	No	No	Yes	Yes	No
Phase ratio: > 5 vol % dispersed phase	No	No	No	Yes	No	No	No	No	Yes	No
Available cartridge length	500, 1000 and 1500 mm					500, 1000 and 1500 mm				
Outer cartridge diameter	Dusec/Dusec Plus 230/156 mm					Dusec/Dusec Plus 230/156 mm				
Max. permissible pressure drop before cartridges have to be replaced	0.75 - 1 bar					0.75 - 1 bar				

Table D: Dusec and Dusec Plus Type Selection Table

Dusec Plus™ Coalescers

Designed to achieve high performance with minimum pressure drop, the Sulzer Dusec Plus model provides a high capacity alternative to conventional Dusec cartridges. The smaller diameter and increased packing density make it suitable for applications where it is necessary to maximize the effective area of the coalescer media in a given size of vessel.

Key benefits

- All the benefits of a Dusec coalescer
- High efficiency at minimal pressure drop
- Increased packing density
- Maximized effective area of the coalescer media in a given size of vessel.

Service & Supply

Sulzer offers a flexible and comprehensive service which includes the design for the complete vessel (including the various nozzle elevations, sizing) and production of additional internals such as weirs and supports, or the mounting plate for Sulzer Dusec and Dusec Plus coalescers.

Wash Tank Distributor

Research co-operation between Sulzer and Total has led to a new phase inversion technology where water-in-oil dispersions are converted to oil-in-water. 'Double emulsions' can be created where very small droplets of water are carried in oil droplets which are themselves dispersed within a continuous water phase - known as a 'water leg'. Water droplets, along with salts and other contaminants, can be removed from the oil by contacting the oil droplets with the continuous water phase. The Sulzer Wash Tank Distributor VROL (Fig. 16) is used at the bottom of the water leg and has been developed to create optimal droplets of oil and removes solids, even when subjected to motion.

In conjunction with Total, the technology is being applied in wash and desalting tanks in the hulls of FPSO vessels for removing entrained water, salts and contaminants from crude oil. The distributor system substantially improves the separation performance and concentrations of <0.5 % vol. BS&W (basic sediment and water) in the oil outlet can be obtained.

