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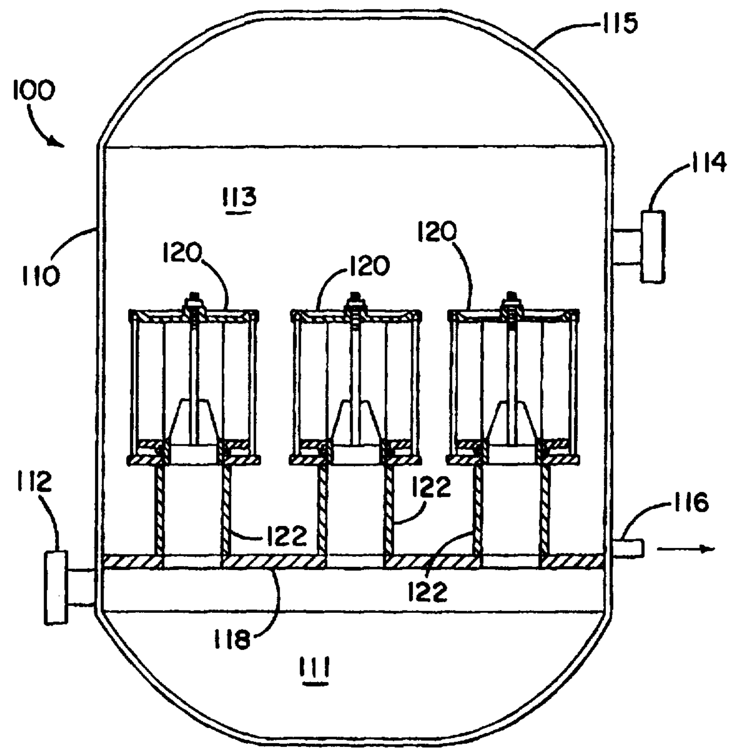
(57) Abstract

A coalescing system, assembly, and element is provided which is capable of separating a first fluid from a second fluid. The coalescing system, assembly, and element is designed such that the coalescing element may be rapidly and easily removed and replaced. Additionally, the coalescing element includes a minimal amount of components and the coalescing assembly provides the necessary components to ensure an efficient coalescing process.



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DISPOSABLE COALESCER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a coalescing system, coalescing assembly, and coalescing element, and more particularly to a coalescing system, coalescing assembly, and a disposable coalescing element.

2. Discussion of the Related Art

Coalescers, sometimes in conjunction with separators, are typically used in industrial processes to separate several phases present in fluids, i.e, gases and/or liquids. In some instances such fluids constitute dispersions of two or more immiscible liquids. In other instances, the fluid is an aerosol, such as a gaseous aerosol. In many instances a solids contaminant, such as a particulate or colloidal substance, will also be present in the fluid.

Coalescers are currently used for a variety of applications. Generally, gas coalescers serve to remove aerosol contaminants, both liquid and solid, from gaseous streams. Typically, this includes the purification of compressed gases such as air, helium, hydrogen, nitrogen, carbon dioxide, and natural gas, and in treating inert gases used in recovering oil. Coalescers may also be used to collect liquid aerosol contaminants, such as those encountered in treating vacuum pump exhausts where coalescers serve both to prevent contamination of the environment and to reclaim expensive vacuum pump oil. Similarly, coalescers may be used in treating chemical mists from low pressure chemical process streams to prevent pollution by, and to reclaim components of, liquid chemical aerosols.

Coalescers are relied upon typically to remove those aerosols which are most difficult to separate. For example, oil lubricated compressors are used widely for compressing gases. Such compressors produce aerosols as a result of mechanical shearing and a combination of oil vaporization and subsequent downstream condensation.

The aerosols formed generally comprise particles ranging in size from about 0.01 to about 50 micrometers.

Water aerosols are formed when the intake gas to a compressor contains sufficient water vapor that the resulting compressed and cooled gas exceeds one hundred percent relative humidity. This occurs commonly, e.g., when the intake gas is atmospheric air or when the gas to be compressed is processed gas that has come in contact with water.

Highly hydrophobic filters, also referred to as "barrier filters", are sometimes used to remove water-based aerosols of relatively large particle size from gas streams. These filters work by preventing water from passing through the filter medium by trapping the water-based aerosols on the upstream surface of the medium. The pores of such barrier filters must be smaller than the aerosol particles being removed. Accordingly, they are not efficient for removal of small aerosol particles since the pressure drop would be prohibitive.

Larger aerosol particles (larger than about 0.6 micrometers) tend to impinge and coalesce on surfaces throughout piping systems because their momentum is often too great to follow the flow path. These larger particles may be removed and, for economic reasons, generally are removed by other separating means, e.g., after-coolers and centrifugal separators or demisters. Coalescing elements, however, typically must be relied upon to remove aerosol particles ranging in size from about 0.1 to 0.6 micrometers. Such aerosols are considered to be the most difficult to separate because they display marginal impact removal and do not have sufficient diffusional characteristics to divert from system flow to allow interaction with separating devices. Smaller aerosol particles, e.g., less than about 0.1 micrometer, typically can be removed with somewhat coarser coalescers since they rapidly diffuse to surrounding surfaces.

Regardless of whether other separating means are used, coalescing elements conventionally are designed with well-known principles in mind. For a coalescer having a given voids volume and for a gaseous stream having a given flow rate and aerosol loading, the capture efficiency is directly proportional to the thickness of the coalescing medium and inversely proportional to the pore size of the medium. However, decreasing the pore size and/or increasing the thickness of the coalescing medium tends to increase the pressure drop across the medium and, thereby, the energy required to maintain a specific flow rate. Given the needs of a specific volume or space constraint, e.g., a coalescing cartridge of specified size, the use of a thicker coalescing packing or medium will generally result in limiting the available coalescing surface area, an increase in overall flow velocity, and correspondingly higher flow resistance. Increased flow velocity through the coalescing medium also decreases separation efficiency for the difficult-to-remove-size aerosol particles or droplets.

Conventional coalescing media have been designed to compromise and optimize these competing factors. Many coalescing media are designed to provide adequate performance under dry conditions. However, eventually the medium accumulates liquid as a result of collecting liquid aerosol particles. The accumulated liquid tends to block smaller pores and thereby reduce the coalescing efficiency of the medium. Blocked pores also increase the pressure drop across the medium which, in turn, increases energy requirements.

Conventional coalescers not only exhibit reduced efficiency and increased pressure drops when wet, but they also tend to produce secondary aerosols. These can be formed by two mechanisms. As small pores are blocked, the velocity of gas passing through the larger unblocked pores increases. The increased velocity raises the likelihood of shearing liquids from the surface of the coalescing medium and forming secondary aerosols downstream of the coalescing element. Additionally, as the coalesced liquid flows down the surface of the coalescing medium, it can form a film over the pores. Gas passing through the coalescing medium then tends to expel the liquid by forming bubbles which burst, forming secondary aerosols downstream of the coalescing medium. In short, the overall performance of the coalescing medium suffers when wetted.

In addition to the presence of aerosols, solid particulate matter is frequently present in gaseous streams which are treated for removal of liquid aerosols. Such dirt may be associated with a gas to be filtered or can arise as a result of wear and corrosion of the apparatus in the system upstream of the coalescer. This solid particulate matter also blocks the pores in the coalescing medium and contributes to increased pressure drops.

Depending upon the particular application, coalescing elements in the separation of a first liquid which is wholly or partly immiscible in and forms a discontinuous phase with a second, continuous phase-forming liquid also suffer from similar problems. That is, particulate or other extraneous matter tends to clog some of the pores of the coalescing medium, resulting in lower coalescing efficiency and higher pressure drops across the medium.

Chemical interactions between some of the substances present in the gases or liquids being treated with a coalescing medium also tend to cause deterioration of the medium. Accordingly, with the passage of time, the efficiency of the coalescer also decreases. Thus, in order to maintain an acceptable level of performance in maintaining the purity of fluids passing through or emanating from various industrial systems, the aforementioned problems require the replacement of coalescers or the coalescing element in a coalescer. In addition, such coalescing elements are typically replaced during routine periodic maintenance when a specific system is serviced.

Although a number of different designs and configurations exist for coalescers and coalescing elements currently used in process streams, cylindrically shaped coalescers and coalescing elements are most frequently employed. This probably results from the fact that this design permits the maximum efficiency for a given volume or size of a housing. Typical of such coalescing elements or cartridges are those which include a packing material or coalescing medium, the functional portion of the coalescing element, arranged coaxially as a coalescing region in the form of a coaxial sheet(s), layer(s) or mat(s). The packing material from which the coalescing medium is formed is porous or microporous and is typically formed from fibers, either woven or non-woven. The packing material chosen for a particular application has the necessary physical and chemical characteristics to allow the dispersed discontinuous phase to be formed into droplets on contact with the medium. Closing the cylinder at opposite ends are two end caps, at least one of which includes an opening. In those instances when the cylindrical coalescing element is not intended to be joined to another element arranged in series, one of the end caps is a closed end cap. For structural strength and support, a centrally located porous or perforated core, arranged coaxially within the cylindrical coalescing medium, is typically provided. One or more of a support and drainage layer and an outer cage may also be provided, each disposed around the cylindrically configured coalescing medium. The support and drainage layer is typically provided to both support the coalescing medium and to channel or direct fluid flow away from the effluent surface of the coalescing medium.

In most cylindrical coalescer systems the fluid to be treated enters the interior of the element through an opening in one of the end caps and passes through the coalescing medium in an inside-out direction. In those instances in which fluid flow is in an outside-in direction, a support and drainage layer may disposed concentrically within the cylindrically disposed coalescing medium and when a core is provided the internal support and draining layer may be arranged between the coalescing medium and the core. The outer cage, when provided in a conventional coalescing element, is intended to provide both structural support and to prevent rupturing of the coalescing medium from rapid expansion of the medium when subjected to high fluid forces flowing in an inside-out direction. One or more of the coalescing medium, core, cage or support and drainage layer may be sealed to the end caps to prevent leakage of fluid.

Although a significant portion of the material cost of such coalescing element is attributable to the functional portion of the element, e.g., the coalescing medium, the other components also contribute to the cost of the cartridge. In some instances, both because of the size of the cartridge and the costs associated with producing a cartridge with the requisite critical tolerances of the coalescing medium and other components, the replacement costs of such a cartridge can be considerable. Thus, were a coalescing system to exist which would permit the same level of performance and efficiency to be achieved but with a decrease in the number of components of the system requiring replacement in order to maintain such performance, considerable savings in replacement costs could be realized by the user of such coalescing systems.

