Development of new media and treatment of existing media permit use of these coalescers for essentially all process streams where entrainment of solids and liquid contaminants are present.

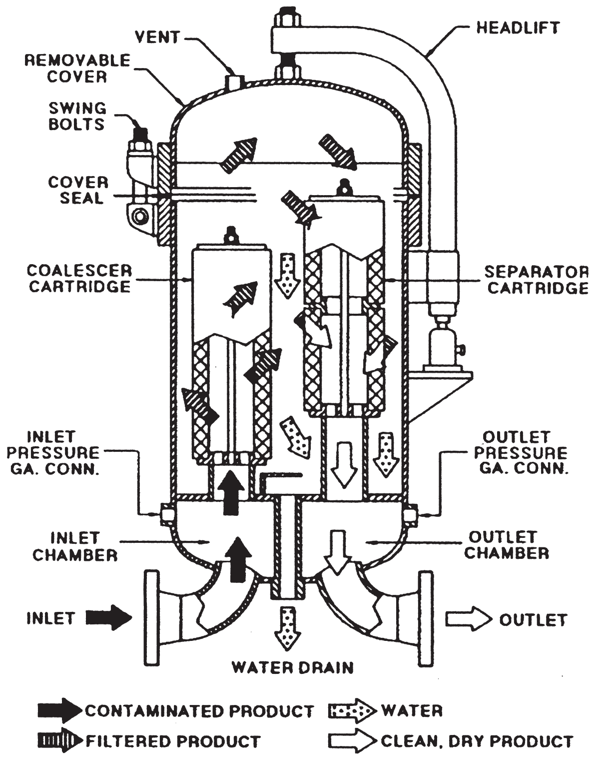

Figure 1. A typical two-stage vertical coalescer.

Three basic designs of cartridge-type coalescers are available for application in chemical processing. They are comprised of single-stage, two-stage, and three-stage units wherein one, two or three types of cartridges are provided. The configuration of each design will vary with the process application and efficiency requirements.

In determining the design of coalescer to be used, the maximum operating conditions and minimum performance efficiencies must be established. With the performance requirements established, the determination of the basic design and media to be utilized is made. Among the various factors which must be considered in arriving at the correct design are the physical characteristics of the fluid to be processed. This applies not only to the continuous phase but equally well to the discontinuous phase. Since all coalescers, whether one-, two-, or three-stage rely to a greater or lesser degree on the natural forces of gravity, the difference in the specific gravity of the two liquids is important. As will be discussed later, the discontinuous phase may be lighter or heavier than the continuous phase without affecting the efficiency of the unit, provided sufficient differential in gravity exists. Since the natural forces of gravity enter into the operation of the equipment, the viscosity of the fluids being processed must also be taken into consideration.

One of the most important single factors to consider in the design of cartridge type coalescers is the interfacial tension between the continuous and discontinuous phase. Since the interfacial tension controls the maximum droplet size of the discontinuous phase and relative wetting of separating surface, the selection of a coalescing media is of prime importance when low interfacial tension values are to be encountered.

Since most fluid process streams contain solids contamination of one form or another, consideration must be given to the type of contaminant involved and the amount of contaminant in the fluid. The next factor that affects the ultimate design is the particle size distribution. From the particle size distribution curve, a determination of how much of the solids contaminant to be retained in the cartridges can be made. The fact that the solids to be filtered are either hydrophobic or hydrophyllic is of importance. If a solid is hydrophobic it will be borne through the system by the hydrocarbon phase and will be more difficult to filter. The hydrophyllic solid is carried by the discontinuous water phase and during the mechanical action of coalescence, this solid will largely be deposited on the media of coalescer cartridge.

Coalescer Cartridge

The coalescer cartridge is made up of one or more layers of media. This media is primarily a porous membrane which retains its dimensional stability by the use of thermal setting resins or binders. Careful selection of the media is imperative to insure that the fluid stream being processed does not remove the binder in the media, which would result in media collapse and contamination of the fluid. In order to assure that coalescing of the discontinuous phase is complete, the media must possess an infinite number of irregular continuous passages of very small diameter. These passages are such that by impingement and preferential wetting of the media surface, the discontinuous phase is commingled to a sufficient size where it can be removed from the continuous phase by gravitational force or by contacting a second stage, commonly referred to as a separator cartridge.