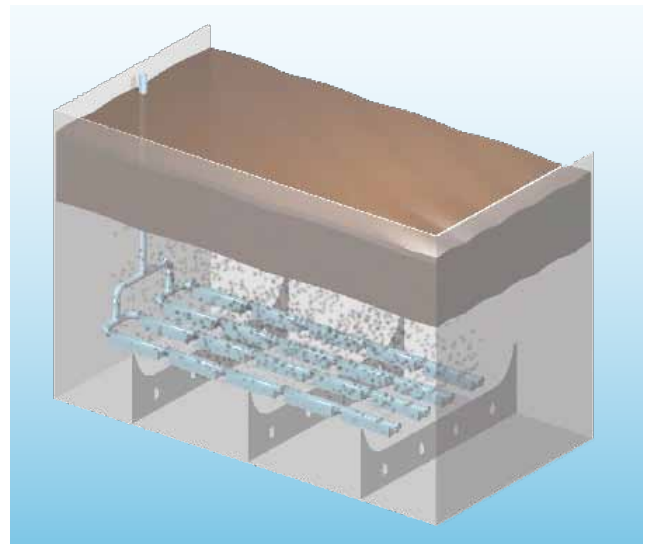


Fig. 16a: Wash Tank with Sulzer Distributor

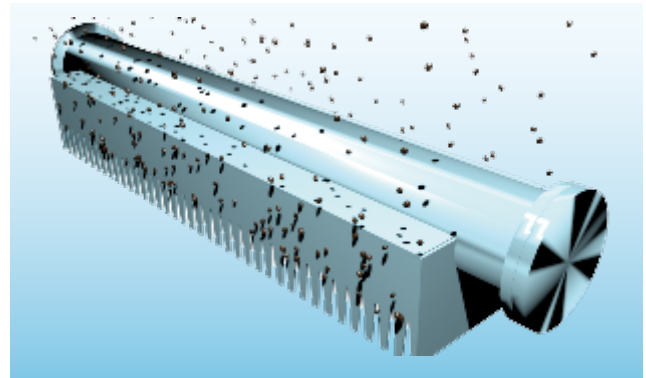


Fig. 16b: Sulzer Wash Tank Distributor

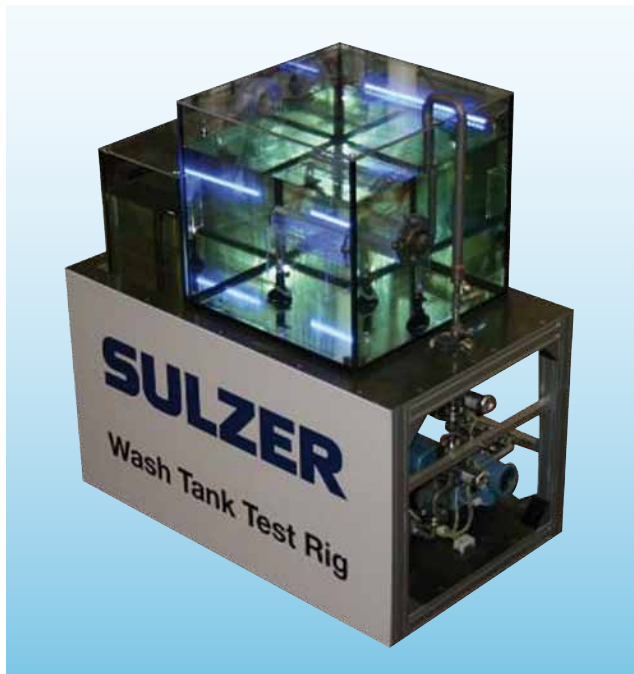


Fig. 17: Sulzer Wash Tank Test Rig

For the development of other innovative wash separator processes, small and large scale test rigs (Fig. 17) have been developed which enable us to investigate detailed coalescence phenomena as well as the whole separation process. CFD is used to simulate the wash tank process particularly taking into account the motion of the tank.

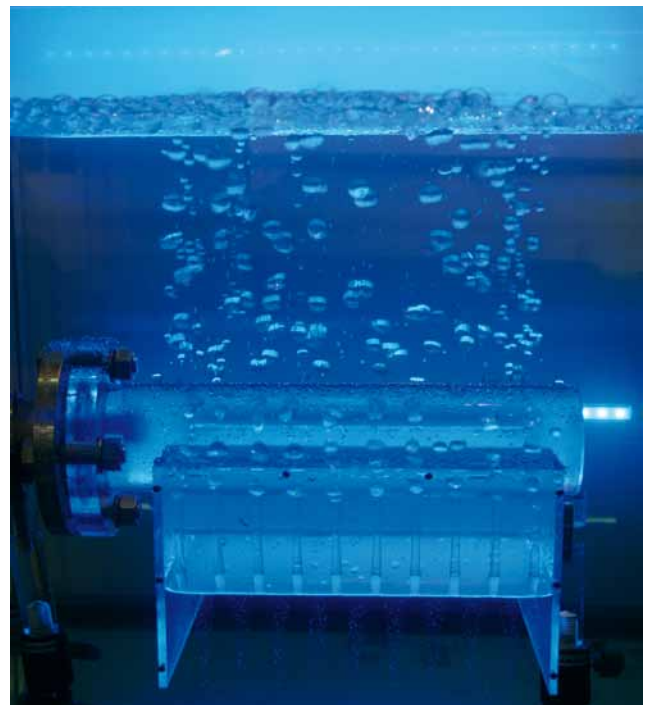


Fig. 16c: Sulzer Wash Tank Distributor

Our liquid phase separation testing facilities (Fig. 18) are available for the development of innovative equipment, and for investigating specific customer problems. In-house development of an automatic droplet size analysis system allows state of the art measurement of drop size distribution (Fig. 19), even in very high concentration dispersions.