SUMMARY OF THE INVENTION

The coalescing systems, coalescing assemblies, and disposable coalescing elements embodying the present invention overcome many of the limitations in the prior art.

In accordance with one aspect, the present invention is directed to a coalescer system. The coalescer system comprises a housing and at least one coalescing assembly. The housing includes an inlet, at least one outlet, and a tube sheet which divides the housing into an uncoalesced fluid chamber and a coalesced fluid chamber, and which has at least one opening therein for fluid to flow from the uncoalesced fluid chamber into the coalesced fluid chamber. The inlet is coupled to and communicates with the uncoalesced fluid chamber. The coalescing assembly is mounted to the tube sheet within the housing such that fluid flows from the inlet through the coalescing assembly. The coalescing assembly includes a coalescing element removably coupled to the tube sheet, an outer support structure disposed around the exterior of the coalescing element and permanently mounted to the tube sheet for providing structural support therefore, and a mechanism cooperatively arranged with the coalescing element to removably secure the coalescing element within the outer support structure. The coalescing element has a coalescing medium, first and second end caps attached to the ends of the coalescing medium, wherein at least one of the end caps has a sealing mechanism for providing a fluid tight seal, and a support core.

In accordance with another aspect, the present invention is directed to a coalescing system. The coalescing system comprises a housing and at least one coalescing assembly. The housing includes an inlet, at least one outlet, and a tube sheet which divides the housing into an uncoalesced fluid chamber and a coalesced fluid chamber and which has at least one opening therein for fluid to flow from the uncoalesced fluid chamber into the coalesced fluid chamber. The inlet is coupled to and communicates with the uncoalesced fluid chamber. The coalescing assembly is mounted to the tube sheet within the housing such that fluid flows from the inlet through the coalescing assembly. The coalescing assembly includes a coalescing element removably coupled to the tube sheet, an outer support structure disposed around the exterior of the coalescing element and permanently mounted to the tube sheet for providing structural support therefor, an inner support structure permanently coupled to the tube sheet and disposed around the interior of the coalescing element for providing structural support therefor, and a mechanism cooperatively arranged with the coalescing element to removably secure the coalescing element between the inner and outer support structures. The coalescing element has a coalescing medium and first and second end caps attached to the ends of the coalescing medium. At least one of the ends caps having a sealing mechanism for providing a fluid tight seal.

In accordance with another aspect, the present invention is directed to a coalescing system. The coalescing system includes a housing, and at least one coalescing assembly. The housing includes an inlet, at least one outlet, and a tube sheet which divides the housing into an uncoalesced fluid chamber and a coalesced fluid chamber and which has at least one opening therein for fluid to flow from the uncoalesced fluid chamber into the coalesced fluid chamber. The inlet being coupled to and communicating with the uncoalesced fluid chamber. The coalescing assembly is mounted to the tube sheet within the housing such that fluid flows from the inlet through the coalescing assembly. The coalescing assembly includes a coalescing element removably coupled to the tube sheet, an outer support structure removably coupled to the tube sheet and disposed around the exterior of the coalescing element for providing structural support therefor, an inner support structure permanently coupled to the tube sheet and disposed around the interior of the coalescing element for providing structural support therefor, and a mechanism cooperatively arranged with the coalescing element and the outer support structure to removably secure the outer support structure and the coalescing element around the inner support structure. The coalescing element has a coalescing medium and first and second end caps attached to the ends of the coalescing medium. At least one of the ends caps having a sealing mechanism for providing a fluid tight seal.

In accordance with another aspect, the present invention is directed to a coalescing system. The coalescing system comprises a housing, and at least one coalescing assembly. The housing includes an inlet, at least one outlet, and a tube sheet which divides the housing into an uncoalesced fluid chamber and a coalesced fluid chamber and which has at least one opening therein for fluid to flow from the uncoalesced fluid chamber into the coalesced fluid chamber. The inlet is coupled to and communicates with the uncoalesced fluid chamber. The coalescing assembly is mounted to the tube sheet within the housing such that fluid flows from the inlet through the coalescing assembly. The coalescing assembly includes a coalescing element removably coupled to the tube sheet, an outer support structure removably coupled to the tube sheet and disposed around the exterior of the coalescing element for providing structural support therefor, and a mechanism cooperatively arranged with the coalescing element and the outer support structure to releasably secure the coalescing element and the outer support structure within the housing. The coalescing element has a coalescing medium and first and second end caps attached to the ends of the coalescing medium, each having a sealing means for providing a fluid tight seal, and a support core.

In accordance with another aspect, the present invention is directed to a coalescing/separating system. The coalescing/separating system comprises a housing, at least one coalescing assembly, and at least one separating assembly. The housing includes first and second tube sheets which divide the housing into an uncoalesced fluid chamber, a coalesced fluid chamber and a continuous phase chamber, each of the first and second tube sheets have at least one opening therein, an inlet coupled to and communicating with the uncoalesced fluid chamber, a first outlet coupled to and communicating with the coalesced fluid chamber, and a second outlet coupled to and communicating with a continuous phase chamber. The coalescing assembly is mounted to the first tube sheet within the housing such that fluid flows from the inlet through the coalescing assembly. The coalescing assembly includes a coalescing element removably coupled to the first tube sheet, an outer support structure disposed around the exterior of the coalescing element for providing structural support therefor, and an inner support structure disposed around the interior of the coalescing element for providing structural support therefor. The coalescing element has a coalescing medium and first and second end caps attached to the ends of the coalescing medium, at least one of which includes a sealing mechanism for providing a fluid tight seal. The separating assembly is removably mounted to the second tube sheet. The separating assembly includes a separating medium.

In accordance with another aspect, the present invention is directed to a coalescing assembly which comprises one or more fixed components and a coalescer element removably mounted with the fixed components.

In accordance with another aspect, the present invention is directed to a coalescer element which may be mounted to or removed from fixed components.

Many of the coalescing systems, coalescing assemblies, and coalescing elements embodying the present invention are designed to facilitate rapid replacement of the spent components, thereby reducing system downtime. In addition, because many of the components are fixed and the coalescing element is removable, the number of components which have to be replaced is minimized, thereby reducing waste. Reducing system downtime and waste generally results in significant savings. For example, reduced system downtime results in higher processing yields per given time period. Reduced waste typically results in a two-fold cost savings. First, the cost of waste disposed is reduced. Second, the cost of replacement components is reduced when there are less components to replace.

The coalescing system, coalescing assembly, and coalescing element of the present invention may be utilized in a wide variety of coalescing operations and may comprise various configurations. However, for any given application and any given configuration, the system, assembly, and element are each designed such that the coalescing element may be rapidly and easily removed from the coalescing system without having to remove a significant number of components of the assembly, if any, from the coalescing system.

The coalescing element of the present invention may be utilized in existing systems with only minor modification, if any. In addition, the coalescing element, which may be the only disposable portion of the coalescing assembly may be manufactured inexpensively and therefore, represent a cost effective replacement module.

In a combination coalescing/separating assembly in accordance with the present invention, the separating assemblies are designed to facilitate and complete the separation process initiated by the coalescing assemblies while providing the advantages discussed above. Accordingly, the coalescing element is designed for easy separation from the separation element as well as for easy removal from the system. In addition, both the coalescing element and the separation assembly are designed with a minimal number of components, thereby leading to reduced costs as well as increased output because of reduced downtime.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1a and 1b are top and sectional views of a first exemplary coalescing system.

Figure 2 is a cross sectional view of a first embodiment of the invention showing a portion of a coalescing housing (including a coalescing cage fixed within the housing) and including a disposable coalescing element.

Figure 2a is a top view of the coalescing element of Figure 2.

Figure 2b is a slightly modified embodiment of cross sectional view of the coalescing system of Figure 2.

Figures 3a and 3b are top and sectional views of a second exemplary coalescing system.

Figure 4 is a cross sectional view of another embodiment of the present invention illustrating a disposable coalescing cartridge and a portion of a coalescing housing to which is fixed both a coalescer core and a coalescer cage.

Figure 4a is a top view of the coalescing element of Figure 4.

Figures 5a and 5b are top and sectional views of a third exemplary coalescing system.

Figure 6 illustrates in cross section another embodiment of the present invention including a disposable coalescing cartridge, a coalescer core fixed within a portion of the housing and a composite cage and final classifier removably fixed within the housing.

Figure 6a is a top view of the coalescing element of Figure 6.

Figures 7a and 7b are top and sectional views of a fourth exemplary coalescing system.

Figure 8 shows a cross sectional view of a portion of a coalescer housing which includes a disposable coalescing element and a composite cage and final classifier removably fixed within the housing.

Figure 8a is a top view of the coalescing element of Figure 8.

Figures 9a and 9b are top and sectional views of a fifth exemplary coalescing system.

Figure 10 shows a cross sectional view of a portion of a coalescer housing, a coalescing element and a separation element.

Figure 10a is a top view of the coalescing element of Figure 10.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Coalescing elements are structures which comprise a coalescing medium for separating one or more phases present in a fluid, i.e., separating a continuous phase of the fluid from a discontinuous phase of the fluid, where fluid may be a liquid and/or a gas. In some instances such fluid constitutes dispersions or suspensions of two or more immiscible liquids, and in other instances such fluid constitutes a gaseous aerosol. In describing the present invention, the term coalescing system shall be construed as a system comprising one or more coalescing assemblies and the term coalescing assembly shall be construed as comprising a coalescing element. The coalescing assembly may also comprise inner and/or outer support structures, and a final classifier which facilitates the separation process. In all instances, the coalescing element may be removed from the coalescing system.

The coalescing systems, assemblies, and elements of the present invention may comprise various configurations and components. For example, in certain embodiments one or both of the inner and outer support structures of the coalescing assembly may be permanently attached to a housing of the coalescing system, while in other embodiments neither the inner or outer support structures are attached to the housing of the coalescing system. Regardless of the particular configuration, however, in each of the exemplary embodiments presented below, the coalescing systems, assemblies, and elements are designed to facilitate removal and replacement of the coalescing elements. In addition, regardless of the particular configuration, each exemplary embodiment is designed such that components not subject to wear or deterioration can be replaced when routine maintenance is required. Accordingly, waste and expense may be minimized.

Figures 1a and 1b are top and sectional views of a first exemplary coalescing system 100. The coalescing system 100 comprises a housing 110 having at least one inlet 112, two outlets 114,116, a tube sheet 118 dividing the housing into an uncoalesced fluid chamber 111 and a coalesced fluid chamber 113 and a plurality of coalescing assemblies 120. The plurality of coalescing assemblies 120 may be oriented within the housing 110 vertically, horizontally, or at any angle between vertical and horizontal. A pressurized feed may be utilized in certain instances to supply fluid to the coalescing system 100; accordingly, the housing 110 may also comprise vents and pressure release valves, as well as fittings for inlet and outlet pressure gauges.