Because of the extremely small pore size of the irregular continuous passages of the coalescing media an accessory function of the media becomes one of removing solids particles. Therefore, if a given coalescing media possesses a sufficiently fine pore size to affect coalescing of a finely dispersed discontinuous phase, it will, at the same time, provide excellent filtration characteristics. The degree of filtration will be in

9910 EAST 56TH STREET NORTH, TULSA, OK 74117-4011
TEL: 918-272-8700 / 800-223-9910 FAX: 918-272-8787
E-MAIL: sales@facetusa.com www.facetusa.com

direct relation to the size of the openings and the total solids retention will vary with the type and depth of media used.

One of the most important single factors regarding the application of cartridge-type coalescers to fluid process streams is the interfacial tension between the continuous and discontinuous phase. Below values of 20 dyne/cm, the size of the particles in the dispersed phase becomes progressively smaller and coalescing becomes more difficult. Media is available which will coalesce at values of less than 10 dyne/cm; however, additional consideration must be made for these reduced values. Under these conditions, the media of the coalescer cartridge must have even smaller diameter pores to insure that all of the dispersed phase contacts one or more surfaces during its passage through the media. Preferential wetting of the media by the dispersed phase will facilitate complete coalescing.

Coalescing media is provided in many forms, the most common being multiple layers of media formed into cylindrical cartridges ranging in size from 4 to 6 inches in diameter and 10 to 57 inches in length. The direction of flow can be either outside-to-inside or inside-to-outside. The most common flow pattern in cartridge type coalescers is inside-to-outside. Higher flow rates can be obtained in the inside-to-outside cartridge coalescer due to the fact that the linear velocity of the fluid passing through the media is progressively reduced as the fluid approaches the outer extremities of the cartridge. This condition permits the discontinuous phase to be commingled into a larger droplet size with the result that the load on the second stage is greatly reduced.

Other forms of coalescing media in bulk form are available and are widely used in some applications. Among the more common types of bulk coalescing media are bonded and unbonded glass fibers, metallic wool of various types, and treated wood fibers. Bulk type coalescing media of the types mentioned herein are normally used in single-stage coalescers. The density of the bulk coalescing media will vary with the type of media used in the installation. Typical bulk densities of this type media will range from 1½ to 4 pounds/cubic foot for glass fibers and up to 20 pounds/cubic foot for metal wool. The degree of coalescing and the nominal pore size of the bulk cartridge can be relatively controlled by the density of the material. Unbonded glass fibers lend themselves to applications wherein the solvent action of the continuous or discontinuous phase prohibits use of bonded materials. Metallic fiber can be used to a great advantage in applications where the pH of the fluid being processed exceeds the limits of glass fibers or other forms of conventional coalescing media. Other forms of coalescing media are also available such as polyethylene encapsulated fibers, inorganic fibers and sintered materials.

Separator Cartridge

The separator cartridge is made up of a single media. This media must allow free passage of the continuous phase and can be treated to repel the discontinuous phase. The separator cartridge is normally comprised of one type or layer of media. The type of media will vary with the application. The separator media must permit maximum flow of the continuous phase at minimum pressure differential. This media must be superficially treated or possess inherent characteristics which will permit free passage of the continuous phase while repelling the discontinuous phase. A common media for this application is silicone-treated cellulose fibers.
The media must be dimensionally stable in the presence of the fluids being processed since any swelling of the fibers due to absorption will result in a change in the pore size of the media. Effectiveness of the separator cartridge is entirely dependent upon the repellent characteristics of the media to the discontinuous phase and the critical pressure at which the discontinuous phase will be forced through the pores of the media. It is, therefore, of absolute necessity that the pore size of the media remain unchanged; otherwise, the critical pressure differential will be exceeded and the cartridge will fail to repel the discontinuous phase. Critical rupture pressure can be expressed by the following formula:

$$p = 2\gamma/r$$

where p is the differential pressure (in. Hg), γ is the interfacial tension (dyne/cm), and r is the radius of maximum pore (micron).