Mobile test rigs are available for the customer to test in the actual process.



Fig. 18b: Sulzer Dusec test rig for customer tests on site



Fig. 18a: Test rig for Sulzer Mellaplate and DC Coalescer

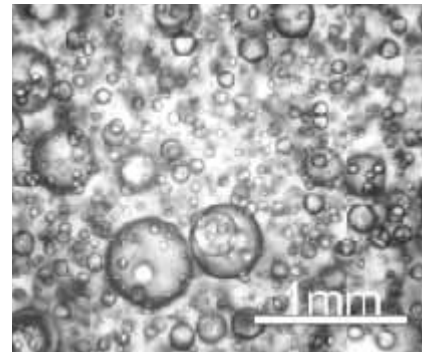


Fig. 19: Drop size analysis

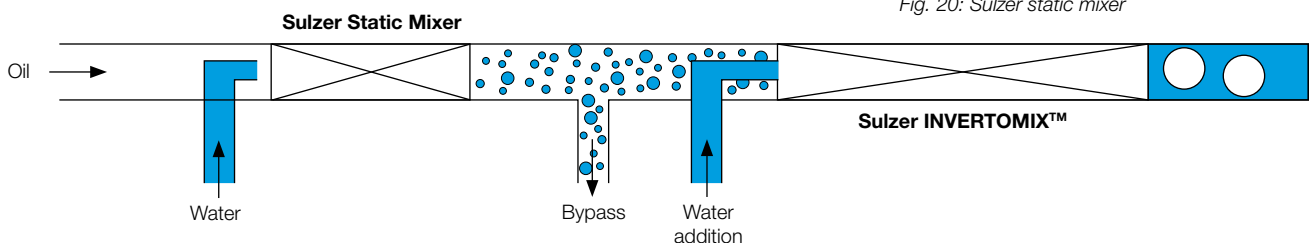
Recent Sulzer Product Developments on the subject Flow Assurance and Phase Inversion

Static mixers from Sulzer (Fig. 20) are used for efficient mixing of one or more phases. When the mixer is used to create dispersions, Sulzer static mixers achieve well-defined droplet size distributions compared to other equipment such as choke valves.

The special Sulzer INVERTOMIX™ (patent pending) can be used to obtain phase inversion from oil-in-water to water-in-oil or vice versa. This provides good control of phase continuity and is of particular interest for phase separation in heavy crude-oil-water systems as well as flow assurance in pipelines.



Fig. 20: Sulzer static mixer



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Sulzer Chemtech Ltd, a member of the Sulzer Corporation, with headquarters in Winterthur, Switzerland, is active in the field of process engineering and employs some 3000 persons worldwide.

Sulzer Chemtech is represented in all important industrial countries and sets standards in the field of mass transfer and static mixing with its advanced and economical solutions.

The activity program comprises:

- Process components such as fractionation trays, structured and random packings, liquid and gas distributors, gas-liquid separators, and internals for separation columns
- Engineering services for separation and reaction technology such as conceptual process design, feasibility studies, plant optimizations including process validation in the test center
- Recovery of virtually any solvents used by the pharmaceutical and chemical industry, or difficult separations requiring the combination of special technologies, such as thin film/short-path evaporation, distillation under high vacuum, liquid-liquid extraction, membrane technology or crystallization.
- Complete separation process plants, in particular modular plants (skids)
- Advanced polymerization technology for the production of PLA and EPS
- Tower field services performing tray and packing installation, tower and column maintenance, vessel welding, and plant turnaround projects
- Mixing and reaction technology with static mixers
- Cartridge-based metering, mixing and dispensing systems, and disposable mixers for reactive multi-component material

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