The housing 110 may comprise any configuration suitable for the particular coalescing application. In the exemplary embodiment, the housing 110 comprises a substantially cylindrical configuration. In addition, the housing 110 may be designed such that at least one section, e.g., the top or bottom, of the housing is removable. For example, the top of the housing 110 may comprise a removable cover 115 such as a swing-up cover. Alternatively, the top of the housing 110 may include bolts or pins to engage nuts, other threaded counterparts, or bayonet base portions in the wall of the housing 110 to removably secure a cover portion of the housing 110 to a base portion of the housing 110. The housing 110 may comprise any suitable material capable of providing the requisite structural support for the particular coalescing operation and which will not react with the fluid being processed.

The tube sheet 118 as stated above separates the housing 110 into two chambers 111,113. The tube sheet 118 may be removably or permanently attached to the housing 110. In the exemplary embodiment, the tube sheet 118 is permanently attached to the inner wall of the housing 110. The tube sheet 118 includes a plurality of openings through which fluid from the uncoalesced fluid chamber 111 flows into the coalescing assemblies 120 in the coalesced fluid chamber 113. The tube sheet 118 also functions to support and maintain the spacing between the coalescing assemblies 120. The coalescing assemblies 120 may be secured to the tube sheet 118 in any suitable manner such that fluid flows through the openings in the tube sheet 118 and into the interior region of the coalescing elements of the coalescing assemblies 120. The coalescing assemblies 120 may be attached directly to the tube sheet 118 or indirectly via standoff tubes 122. If the coalescing assemblies 120 are attached directly to the tube sheet 118, a constant drain, e.g., a scavenge flow, may be preferred so that the coalescing assemblies are not submerged in the discontinuous phase fluid. In the exemplary embodiment illustrated in Figure 1b, the coalescing assemblies 120 are preferably connected to the tube sheet 118 via standoff tubes 122. The standoff tubes 122 raise the height of the coalescing assemblies 120 for easy removal of the coalescing elements from the housing 110, i.e., the coalescing elements are closer to the top of the housing 110. In addition, the standoff tubes 122 raise the level of the coalescing assemblies 120 such that they are not submerged in the discontinuous phase fluid. The tube sheet 118 and the standoff tubes 122 may comprise any suitable material capable of providing sufficient structural support for the coalescing assemblies 120 and which will not react with the particular fluid being processed.

Fluid which is to undergo coalescence enters the uncoalesced fluid chamber 111 of the housing 110 through inlet 112. The fluid flows from the uncoalesced chamber 111 through the openings in the tube sheet 118, through the standoff tubes 122 and into the coalescing assemblies 120 which are in the coalesced fluid chamber 113. The fluid then passes through coalescing elements of the coalescing assemblies 120 and the coalescing media of the coalescing elements, discussed in detail subsequently, wherein the fluid is coalesced. In coalescence, one phase of the fluid passes through the medium, this phase of the fluid being referred to as the continuous phase. The other phase of the fluid tends to collect or be captured on the medium in droplet form before continuing through the medium, this phase of the fluid being referred to as the discontinuous phase. From the coalescing assembly 120 both the continuous phase and discontinuous phase pass into the coalesced fluid chamber 113. Typically, the continuous phase is removed via one outlet and the discontinuous phase is removed via a separate outlet. For example, if in the exemplary embodiment the fluid undergoing coalescence comprises two liquids and the one liquid forming the discontinuous phase is more dense than the other liquid, then the continuous phase liquid exits the housing 110 through outlet 114 and the discontinuous phase, with the help of gravity and a final classifier, discussed subsequently, runs down the medium and collects at the bottom of the coalesced fluid chamber 113 and exits the housing 110 via outlet 116. If the discontinuous phase were less dense than the continuous phase, then the positions of the inlets and outlets may be reversed.

Figure 2 is a detailed partial sectional view of the coalescing assembly 120 of the coalescing system 100 of Figures 1a and 1b. The coalescing assembly 120 may, as described above, be attached to the tube sheet 118 of the housing 110 via standoff tubes 122. In this embodiment, the coalescing assembly 120 comprises a coalescing element, an outer support structure 124, an alignment element 136, a sealing collar 142, and a fastener 138. In the exemplary embodiment of Figure 2, the coalescing element includes a coalescing medium 128, an upper end cap 132, a lower end cap 134, and a support core 130. Preferably, the coalescing element consists only of a coalescing medium 128, an upper end cap 132, a lower end cap 134, and a support core 130. The coalescing assembly 120 may be designed such that the coalescing element may be quickly and easily removed from the fixed components of the coalescing assembly 120 and from the housing 110. Accordingly, when replacement of the coalescing element becomes necessary, only the coalescing element itself need be removed, thereby leaving the outer support structure 124, alignment element 136, sealing collar 142, and fastener 138 intact and reusable inside the housing 110. With a reduction in the number of components which have to be discarded, waste is reduced as well as expense.

The coalescing element may comprise any suitable configuration for the particular coalescing process. In the exemplary embodiment the coalescing element comprises a substantially cylindrical configuration and, as stated above, comprises the coalescing medium 128, the core 130, and the upper and lower end caps 132,134. The coalescing medium 128 may include any type of medium suitable for the application in which the coalescing element is employed. Typically, the coalescing medium uses fibrous materials, such as a fibrous mass, fibrous mats, woven or non-woven fibrous sheets, or porous membranes, such as supported or non-supported microporous membranes. The coalescing medium 128 may have a uniform or graded pore structure and any appropriately effective pore size. The coalescing medium 128, in addition to being porous, may be configured in a non-pleated or pleated arrangement, and when pleated, the pleats may be straight, radially extending from the axis of the cylindrical coalescer, or they may be arranged in a laid-over configuration. Preferably, the coalescing medium 128 is configured in a radial pleat structure as illustrated in Figure 2a which is a top view of the coalescing assembly 120.

In the exemplary embodiment, the coalescing medium 128 may comprise glass fibers or polymers such as olefins, polyesters, fluoropolymers, and nylon. Preferably, the coalescing medium 128 comprises a glass fiber medium having a surface modifying coating thereon. The particular surface modifying coating may be selected to have the requisite critical surface energy for the particular application. Examples of glass fiber media and surface modifying coatings are described in U.S. Patent No. 4,759,782, assigned to the same assignee as the present invention and incorporated by reference herein.

In the exemplary embodiment, the upper end cap 132 is a blind end cap and the lower end cap 134 is an open end cap. Accordingly, fluid to be coalesced enters through an opening in the lower end cap 134 and is constrained to flow through the coalescing medium 128 by the upper blind end cap 132.

The upper and lower end caps 132,134 may comprise any suitable fluid impervious material which is compatible with the particular fluid being treated. For example, the end caps 132,134 may comprise any impervious metals, ceramics, elastomers, or polymeric materials. In a preferred embodiment, the end caps 132,134 comprise polymeric materials.

The upper and lower end caps 132,134 may be attached to the ends of the coalescing medium 128 in any suitable manner. For example, the end caps may be thermally bonded, spin welded, sonically welded, polycapped, or bonded by means of an adhesive or a solvent to the ends of the coalescing medium 128. In the preferred embodiment, the end caps 132,134 are thermally bonded to the ends of the coalescer medium 128.

The upper end cap 132 comprises a substantially circular configuration and includes a small opening in a central region thereof to position the fastening means 138 of the coalescing assembly 120. The upper end cap 132 may be thicker in this region to provide sufficient structural integrity for the fastening means 138. In addition, the upper end cap 132 comprises a sealing mechanism 150 along an outer periphery of the end cap 132. The sealing mechanism 150 provides for a substantially fluid tight seal between the end cap 132 and the outer support structure 124 to prevent fluid by-pass. The sealing mechanism 150 comprises an annular channel 152 in a lower surface of the upper end cap 132 and a sealing member 154 such as an O-ring seal. The channel 152 and sealing member 154 are preferably configured such that the O-ring seal 154 does not extend past the annular channel 152; rather, a sealing end of the outer support structure 124 extends into the channel 152 and contacts the O-ring 154. The O-ring 154 may be energized by compressive forces generated when the coalescing element is connected to the remaining components of the coalescing assembly 120 by the fastener 138. Alternatively, in place of the O-ring 154, the sealing end of the outer support structure 124, where it partially extends into the channel 152, could be coined or swaged to achieve an interference fit. Depending upon the materials from which the end cap 132 and outer support structure 124 are formed, as well as the tolerance and specifications to which the engaging portions the end cap 132 and support structure 124 are formed, sealing means such as an O-ring may not be necessary.

The lower end cap 134 comprises an annular configuration and includes a sealing mechanism 144 along an inner periphery thereof. The sealing mechanism 144 provides a substantially fluid tight seal between the end cap 134 and the sealing means 142 of the coalescing assembly 120 to prevent fluid by-pass. The sealing mechanism 144 comprises an annular channel 146 and a sealing member 148 such as an O-ring seal. The channel 146 and the sealing member 148 are preferably configured such that the O-ring seal 148 extends past the recess 146 and contacts the sealing collar 142 of the coalescing assembly 120. The O-ring 148 may be energized by the compressive forces generated when the coalescing element is forced over the sealing arrangement 142.

In the embodiment of Figure 2 the coalescing element also comprises the support core 130 which provides structural support for the coalescing medium. The upstream or inner surface of the coalescing medium 128 lies adjacent to or contacts the coaxially positioned core 130 and may be permanently attached to the end caps 132,134 by any suitable means. The core 130 may be formed from very open pore or perforated materials which are chemically compatible with the fluid undergoing coalescence. The core 130 may also be chemically inert, i.e., substantially unreactive with substances present in the fluids being treated by the coalescing element. The core 130 provides structural support for the coalescing element against radially inward directed forces caused by fluid flow during a coalescing operation.

The core 130 may include any substantially rigid structure which functions to prevent the coalescing medium 128 from collapsing inward under the pressure of an inwardly directed flow of fluid or from the forces generated during insertion of the coalescing element 120 into the outer support structure 124. The core 130 preferably comprises a multiplicity of openings to permit the passage of fluid through the coalescing element 120 without creating any substantial pressure differential between an inlet of the coalescing system utilizing the coalescing element 120 of the present invention and an outlet of the coalescing system.

The core 130 may comprise any material which has sufficient strength to withstand the forces generated by the fluid during coalescing and which is compatible with the particular fluid and its constituents. For example, the core 130 may comprise metallic materials, such as stainless steel or plated carbon steel, or polymeric materials, such as polyphenylene sulfide, polyester, polypropylene or acetals. In a preferred embodiment, the core 130 comprises stainless steel.