Other materials are available for use as a separator media. One of the more common materials is the use of polytetrafluoroethylene coating on fine-mesh wire filter cloth. This particular type of separator cartridge lends itself to those applications where the continuous phase would wash out or otherwise be detrimental to the silicone-impregnated cellulose materials. An auxiliary function of the separator cartridge is one of filtration. Since the pore size of the separator media is controlled, this media then becomes a secondary filter to prevent migration of fibers from the preceding stages; or in the event of mechanical failure of the coalescer cartridge, the separator cartridge will prevent solids contaminant from flowing into the effluent stream.

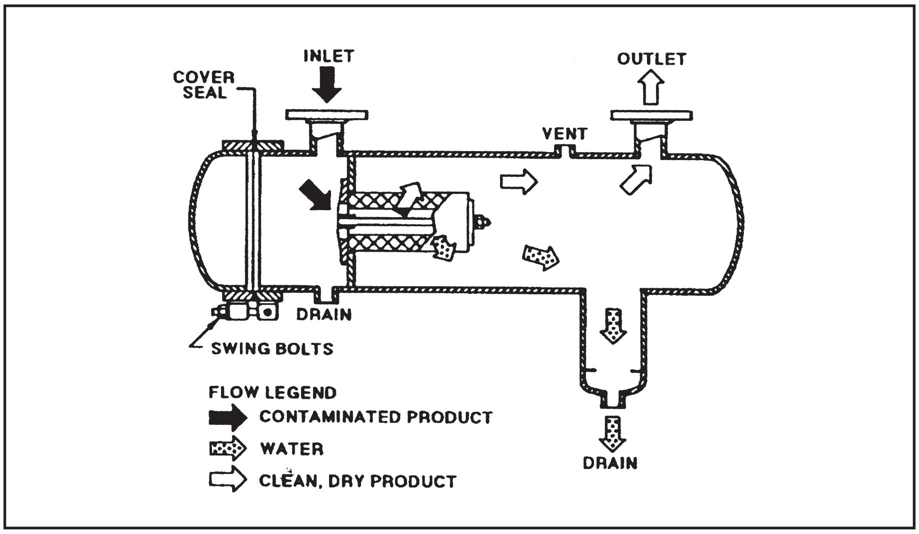

Figure 2. A typical single-stage coalescer.

Due to our continuing program of improvement, specifications are subject to change without notice.

Filter Cartridge

In three-stage units the first stage is made up of single or multiple installations of one of the various types of filter cartridges. The function of this cartridge is one of removing solids contaminants only. Its purpose is to reduce the loading on the second-stage coalescer cartridge, thereby greatly improving coalescer life and to insure ultimate efficiency from the media. The direction of flow through the filter cartridge is from outside-to-inside. This design permits maximum solids retention in a minimum envelope size.

The selection of media for the filter cartridge will be determined by a number of factors; the most important of which are chemical characteristics of fluid to be processed, temperature, amount of solids contaminants in the process stream, particle size distribution, maximum particle size permitted in effluent, and minimum solids retention before change is required. The cartridge may be made from any of the various common media such as pleated cellulose, woven materials, and impregnated organic fibers. For those applications where the process stream prevents use of bonded or impregnated media due to solvent action, other materials are used. There are now available polyethylene-encapsulated fibers which retain all filtration characteristics of impregnated cellulose with regard to pore size and offer essentially zero media migration. This material now affords economical filtration to numerous process applications which are beyond the operational limits of low cost media.

Two-Stage Unit

A typical two-stage vertical coalescer is shown in Figure 1. This design is commonly referred to as a filter separator.

The contaminated fluid enters the lower inlet chamber and flows upward into the inside of the multiple coalescer cartridges. In this area of reduced velocity, the initial phase of commingling is begun. When the fluid contacts the initial surface of the media, any large particles of contaminant will be filtered from the stream. As the fluid continues its tortuous passage through the media, the discontinuous phase is impinged upon the infinite surfaces and commingling of the dispersed particles results. As the two liquid phases near the outer surface of the coalescer cartridge, the discontinuous phase has been coalesced to large droplets. Simultaneously with coalescing of the discontinuous phase the media is filtering solids contaminant from the process stream.