A filter may be placed within the coalescing element to capture particulate material before it contacts the coalescing medium 128. For example, the filter may be a depth filter having an effective pore size significantly different from that of the coalescing medium 128. A filter with a graded pore structure which tapers from upstream to downstream may be particularly advantageous because the larger pores may be utilized to remove particulate matter and the smaller pores may aid in coalescence.

Many of the remaining components of the coalescing assembly 120 of this first exemplary coalescing system 100 are fixed components which are not removed from the housing 110. The fixed components include the outer support structure 124, the alignment element 136, the sealing collar 142 and the fastener 138. These components may be permanently attached to the standoff tube 122 or to the tube sheet 118 directly. In the exemplary embodiment, as illustrated in Figures 1b and 2, the outer support structure 124, the alignment element 136, the sealing collar 142, and the fastener 138 are attached to the standoff tubes 122.

The outer support structure 124 may comprise a support element, such as a cage, and/or a final classifier. The cage provides radial and axial strength and rigidity against radially outward and axially directed forces acting on the coalescing medium 128. Thus, the cage not only provides structural integrity and rigidity for the coalescing element but also supports the coalescing element to minimize distortions or ruptures from forces generated during fluid flow. Thus, the cage functions as a hoop stress structural member. The final classifier functions as a porous drainage layer. In acting as a drainage layer, the final classifier assists the coalescing medium to accumulate the droplets of liquid. For example, if as stated above the discontinuous phase is more dense than the continuous phase the final classifier assists the coalescing medium to accumulate liquid in a lower region of the coalesced fluid chamber 113 of the housing 110. To improve drainage and accumulation of liquid droplets, the final classifier may be coated with or formed from a material which facilitates coalescence by allowing droplets to form, collect and fall to a drain area. For example, the final classifier may be formed from a material which facilitates the separation of the discontinuous phase from the continuous phase and is chemically inert to each of the materials present in the phases being separated. Polyester materials are preferred with polybutylene terephthlate being most preferred. Preferably, the material is present in fibrous form as a non-woven material, typically air-laid or needled. The final classifier may have any suitable thickness or Frasier number and it preferably has a coarser pore structure than the coalescing medium. An example of a preferred final classifier is a polyester, non-woven, air laid fibrous bat having a thickness of about .25 - .375 inch. U.S. Patent No. 5,443,724 and U.S. Patent No. 4,759,782, both assigned to the same assignee or the present invention and incorporated by reference herein disclose various materials which facilitate coalescence.

The outer support structure 124 may comprise a final classifier and support element formed as a single, integral unit or as separate elements. In the instance where the final classifier and support element are formed as a single, integral unit, the support element may be coated with a material which repels, i.e., which is not wetted by, the discontinuous phase of the fluid. It is the material that may be coated on the support element which acts as the final classifier. In the exemplary embodiment, the outer support structure 124 comprises a combined final classifier and support element.

As stated above, the support element may comprise any structure capable of providing support for the coalescing medium, such as a cage. In the exemplary embodiment, the support element comprises a porous cage concentrically disposed around the downstream or outer surface of the coalescing medium 128 such that the medium 128, e.g., the outer ends of the radial pleats, contact the inner surface of the cage, as is illustrated in detail in Figure 2b. The cage provides axial and radial strength and rigidity against forces acting on the coalescing medium 128. This may be particularly advantageous when the coalescing element is used in coalescing arrangements in which fluid flow is from the inside of the element to the outside of the element.

The tolerance between the inner surface of the cage and the outer diameter of the coalescing medium 128 should be close enough to allow sufficient support of the coalescing medium 128 but not close enough to inhibit insertion and/or removal of the coalescing element or to distort the coalescing medium 128 when disposed within the cage. The cage may be configured such that there is an extremely small gap 156 between the inner surface of the cage and the outer surface of the coalescing medium 128. This small gap 156 provides for axial movement of the coalescing element within the cage during insertion and/or removal of the coalescing element while providing structural support for the medium 128.

The cage preferably comprises a porous structure to permit the passage of fluid through the coalescing element without creating any substantial pressure differential between the upstream and downstream regions of the coalescing element. In addition, the porous structure may be utilized to reduce turbulence and to orient or straighten fluid flow which aids in the coalescence of the fluid.

Materials suitable for use as the cage include any materials which are chemically compatible with the fluids passing through the coalescing element. For example, the cage may comprise polymeric or metallic materials. In a preferred embodiment, the cage comprises a porous sintered metal structure. The sintered metal structure preferably comprises a structure having a substantially uniform pore distribution along the face of the structure, each pore having a mean geometric pore size in the range from about 10 thousandths of an inch to about 250 thousandths of an inch. The sintered metal structure provides for a more uniform flow and facilitates the coalescence of larger droplets of the discontinuous phase. In a preferred embodiment, the cage comprises a sintered fiber metal, such as sintered stainless steel fibers and includes a wire reinforcement 125 circumferentially or helically arranged in the cage to provide additional support.

The final classifier, as stated above, may comprise a coating on the cage. The coating comprises a material which is not wetted by the droplets of the discontinuous phase. Such a material should not react with any liquid or other substance present in the fluid to be processed. Essentially, the material should have a critical surface energy below the surface tension of the discontinuous phase fluid. For example, in applications in which water is the discontinuous phase, materials which may be coated on the cage include silicones and fluoropolymeric materials.

Alternatively, or in addition to the cage and final classifier, an upstream support and/or drainage material may be utilized to support the coalescing medium 128 and facilitate coalescence. Since most cylindrical coalescer elements are employed in situations in which flow is in an inside-out direction, provisions are generally taken to protect the downstream surface of the medium from damage and undue compression induced by elevated pressures, turbulent flow conditions, or installation of the element into the outer support structure 124. Thus in order to retain structural integrity and allow free flow of liquid, porous wrap may be disposed or wound around the downstream side of the medium. The wrap may comprise any suitable material, including a polymeric or plastic, glass, or metallic material, and may have any suitable structure, such as a woven or non-woven fabric or a mesh. For example, a PVC coated glass fabric or a stainless steel mesh may be placed around the medium. Alternatively, a needled felt or air laid fiber batting, preferably formed from polyester, may be placed around the medium. This element, which has very large pores, i.e., significantly larger than those of the coalescing medium, is provided to reduce turbulence and to orient or "straighten" fluid flow. Optionally, a "sock" or outer sleeve formed from Reemay fabric, Orlon fabric or cotton may be located downstream of the turbulence-reducing layer to prevent fiber migration from the latter layer.

The outer support structure 124 may be attached directly to the tube sheet 118 of the housing 110 or it may preferably be attached to the standoff tube 122. In the exemplary embodiment illustrated in Figure 2, the support structure 124 is permanently mounted at one end thereof to a support section 123 of the standoff tube 122. The support section 123 may comprise an annular disc having a central opening corresponding to the opening of the standoff tube 122. The support section 123 serves as a platform to which the outer support structure 124 as well as the other components of the coalescing assembly 120 are attached. The outer support structure 124 may be permanently attached to the support section 123 by any suitable means including welding, brazing, soldering or appropriate adhesive means. In the exemplary embodiment, the outer support structure 124 may be permanently attached to the support section 123 by a weld joint 126. The free end of the outer support structure 124 serves as a sealing end as described above.

The alignment element 136 may comprise any structure suitable for guiding the coalescing element into position within the outer support structure 124. In alternative embodiments, no alignment means may be utilized. In the exemplary embodiment, the alignment element 136 comprises a tapered spade with a maximum width less than the inside diameter of the core 130 of the coalescing element. The alignment element 136 may be permanently mounted to the support section 123 of the standoff tube 122 by any suitable means and may comprise any material which does not react with the fluid undergoing coalescence. In the illustrated embodiment, the alignment element 136 is welded to the sealing collar 142 which in turn is welded to the standoff tube 122.

The sealing collar 142 may comprise any suitable structure for providing a sealing surface for the sealing mechanism 144 of the lower open end cap 134 to prevent fluid by-pass as described above. In the exemplary embodiment, the sealing collar 142, comprises a sealing post which may be permanently attached to the support section 123 of the standoff tubes 122. The sealing collar 142 may comprise any suitable material which will not react with the particular fluid and may be attached to the support section 123 by any suitable means.

The fastener 138 may comprise any releasable type structure for removably securing the coalescing element within the outer support structure 124. In the exemplary embodiment, the fastener 138 comprises a tie rod. The tie rod 138 may be positioned at the longitudinal axis of the cylindrical coalescing element and extend through the coalescing element. The lower end of the tie rod 138 may be attached to a portion of the standoff tube 122, for example, the support section 123. The lower end of the tie rod 138 may be permanently or removably mounted to the support section 123 by any suitable means. In the illustrated embodiment, the tie rod 138 is fixed to the alignment spade 136. The upper or free end of the tie rod 128 may be positioned through the opening in the upper end cap 132. The free end of the tie rod 138 may comprise any suitable structure for securing the coalescing element into position. In the exemplary embodiment, the upper end comprises a threaded section 140 so that a nut 141 or other securing means may be utilized. One or more gaskets and/or washers 143 may be utilized to provide a fluid tight seal thereby preventing fluid by-pass through the opening in the end cap 132.

Figure 2a illustrates a slightly modified embodiment where the coalescing assemblies 120 are attached directly to the tube sheet 118. The modified embodiment is similar in structure and operation to the first exemplary coalescer 100 except the outer support structures 124 and the sealing collar 142 are connected directly to the tube sheet 118. The standoff tubes 122 and the supporting sections 123 may be eliminated.

Figures 3a and 3b are top and sectional views of a second exemplary coalescing system 200. Many of the components and features of the second exemplary coalescing system 200 may be used with the first exemplary coalescing system 100 and vice versa. Accordingly it is within the scope of the invention to combine any one or more of the components or features of one exemplary system with one or more components or features of the other exemplary system.

The second exemplary coalescing system 200 comprises a housing 210 having at least one inlet 212, two outlets 214,216, and a tube sheet 218 dividing the housing into an uncoalesced fluid chamber 211 and a coalesced fluid chamber 213, and a plurality of coalescing assemblies 220. The plurality of coalescing assemblies 220 may be oriented within the housing 210 vertically, horizontally, or at any angle between vertical and horizontal. A pressurized feed may be utilized in certain instances to supply fluid to the coalescing system 200; accordingly, the housing 210 may also comprise vents and pressure release valves, as well as fittings for inlet and outlet pressure gauges.

As in the above described first exemplary embodiment, the housing 210 may comprise any suitable configuration for the particular application and may be designed such that at least one section, e.g., a cover 215, is removable. In addition, the coalescing assemblies 220 may be secured to the tube sheet 218 directly or indirectly via standoff tubes 222. Preferably, the coalescing assemblies 220 are secured to the standoff tubes 222 for the reasons explained above. Also, the fluid flow path in the present embodiment may be identical to the fluid flow path described with respect to the first exemplary embodiment.

Figure 4 is a detailed partial sectional view of the coalescing assembly 220 of the coalescing system of Figures 3a and 3b. The coalescing assembly 220 may, as described above, be attached to the tube sheet 218 of the housing 210 via standoff tubes 222. In this exemplary embodiment, the coalescing assembly 220 comprises a coalescing element, an outer support structure 224, an inner support structure 230, a closure cap 262, and a closure element 264. The exemplary coalescing element comprises a coalescing medium 228, an upper end cap 232, and a lower end cap 234. Preferably, the coalescing element consists only of a coalescing medium 228, an upper end cap 232, and a lower end cap 234. The coalescing assembly 220 may be designed such that the coalescing element may be quickly and easily removed from the fixed components of the coalescing assembly 220 and from the housing 210. Accordingly, when replacement of the coalescing element becomes necessary, only the coalescing element itself need be removed, thereby leaving the outer and inner support structures 224,230, the closure cap 262, and the closure element 264 for reuse inside the housing 210. With a reduction in the number of components which have to be discarded, waste is reduced as well as expense.

In this embodiment, as compared to the previous embodiment, the coalescing element comprises one less component, i.e., the support core 130, which may be replaced by the inner support structure 230. In certain applications, the inner support structure may be an expensive component which need not be replaced when the remaining components of the coalescing element require replacement. Accordingly, a significant cost savings may be achieved.

The coalescing element may comprise any suitable configuration for the particular coalescing process. In the exemplary embodiment of Figure 4, the coalescing element comprises a substantially cylindrical configuration, and as stated above, comprises the coalescing medium 228, the upper end cap 132, and the lower end cap 134. The coalescing medium 228 may include any type of medium suitable for the application in which the coalescing element is employed. For example, the coalescing medium 228 may comprise the same configuration and materials as that of the coalescing medium 120 described above.

In the exemplary embodiment, the upper and lower end caps 232,234 are both open end caps. The upper and lower end caps 232,234 may comprise any suitable fluid impervious material which is compatible with the particular fluid being treated. The upper and lower end caps 232,234 may also be attached to the coalescing medium 228 via any suitable means. In the exemplary embodiment, the upper and lower end caps 232,234 may comprise the same materials and be attached in the same manner as that of the previously described embodiment.

The upper end cap 232 comprises an annular disc structure having a sealing mechanism 276 mounted around an inner periphery of the end cap 232. The sealing mechanism 276 provides for a substantially fluid tight seal between the end cap 232 and the inner support structure 230 to prevent fluid by-pass. The sealing mechanism 276 comprises an annular channel 278 and a sealing member 280 such as an O-ring seal. The annular channel 278 and the sealing member 280 are preferably configured such that the O-ring seal 280 extends past the annular recess 278 and contacts the inner support structure 230 of the coalescing assembly 220. The O-ring seal 280 may also be energized by the compressive forces generated when the coalescing element is positioned between the inner and outer support structures 230,224.

The lower end cap 234 comprises an annular configuration and includes a sealing mechanism 244 along an inner periphery thereof. The sealing mechanism 244 provides a substantially fluid tight seal between the end cap 234 and the inner support structure 230 of the coalescing assembly 220 to prevent fluid by-pass. The sealing mechanism 244 comprises an annular channel 246 and a sealing member 248 such as an O-ring seal. Again, the annular channel 246 and the sealing member 248 are preferably configured such that the O-ring seal 248 extends past the recess 246 and contacts the inner support structure 230 of the coalescing assembly 220. The O-ring 248 may be energized by the compressive forces generated when the coalescing element is connected to the remaining components of the coalescing assembly 220.

As in the previously described embodiment, a filter may be positioned within the coalescing element to capture particulate material before it contacts the coalescing medium 228.

Many of the remaining components of the coalescing assembly 220 of this second exemplary coalescing system 200 are fixed components which are not removed from the housing 210. The fixed components include the outer support structure 224, the inner support structure 230, and the closure element 264. The inner and outer support structures 230,224 may be permanently attached to the standoff tubes 222 or directly to the tube sheet 218. In the preferred embodiment illustrated in Figure 4, the inner and outer support structures 224,230 are permanently attached to the standoff tubes 222 for the reasons explained above. The closure cap 262, however, may be removable. In the exemplary embodiment, the removable closure cap 262 may be mounted to the closure element 264 which may be permanently attached to the inner support structure 230. These elements serve to secure and seal the coalescing element in position.

The outer support structure 224 may be identical to the outer support structure 124 of the previously described embodiment. Specifically, the outer support structure 224 preferably comprises a combination cage and final classifier. In addition, the outer support structure 124 may be mounted to the standoff tubes 222 in an identical manner as that of the previously described embodiment. The exemplary coalescing assembly 220 may also comprise upstream support and/or drainage material as described above.

The inner support structure 230 may comprise any structure suitable for supporting the coalescing medium 228. Unlike the previously described embodiment, the inner support structure 230 may be permanently attached to the support surface 223 of the standoff tubes 222 similarly to the attachment of the outer support structure 224. In the illustrated embodiment the inner support structure 230 is attached to the support section 223 by a weld joint (not illustrated), and comprises an annular projection 258 at a lower end thereof. The annular projection 258 provides a sealing surface for the O-ring 248 of the sealing mechanism 244.

The inner support structure 230 comprises the same materials, i.e., materials substantially unreactive with substances present in the fluids being treated by the coalescing element, and the same basic structure where it is adjacent to the coalescing medium 228, i.e., substantially rigid open pore structure, as the exemplary core 130 described above with respect to Figure 2. The inner support structure 230 may, however, differ from that of the support core 130 described above in a number of respects. For example, as described above, the inner support structure may be permanently affixed to the support section 223 of the standoff tubes 222 and it may comprise the annular projection 258 as a sealing surface for the O-ring 248 of the sealing mechanism 244. In addition, both the upper and lower regions of the inner support structure 230 may comprise structures which facilitate the positioning of the coalescing element between the inner and outer support structures 230,224. For example, the upper region may comprise a tapered or beveled section 231 so that the coalescing element may be inserted without incurring damage due to abrasion or the like. The upper tapered section 231 may have a smaller diameter section which is less than the inner diameter of the upper end cap 232 of the coalescing element and a larger diameter section which is substantially equal to the inner diameter of the upper end cap 232 of the coalescing element. Similarly, the lower region may also comprise a tapered or beveled section 233. The lower tapered section 233 may have a smaller diameter section which is less than the inner diameter of the lower end cap 234 of the coalescing element and a larger diameter section which is substantially equal to the sealing mechanism 244 portion of the lower end cap 234.

The tolerance between the internal diameter of the outer support structure 224 and the outer diameter of the coalescing medium 228 preferably is close enough to allow sufficient support of the coalescing medium 228 but not close enough to inhibit insertion and/or removal of the coalescing element 220 or to distort the coalescing medium 228 when placed within the outer support structure 224. Likewise, the tolerance between the outer diameter of the inner support structure 230 and the inner diameter of the coalescing medium 228 preferably is close enough to allow sufficient support of the coalescing medium 228 but not close enough to inhibit insertion and/or removal of the coalescing element 220 or to distort the coalescing medium 228 when placed over the core 230.

Figure 4a illustrates the gap 256 between the coalescing element and the inner and outer support structures 230,224.

The closure cap 262 and the closure element 264 facilitate the rapid removal and replacement of the coalescing element. The closure cap 262 may be positioned above the upper end cap 232 to secure the coalescing element in position as well as to ensure the flow of the fluid entering the coalescing element exits through the coalescing medium 228 and not through the open end cap 232. A closed end cap structure similar to the above described first embodiment may be utilized instead of the additional two elements 262,264; however, an open end cap may be less expensive than a blind end cap because less material is utilized in the manufacture thereof so that when the coalescing element is replaced waste and cost are reduced. The closure cap 262 and the closure element 264 unlike the end caps which are attached to the coalescing medium, may be saved and reused.

The closure element 264 may comprise an imperforate disc mounted to an upper portion of the inner support structure 230. The closure element 264 may be attached to the inner support structure 230 by any suitable means including welding, bonding or via a threaded connection. The closure cap 262 may also comprise an imperforate disc contoured to fit around the closure element 262 and the coalescing element. The closure cap 262 may be secured to the closure element 264 by various means. In the exemplary embodiment, a short threaded rod 266 or the like may be placed in one or the other of the closure cap 262 or closure element 264 and engage a commensurately threaded portion in the other closure member. Another option may be to utilize the tie rod, illustrated in Figure 2, which may pass through both the closure cap 262 and closure element 264, as described above. Alternatively, a form of a clamping device may be employed. A quick release type structure is preferred for easy removal.

The closure cap 262 and the closure element 264 may comprise any suitable fluid impervious material which is compatible with the particular fluid being treated. For example, the closure cap 262 and the closure element 264 may comprise any impervious metals, ceramics, elastomers or polymeric materials. In a preferred embodiment, the closure cap 262 and the closure element 264 comprise stainless steel.

The closure cap 262 comprises a sealing mechanism 270 to prevent fluid by-pass between the outer support structure 224 and the closure cap 262. The sealing mechanism

270 comprises an annular recess 272 and a sealing member such as an O-ring 274. The O-ring 274 preferably contacts the upper end of the outer support structure 224 in a manner similar to that described for the sealing mechanism 150 of the first exemplary embodiment of the coalescing assembly 120. The O-ring 274 is energized by the compressive forces generated when the cap 262 is secured to the closure element 264.

As one of the differences from the coalescing element illustrated in Figure 2, the coalescing element illustrated in Figure 4 preferably does not include an alignment spade 136 or seal collar 142. In this embodiment, the inner support structure 230, in addition to serving its intended function of providing structural support for the coalescing element, also serves to align and position the coalescing element as well as to insure adequate fluid sealing.

Figures 5a and 5b are top and sectional views of a third exemplary coalescing system 300. Many of the components and features of the third exemplary coalescing system 300 may be used with the first or second exemplary coalescing system 100,200 and vice versa. Accordingly, it is within the scope of the invention to combine any one or more of the components or features of one of these exemplary systems with one or more components or features of the other exemplary systems.