As the two liquid phases flow from the outside surface of the coalescer cartridge, the large droplets of the discontinuous phase will fall by gravitational force to the sump or collection area. The lower velocity in this area greatly reduces the possibility of rupture of the coalesced droplets of the dispersed phase. Any remaining entrainment of the discontinuous phase will be repelled by the separator cartridge. In addition to preventing any passage of the discontinuous phase into the effluent stream this cartridge also performs as a secondary filter in event of mechanical failure or bypass of the coalescer cartridge.

The two-stage unit is also provided in horizontal configurations. In this design the sump for accumulation of the discontinuous phase may be located below or on top of the horizontal vessel. Normally the coalescer cartridges are installed in one end of the vessel and the separator cartridges in the opposite end. The void area between the ends of the cartridges provide fall-out area for the discontinuous phase. This type of two-stage design is particularly desirable where the viscosity of the fluids being processed is relatively high or where the differential gravity between the two products is relatively low. This design further lends itself to application on streams where the discontinuous phase is lighter than the continuous phase with the result that the accumulation sump must be installed on the top of the vessel.

Another design of the two-stage unit follows the general configuration of the vertical design wherein the unit is rotated 90 degrees on its normal axis and installed in a horizontal position. The coalescer cartridges are installed in the lower section of the horizontal shell and the separator cartridges are installed in the upper or top section of the horizontal vessel. A vertical accumulator sump for collection of the discontinuous phase is added to the horizontal chamber.

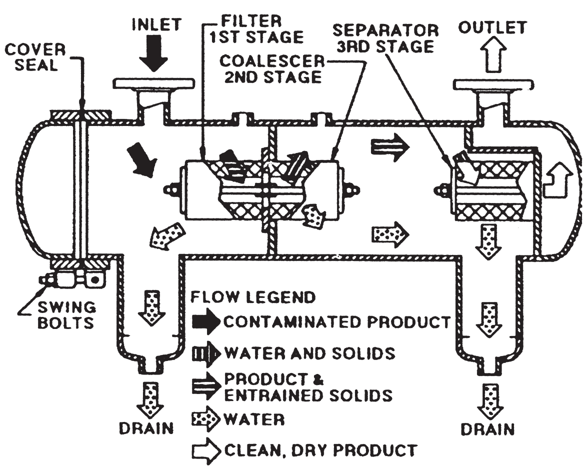

Figure 3. A typical three-stage horizontal coalescer.

Two-Stage Unit Application

Typical of a two-stage coalescer installation is the following:

Process problem: Removal of undissolved water containing hydrochloric acid from perchloroethylene.

Operating conditions:

	Heavy Phase	Light Phase
Feed Rate lb./hr.	112,000	10,000
Specific gravity	1.6	1.0
Liquid	Perchloro-ethylene	Water
pH		5.0
Temperature, °F		122
Pressure, lb./sq. in. gauge		150

Required performance: Nominal size of effluent solid particle five microns. Effluent stream to contain not more than 5 ppm undissolved water.

Due to our continuing program of improvement, specifications are subject to change without notice.

9910 EAST 56TH STREET NORTH, TULSA, OK 74117-4011
TEL: 918-272-8700 / 800-223-9910 FAX: 918-272-8787
E-MAIL: sales@facetusa.com www.facetusa.com

For this installation a horizontal two-stage unit using multiple coalescer and separator cartridges was used. This design was selected primarily because the discontinuous water phase is lighter than the continuous phase. A second important factor in selection of this design was the high concentration of water in the process stream. The settling area between the two stages permits the major portion of the water to rise to the accumulator sump before reaching the separator cartridges.

The physical and chemical characteristics of the continuous phase permitted use of conventional coalescing and separating media. The hydrochloric acid dissolved in the water phase had reduced the pH to five which is within normal operating limits of glass fibers used in the coalescer cartridges and silicone treated cellulose in the separator cartridges. The operating temperature was considerably less than the 275°F permitted for this type of media.