The third exemplary coalescing system 300 comprises a housing 310 having at least one inlet 312, two outlets 314,316, a tube sheet 318 dividing the housing into an uncoalesced fluid chamber 311 and a coalesced fluid chamber 313, and a plurality of coalescing assemblies 320. The plurality of coalescing assemblies 320 may be oriented within the housing 310 vertically, horizontally, or at any angle between vertical and horizontal. A pressurized feed may be utilized in certain instances to supply fluid to the coalescing system 300; accordingly, the housing 310 may also comprise vents and pressure release valves, as well as fittings for inlet and outlet pressure gauges.

As in the above described first and second exemplary embodiments, the housing 310 may comprise any suitable configuration for the particular application and designed such that at least one section, e.g., a cover 315, is removable. In addition, the coalescing assemblies 320 may be secured to the tube sheet 318 directly or indirectly via standoff tubes 322. Also, the fluid flow path in the present embodiment may be identical to the fluid flow path described with respect to the first exemplary embodiment.

Figure 6 is a detailed partial sectional view of the coalescing assembly 320 of the coalescing system 300 of Figures 5a and 5b. The coalescing assembly 320 may, as described above, preferably be attached to the tube sheet 318 of the housing 310 via standoff tubes 322. In this exemplary embodiment, the coalescing assembly 320 comprises a coalescing element, an inner support structure 330, a closure cap 362, and a closure element 364. The exemplary coalescing element comprises a coalescing medium 328, an upper end cap 332 and a lower end cap 334. Preferably, the coalescing element consists only of a coalescing medium 328, an upper end cap 332 and a lower end cap 334. The coalescing element may be identical to the coalescing element of Figure 4, and as described above, the coalescing element may be quickly and easily removed from the fixed components of the coalescing assembly 320 and from the housing 310. Accordingly, when replacement of the coalescing element becomes necessary, only the coalescing element itself need be removed. The fixed components include the inner support structure 330 and the closure element 364, which may be identical to those described in the second embodiment described above with respect to Figure 4. However, unlike the previously described embodiments, an outer support structure 324 may be separately provided. Alternately, the outer support structure 324 may be permanently attached to the coalescing element. Additionally, in accordance with another aspect of the present invention, the outer support structure 324 comprises a separate support element 382 and final classifier 376, both of which may be permanently or removably mounted to the coalescer element and not the support section 323 of the standoff tubes 322.

The outer support structure 324 may preferably be removably disposed concentrically around the coalescing element such that the support element 382 comes into contact with the coalescing medium 328. As illustrated in Figure 6a, the crests of the radial pleats of the coalescing medium 328 may be in contact with the inner surface of the support element 382. The outer support structure 324 may be secured in position around the coalescing element by any suitable means such as wire ties or bands 378,380. Since the outer support structure 324 is removably secured to the coalescing element, they may be removed with the coalescing element and easily cleaned when the coalescing element is discarded and then easily reattached to the new coalescing element before being reinserted into position within the housing 310.

The support element 382 may comprise a wrap and/or cage for providing axial strength and rigidity against radially outward directed forces acting on the coalescing medium 328. In the exemplary embodiment, the support element 382 comprises a porous cage concentrically disposed around the coalescing element 382. The support element 382 also comprises upper and lower annular flared rim sections 384,386, each of which makes contact with a sealing mechanism 370 and 388. The upper sealing mechanism 370 may be identical to the sealing mechanism 270 described above. The lower sealing mechanism 388 comprises an annular recess 390 in an upper surface of the support section 323 of the standoff tubes 322 and an O-ring seal 392 positioned in the recess 390. Both seals 374 and 392 contact the flared rim sections 384 and 386 and are energized by the compressive forces when the coalescing element is secured in position.

In an alternative embodiment, the support element 382 may comprise a material which eliminates the need for O-ring seals 374,392. For example, the flared rim sections 384,386 may be secured in channels 372 and 390 such that an interference fit is formed, thereby preventing fluid by-pass.

The cage 382 preferably comprises a porous structure to permit the passage of fluid through the coalescing element without creating any substantial pressure differential between the upstream and downstream regions of the coalescing element. In addition, the porous structure may be utilized to reduce turbulence and to orient or straighten fluid flow which aids in the coalescence of the fluid. However, unlike the above described embodiments, a sintered structure may not be preferred because the cage 382 is used primarily for support in this embodiment, whereas in the previous embodiments, the outer support structure comprised a combination cage and final classifier.

Materials suitable for use as the cage include any materials which are chemically compatible with the fluids passing through the coalescing element. For example, the cage may comprise polymeric or metallic materials. In a preferred embodiment, the cage comprises perforated or expanded metals such as stainless steel.

The final classifier 378, as stated above, functions as a porous drainage layer which facilitates the coalescence process by aiding gravity and reducing the adhesive properties of the fluid and allowing the droplets to fall. Unlike the combined final classifier/cage of the first two embodiments, the final classifier 376 is a separate structure which may be attached to the support element 382 by the ties or bands 378,380.

The final classifier, which may be similar to the previously described final classifier, preferably comprises a cylindrical configuration and comprises suitable materials for facilitating coalescence of the particular fluids. In the exemplary embodiment, the final classifier 376 comprises a fibrous matting formed from a polymeric material, such as a polyester. Suitable as a polyester is polybutylene terephthlate.

Figure 6a illustrates the spacing between the various components of the coalescer assembly 320. As illustrated, there may be contact between the support element 382, the final classifier 376, the coalescing medium 328 and the inner support structure 330. Alternatively, there may be gaps between various pairs of these structures.

Figures 7a and 7b are top and sectional views of a fourth exemplary coalescing system 400. Many of the components and features of the fourth exemplary coalescing system 400 may be used with the previous coalescing systems 100,200,300 and vice versa. Accordingly, it is within the scope of the invention to combine any one or more of the components or features of one of these exemplary systems with one or more components or features of the other exemplary systems. The fourth exemplary coalescing system 400 comprises a housing 410 having at least one inlet 412, two outlets 414,416, a tube sheet 418 dividing the housing into an uncoalesced fluid chamber 411 and a coalesced fluid chamber 413, and a plurality of coalescing assemblies 420. The plurality of coalescing assemblies 420 may be oriented within the housing 410 vertically, horizontally, or at any angle between vertical and horizontal. A pressurized feed may be utilized in certain instances to supply fluid to the coalescing system 400; accordingly, the housing 410 may also comprise vents and pressure release valves, as well as fittings for inlet and outlet pressure gauges.

As in the above described exemplary embodiments, the housing 410 may comprise any suitable configuration for the particular application and designed such that at least one section, e.g., a cover 415, is removable. In addition, the coalescing assemblies 420 may preferably be secured to the tube sheet 418 indirectly via standoff tubes 422. Also, the fluid flow path in the present embodiment may be identical to the fluid flow path described with respect to the first exemplary embodiment.

Figure 8 is a detailed partial sectional view of the coalescing assembly 420 of the coalescing system of Figures 7a and 7b. In this embodiment, the coalescing assembly 420 comprises a coalescing element, an alignment element 436, a sealing collar 442, and a fastener 438. The exemplary coalescing element comprises a coalescing medium 428, an upper end cap 432, a lower end cap 434, and a support core 430. Preferably, the coalescing element consists only of a coalescing medium 428, an upper end cap 432, a lower end cap 434, and a support core 430. As described above with respect to the third exemplary embodiment, an outer support structure 424 may be separately provided. Alternatively, the outer support structure 424 may be permanently attached to the coalescing element. The coalescing assembly 420 may be designed such that the coalescing element may be quickly and easily removed from the fixed components of the coalescing assembly 420 and from the housing 410. Accordingly, when replacement of the coalescing element becomes necessary, only the coalescing element itself need be removed, thereby leaving the alignment element 436, sealing collar 442, and fastener 438 intact inside the housing 410. With a reduction in the number of components which have to be discarded, waste is reduced as well as expense.

In this embodiment, the coalescing element may be identical to the coalescing element of the first exemplary embodiment. The fixed components include the alignment element 436, sealing collar 442, and fastener 438 of the coalescing assembly 420, which may be identical to the one illustrated in Figure 2 and described above. The outer support structure 424, however, may be identical to the outer support structure 324 of the third exemplary embodiment and illustrated in Figure 6, i.e., separate support element 482 and final classifier 476.

Accordingly, the fourth exemplary embodiment of the present invention comprises a structure wherein the coalescing element comprises a number of components which can be easily removed, and an outer support structure which may be cleaned outside of the housing when the coalescing element is removed and then replaced with the new coalescing element.

The above described coalescing assemblies of the present invention may be utilized in conjunction with separating assemblies which include one or more separating elements for separating the coalesced droplets from the continuous phase. The coalescing assemblies and the separating assemblies may be arranged in stacked or superposed relationship and mounted in a coalescing/separating system. Accordingly, this embodiment of the invention combines the rapid and easy removal coalescing elements having a reduced number of disposable components with separating elements which may also be rapidly and easily removed.

The coalescing assemblies and the separating assemblies of the present invention may be manufactured as a single unit with one or more coalescing assemblies and one or more separating assemblies. For example, the present invention may comprise a coalescing assembly and a separating assembly combination, one or more coalescing assemblies with a single separating assembly, a single coalescing assembly, and one or more separating assemblies, multiple coalescing assemblies and multiple separating assemblies. Preferably, the coalescing and separating assemblies are manufactured and assembled as separate units. In practice, this permits removal and replacement of the individual assemblies. Accordingly, if one of the components, e.g., the coalescing element, needs replacement, then only the coalescing element of the coalescing assembly is discarded and replaced rather than both components, thereby reducing waste and saving money. Typically, separating elements require cleaning or replacement much less often than coalescing elements. Accordingly, it may be particularly advantageous to have the coalescing elements easily separable from the separating elements.

Figures 9a and 9b are top and sectional views of an exemplary coalescing/separating system 500. The coalescing/separating system 500 comprises a housing 510 having a least one inlet 512, two outlets 514,516, first and second tube sheets 518,520 which divide the housing 510 into an uncoalesced fluid chamber 511, a coalesced fluid chamber 513, and a continuous phase chamber 515, a plurality of coalescing assemblies 522 and a plurality of separating assemblies 524. The plurality coalescing assemblies 522 and separating assemblies 524 are preferably oriented vertically within the housing 510, but may be oriented horizontally or at any angle between vertical and horizontal. A pressurized feed may be utilized in certain instances to supply fluid to the coalescing/separating system 500; accordingly, the housing 510 may also comprise vents and pressure release valves, as well as fittings for inlet and outlet pressure gauges.

The housing 510 may comprise any configuration suitable for the particular application. In the exemplary embodiment, the housing 510 comprises a substantially cylindrical configuration. In addition, the housing 510 may be designed such that at least one section, e.g., the top or bottom, of the housing 510 is removable. For example, the top of the housing 510 may comprise a removable cover 517 such as a swing-up cover. Alternatively, the top of the housing 510 may include bolts or pins to engage nuts, other threaded counterparts, or bayonet base portions in the wall of the housing 510 to removably secure a cover portion 517 of the housing 510 to a base portion of the housing 510. The housing 510 may comprise any suitable material capable of providing the requisite structural support and which will not react with the fluid being processed.

The first and second tube sheets 518,520, as stated above, divide the housing 510 into three chambers 511,513,515. The tube sheets 518,520 may be removably or permanently attached to the housing 510. In the exemplary embodiment, both tube sheets 518,520 are permanently attached to the inner wall of the housing 510. The tube sheets 518,520 each include a plurality of openings through which fluid from the uncoalesced fluid chamber 510 flows into the coalescing and separating assemblies 522,524 in the coalesced fluid chamber 513 and then into the continuous phase chamber 515. The tube sheets 518,520 also function to support and maintain the spacing between the coalescing and separating assemblies 522,524. The coalescing assemblies 522 may be secured to the first tube sheet 518 in any suitable manner such that fluid flows through the openings in the tube sheet 518 and into the interior region of the coalescing elements of the coalescing assemblies 522. The separating assemblies 524 may be secured to the second tube sheet 520 in any suitable manner such that fluid flows through the separating assemblies 524 and into the openings in the second tube sheet 520. The separating elements 524 may be attached directly to the second tube sheet 520 or indirectly via standoff tubes 526. In the exemplary embodiment illustrated in Figure 9b, the separating assemblies 524 are preferably connected to the second tube sheet 520 via standoff tubes 526. As explained in detail below, the separating assemblies 524 may be attached to the standoff tubes 526 such that the coalescing and separating assemblies 522,524 may be rapidly and easily removed from the housing 510.

Fluid which is to undergo coalescence enters the uncoalesced fluid chamber 511 of the housing 510 through inlet 512. The fluid flows from the uncoalesced fluid chamber 511 and into the coalescing assemblies 522. The coalescing assemblies 522 may be connected to the first tube sheet 518 such that they extend from the coalesced fluid chamber 513 through the openings in the first tube sheet 518 at least partially into the uncoalesced fluid chamber 511. The coalescing medium of the coalescing elements coalesces the fluid therein. Although some of the droplets of the discontinuous phase collect and are separated due to gravity (e.g., if the discontinuous phase of the fluid is more dense than the continuous phase of the fluid, the discontinuous phase will fall to the bottom of the coalesced fluid chamber 513), the smaller droplets typically drain or fall much slower than the larger droplets of the discontinuous phase. Accordingly, the fluid may be passed through a separating assembly 524 which comprises a material which allows the continuous phase of the fluid to pass therethrough but resists the passage of the discontinuous phase of the fluid. Essentially, the larger droplets of the discontinuous phase by-pass the separating assembly 524 and simply drain to the bottom of the coalesced fluid chamber due to their high momentum, while the smaller droplets are rejected by the separating assembly 524, i.e., the separating medium is not wetted by the smaller droplets. Therefore, the continuous phase of the fluid flows through the separating assembly 524, through the standoff tubes 526, through the openings in the second tube sheet 520, into the continuous phase chamber 515 and out through outlet 514. The discontinuous phase collects in the coalesced fluid chamber 513 and exits via outlet 516.

If the discontinuous phase were less dense than the continuous phase, then the separating assembly 524 would be positioned above the coalescing assembly 522 and the positions of the inlets and outlets reversed.

Figure 10 is a partial sectional view of an exemplary embodiment of the coalescing assembly/separating assembly combination of the coalescing/separating assembly 500 of the present invention. The separating assembly 524 may comprise any suitable configuration for the separation of the particular fluid which is undergoing coalescence. In the exemplary embodiment, the separating assembly 524 comprises first and second end caps 528,530, an inner support structure 532, an outer support structure 534, and a substantially cylindrically configured separating medium 536. The particular type of separating medium 536 may vary depending upon the particular application. For example, in one embodiment, the separating medium 536 comprises a material or is coated with a material which repels or is not wetted by the discontinuous phase liquid. Such a material preferably does not react with any liquid or other substance present in the fluid. A preferred separating medium includes a coating of materials which are not wetted by the discontinuous phase fluid on a stainless steel screen or a pleated fibrous pack. Generally, the separation medium 536 may be selected to have pores smaller than a substantial amount of the droplets of the discontinuous phase liquid in the coalesced fluid chamber 513. Examples of various separating media and how they are utilized are disclosed in U.S. Patent No. 5,443,724, which, as stated above, is assigned to the same assignee as the present invention and incorporated by reference herein.

The inner and outer support structures 532,534 may be utilized for support as described above with respect to the various embodiments of the coalescing assemblies 120,220,320 and 420 and may be formed out of any suitable material which is compatible with the particular fluid being processed. Exemplary structures are disclosed in U.S. Patent No. 5,443,724.

The lower end cap 528 may be an open end cap while the upper end cap 530 is a closed or blind end cap. The separating assembly 524 may be secured to the coalescing assembly 522 in any suitable manner. In accordance with one aspect of the invention, the separating assembly 524 is removably mounted to the coalescing assembly 522. For example, the upper end cap 530 of the separating assembly 524 may be removably secured to a lower end cap 539 of the coalescing assembly 522 by a mounting arrangement 538. In the illustrated embodiment, the upper end cap 530 of the separating assembly 524 may be bolted to the mounting arrangement 538. The mounting arrangement 538 may be permanently or removably attached to the lower end cap 539 of the coalescing assembly 524. The lower end cap 528 of the separating assembly 524 comprises a sealing mechanism for providing a fluid tight seal between the lower end cap 528 and the standoff tube 526. In addition, the sealing mechanism preferably provides a mechanism for securing the separating assembly 524 to the standoff tube 526. The sealing mechanism may comprise any suitable structure for providing a fluid tight seal as well as for securing the separating assembly 524 to the standoff tube 526. In the exemplary embodiment, the sealing mechanism comprises an annular channel 560 and an O-ring seal 562 for providing the fluid tight seal as well as securing the separating assembly 524 to the standoff tube 526 by frictional engagement. Similarly to the inner and outer support structures 532,534, the upper and lower end caps 530 and 528 may comprise any material which is compatible with the particular fluid being processed. For example, the end caps 530,528 may be formed from the same materials as the end caps described above with respect to the coalescing assemblies. In addition, exemplary end caps are described in U.S. Patent No. 5,443,724. In a preferred embodiment, the end caps 530,528 comprise stainless steel. In the exemplary embodiment, the support structures 532,534, and the medium 536 may be permanently attached to the end caps 528,530 by any suitable means.

In a preferred embodiment, the separating assembly 524 may be configured as a disposable structure, and is accordingly removably mounted to the standoff tube 526. Preferably, in the exemplary embodiment, the lower end cap 528 is designed such that it may slip over the end of the standoff tube 526 and be secured in position by frictional engagement between the sealing mechanism and the outer surface of the standoff tube 526 as described above. The O-ring seal 562 of the sealing mechanism is energized by the compressive forces generated when the end cap 528 is positioned over the standoff tube 526.

The coalescing assembly 522 may comprise any suitable structure. For example, the coalescing assembly 522 may be configured as any of the coalescing assemblies 120,220,320,420 described above. In the illustrated embodiment, the coalescing assembly 522 comprises a coalescing element, and an outer support structure. The outer support structure comprises a separate support element 542 and a final classifier 544. This configuration of the outer support structure may be similar to the structures of the third and fourth embodiments and comprise the same materials. The outer support structure may be secured to the coalescing element by bands or ties 546 as described above in the third and fourth embodiments.

A connector assembly 556 may be utilized for mounting the coalescing assembly 522 in an opening in the first tube sheet 518. The connector assembly 556 may be permanently or removably attached to the support element 542 or to the upper end cap 552 of the coalescing element. In the exemplary embodiment, the connector assembly 556 is mounted to the support element 542. The connector assembly 556 may be mounted to the support element 542 by any suitable means including welding or bonding. The connector assembly 556 comprises a sealing mechanism for providing a fluid tight seal between the coalescing assembly 522 and the first tube sheet 518. In addition, an upper portion 599 of the connector assembly 556 may be secured in position by a portion of the housing cover 517, thereby securing the coalescer assembly 522 and separating assembly 524 in position.

The coalescing element comprises a coalescing medium 548 and an inner support core 550 which may comprise the same materials and be configured in the same manner as in the previously described embodiments. For example, as illustrated in Figure 10a, the coalescing medium 548 comprises radial pleats. The coalescing element also comprises upper and lower end caps 552,539. The lower end cap 539 is a blind end cap. The lower end cap 539 comprises a disc shaped structure configured into an annular channel along its outer periphery and a raised central portion. The coalescing medium 548 and the core 550 are positioned in the channel and sealed thereto by any suitable means, such as bonding, which prevents fluid by-pass. The lower end cap 539 may be secured to mounting arrangement 538 by any suitable means. For example, the mounting arrangement 538 may be removably secured to the lower end cap 539 by bolts or the like or permanently mounted to the lower end cap 539. In the exemplary embodiment, the mounting arrangement 538 may be permanently mounted to the lower end cap 539 by welding, or bonding or via any suitable means. The upper end cap 552 is an open end cap which includes a sealing mechanism for providing a fluid tight seal between the end cap 552 and the connector assembly 556 to prevent fluid by-pass. The sealing mechanism may comprise any suitable mechanism, for example, an O-ring 566 positioned in an annular channel 568. The upper and lower end caps 552 and 538 may comprise any fluid impervious material which will not react with the fluid. For example, the end caps 552,538 may comprise the same materials as the embodiments described above. Preferably, the end caps 552,539 and the mounting arrangement all comprise stainless steel.

The upper end cap 552 may also comprise an element for facilitating removal of the coalescing assembly 522/separating assembly 524 combination from the housing 510. For example, a handle 554 may be attached to the upper end cap 552 to facilitate removal of the combination. The handle 554 may be permanently or removably mounted to the upper end cap 552. In the exemplary embodiment, the handle 554 is permanently attached to the end cap 552.

As in the first four embodiments, the coalescing element of the coalescing assembly 522 may be designed for rapid and easy replacement as well as with a minimum number of components. Accordingly, as in the previous embodiments, waste is reduced and money is saved. In addition, since the coalescing assembly 522 is easily separable from the separating assembly 524, and since separating assemblies typically require less maintenance, when the coalescing element of the coalescing assembly 522 is replaced, the separating assembly 524 which is already out of the housing 510 may be cleaned or rapidly attached to the new coalescing element.