All metal in contact with the process fluid was of stainless steel and all non-metallic parts are resistant to the corrosive action of the hydrochloric acid solution.

Single-Stage Unit

A typical single-stage coalescer is shown in Figure 2. Single-stage units may be comprised of multiple installation of coalescer cartridges as illustrated, or the entire cross section of the vessel may be packed with a bulk-type media. This design is used when the differential in specific gravity of the two liquid phases is sufficient to provide separation by gravitational force or where a separator cartridge would not possess sufficient repellent characteristics to the discontinuous phase.

In the design of single-stage units, the size of the vessel is of prime consideration since separation is entirely dependent upon the difference in the density of the two liquids. Linear velocity in the settling area of the vessel will vary from 0.25 ft/sec on light fluids to 0.10 ft/sec on heavier products. If the discontinuous phase is lighter than the continuous phase the accumulator chamber is placed on top of the vessel.

The contaminated fluid flows into the large inlet chamber and the immediate reduction in velocity will permit a portion of the entrained discontinuous phase and solids to settle out. The discontinuous phase will then pass through the lower half of the coalescer pack. Any remaining entrainment is coalesced and solids are filtered from the fluid as it flows through the media.

Single-Stage Unit Application

Typical of a single-stage coalescer installation is the following:

Process problem: Removal of entrained water containing sodium hydroxide from butadiene.

Operating conditions: Specific gravity 0.628 at 60°F. Flow 200 gpm Entrained water 10% volume; pH of water 9.5 to 10.0. Solids contaminant negligible.

Required performance: Water not to exceed 50 ppm in effluent. For the above installation a single-stage horizontal unit using a bulk-type coalescer cartridge was used. The design was selected because the pH value of the water phase exceeds the recommended values for secondary separator cartridges of conventional media. The media selected was a fine-grade stainless steel wool compressed to an optimum density to provide maximum contact surface for coalescing and minimum differential pressure.

Three-Stage Unit

A typical three-stage horizontal coalescer is shown in Figure 3. This unit consists of coalescer and separator cartridges as used in the horizontal two-stage device, and is provided with a first-stage cartridge whose primary function is the removal of solids contaminant from the stream. The product enters the low-velocity inlet chamber where the larger particles of solids contaminant will settle out by gravitational force. In this area, any sludge or other heavy entrainment will also settle out and accumulate in an auxiliary sump. Controls may be provided on the auxiliary sump for automatic blowdown of the accumulated material. As the fluid flows through the first-stage filter cartridge, the solids contaminant is filtered from the stream. Simultaneously, some initial coalescing of the discontinuous phase may occur depending upon the media used in the filter cartridge and the characteristics of the discontinuous phase.

As the filtered product and discontinuous phase flows from the first-stage filter cartridge, it is discharged directly into the inside of the second-stage coalescer cartridge. The second-stage coalescer cartridge then performs the function of completing the coalescing of the discontinuous phase and filtering out any remaining solids which may be in the stream. Immediately downstream from the coalescer cartridge is a void area which provides settling space for gravitational fallout of the discontinuous phase. As the product flows to the outlet through the third-stage separator cartridge any remaining entrainment of the coalesced discontinuous phase is repelled and the clean, dry product leaves the vessel.

Use of a three-stage device permits a very wide selection of filter and coalescing media. This unit offers great advantages for those installations where the solids contaminant in the process stream is relatively high, i.e., 5 mg/l. The first stage filter cartridges can be removed from the unit without disconnecting any of the piping or without removing the cartridges in the second- or third-stages.

Application

The use of cartridge-type coalescers, as applied to the chemical process industry, has resulted from the development of new media and treatment of existing media to permit their use. The art of coalescing has advanced to a point where there are only a few isolated process systems where cartridge-type coalescers cannot be utilized.

Cartridge-type coalescers can be provided for essentially all process streams where entrainment of solids and liquid contaminant is present, the only limiting factors being equal density of the two liquid phases or essentially zero interfacial tension.

9910 EAST 56TH STREET NORTH, TULSA, OK 74117-4011
TEL: 918-272-8700 / 800-223-9910 FAX: 918-272-8787
E-MAIL: sales@facetusa.com www.facetusa.com