In the above described embodiments, coalescing systems and coalescing/separating systems are described as including multiple coalescing assemblies or multiple coalescing/separating assemblies in a single housing. However, systems employing a single coalescing assembly or a single coalescing/separating assembly in a single housing may be constructed in such a manner as to recognize the advantages of the previously described embodiments. Thus single assembly systems may comprise housings adapted to receive and hold a single coalescing assembly or a single coalescing/separating assembly.

Although shown and described are what is believed to be the most practical and preferred embodiments, it is apparent that departures from specific methods and designs described and shown will suggest themselves to those skilled in the art and may be used without departing from the spirit and scope of the invention. The present invention is not restricted to the particular constructions described and illustrated, but should be constructed to cohere with all modifications that may fall within the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A coalescer system comprising:

a housing including an inlet, at least one outlet, and a tube sheet which divides the housing into an uncoalesced fluid chamber and a coalesced fluid chamber and which has at least one opening therein for fluid to flow from the uncoalesced fluid chamber into the coalesced fluid chamber, the inlet being coupled to and communicating with the uncoalesced fluid chamber; and

at least one coalescing assembly which is mounted to the tube sheet within the housing such that fluid flows from the inlet through the coalescing assembly, the coalescing assembly including:

a coalescing element removably coupled to the tube sheet, the coalescing element having a coalescing medium, first and second end caps attached to the ends of the coalescing medium, at least one of the end caps having a sealing mechanism for providing a fluid tight seal, and a support core;

an outer support structure disposed around the exterior of the coalescing element and permanently mounted to the tube sheet for providing structural support; and

a mechanism cooperatively arranged with the coalescing element to removably secure the coalescing element within the outer support structure.

2. A coalescer system comprising:

a housing including an inlet, at least one outlet, and a tube sheet which divides the housing into an uncoalesced fluid chamber and a coalesced fluid chamber and which has at least one opening therein for fluid to flow from the uncoalesced fluid chamber into the coalesced fluid chamber, the inlet being coupled to and communicating with the uncoalesced fluid chamber; and

at least one coalescing assembly which is mounted to the tube sheet within the housing such that fluid flows from the inlet through the coalescing assembly, the coalescing assembly including:

a coalescing element removably coupled to the tube sheet, the coalescing element having a coalescing medium and first and second end caps attached to the ends of the coalescing medium, at least one of the end caps having a sealing mechanism for providing a fluid tight seal;

an outer support structure disposed around the exterior of the coalescing element and permanently mounted to the tube sheet for providing structural support;

an inner support structure permanently coupled to the tube sheet and disposed around the interior of the coalescing element for providing structural support; and

a mechanism cooperatively arranged with the coalescing element to removably secure the coalescing element between the inner and outer support structures.

3. A coalescer system comprising:

a housing including an inlet, at least one outlet, and a tube sheet which divides the housing into an uncoalesced fluid chamber and a coalesced fluid chamber and which has at least one opening therein for fluid to flow from the uncoalesced fluid chamber into the coalesced fluid chamber, the inlet being coupled to and communicating with the uncoalesced fluid chamber; and

at least one coalescing assembly which is mounted to the tube sheet within the housing such that fluid flows from the inlet through the coalescing assembly, the coalescing assembly including:

a coalescing element removably coupled to the tube sheet, the coalescing element having a coalescing medium and first and second end caps attached to the ends of the coalescing medium, at least one of the end caps having a sealing mechanism for providing a fluid tight seal;

an outer support structure removably coupled to the tube sheet and disposed around the exterior of the coalescing element for providing structural support;

an inner support structure permanently coupled to the tube sheet and disposed around the interior of the coalescing element for providing structural support; and a mechanism cooperatively arranged with the coalescing element and the outer support structure to removably secure the outer support structure and the coalescing element around the inner support structure.

4. A coalescer system comprising:

a housing including an inlet, at least one outlet and a tube sheet which divides the housing into an uncoalesced fluid chamber and a coalesced fluid chamber and which has at least one opening therein for fluid to flow from the uncoalesced fluid chamber into the coalesced fluid chamber, the inlet being coupled to and communicating with the uncoalesced fluid chamber; and

at least one coalescing assembly which is mounted to the tube sheet within the housing such that fluid flows from the inlet through the coalescing assembly, the coalescing assembly including:

a coalescing element removably coupled to the tube sheet, the coalescing element having a coalescing medium, first and second end caps attached to the ends of the coalescing medium, each having a sealing means for providing a fluid tight seal, and a support core;

an outer support structure removably coupled to the tube sheet and disposed around the exterior of the coalescing element for providing structural support; and

a mechanism cooperatively arranged with the coalescing element and the outer support structure to releasably secure the coalescing element and the outer support structure within the housing.

5. A coalescing/separating system comprising:

a housing including first and second tube sheets which divide the housing into an uncoalesced fluid chamber, a coalesced fluid chamber and a continuous phase chamber, each of the first and second tube sheets have at least one opening therein, an inlet coupled to and communicating with the uncoalesced fluid chamber, a first outlet coupled to and communicating with the coalesced fluid chamber, and a second outlet coupled to and communicating with the continuous phase chamber;

at least one coalescing assembly which is mounted to the first tube sheet within the housing such that fluid flows from the inlet through the coalescing assembly, the coalescing assembly including:

a coalescing element removably coupled to the first tube sheet, the coalescing having a coalescing medium and first and second end caps attached to the ends of the coalescing medium, at least one of which includes a sealing mechanism for providing a fluid tight seal; and

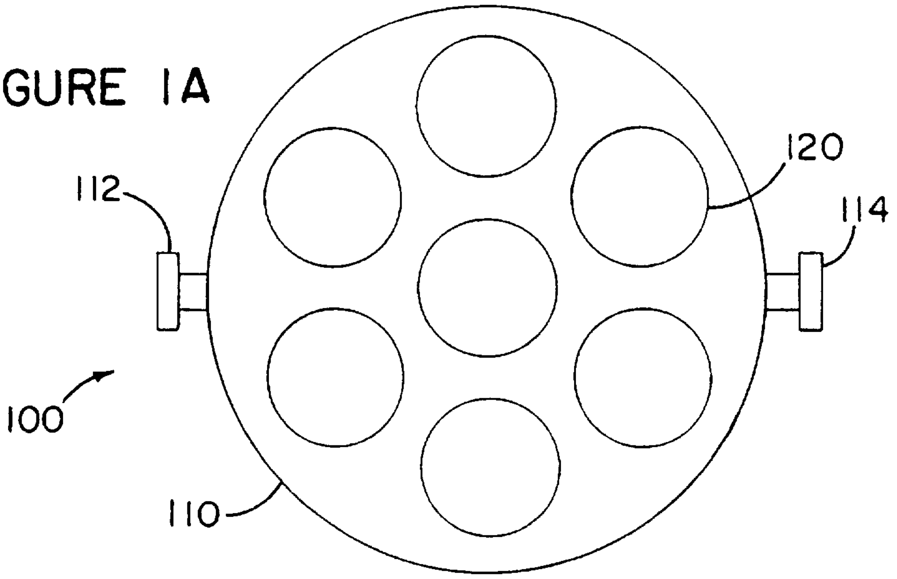
an outer support structure disposed around the exterior of the coalescing element for providing structural support; and

an inner support structure disposed around the interior of the coalescing element for providing structural support; and

at least one separating assembly which is removably mounted to the second tube sheet, the separating assembly including a separating medium.

6. A coalescing assembly comprising one or more fixed components and a coalescer element removably mounted with the fixed components.

FIGURE 1A



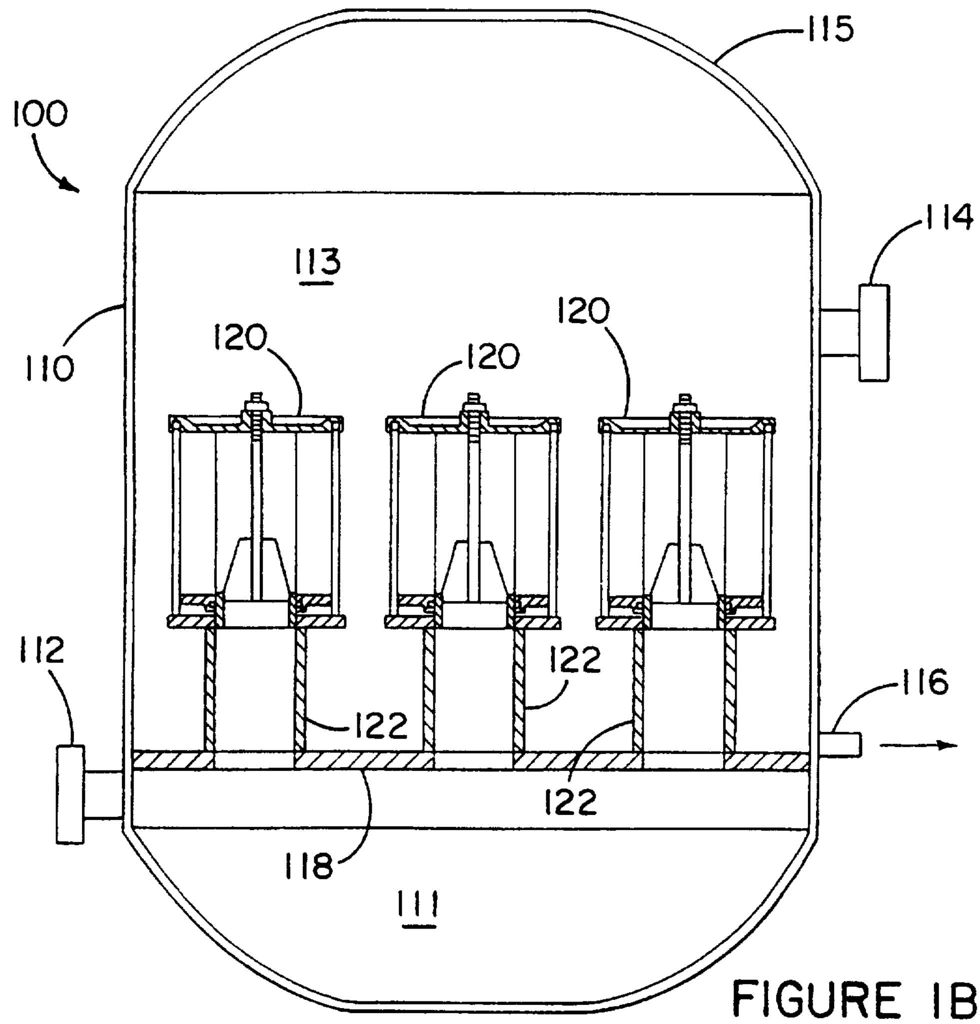


FIGURE 1B

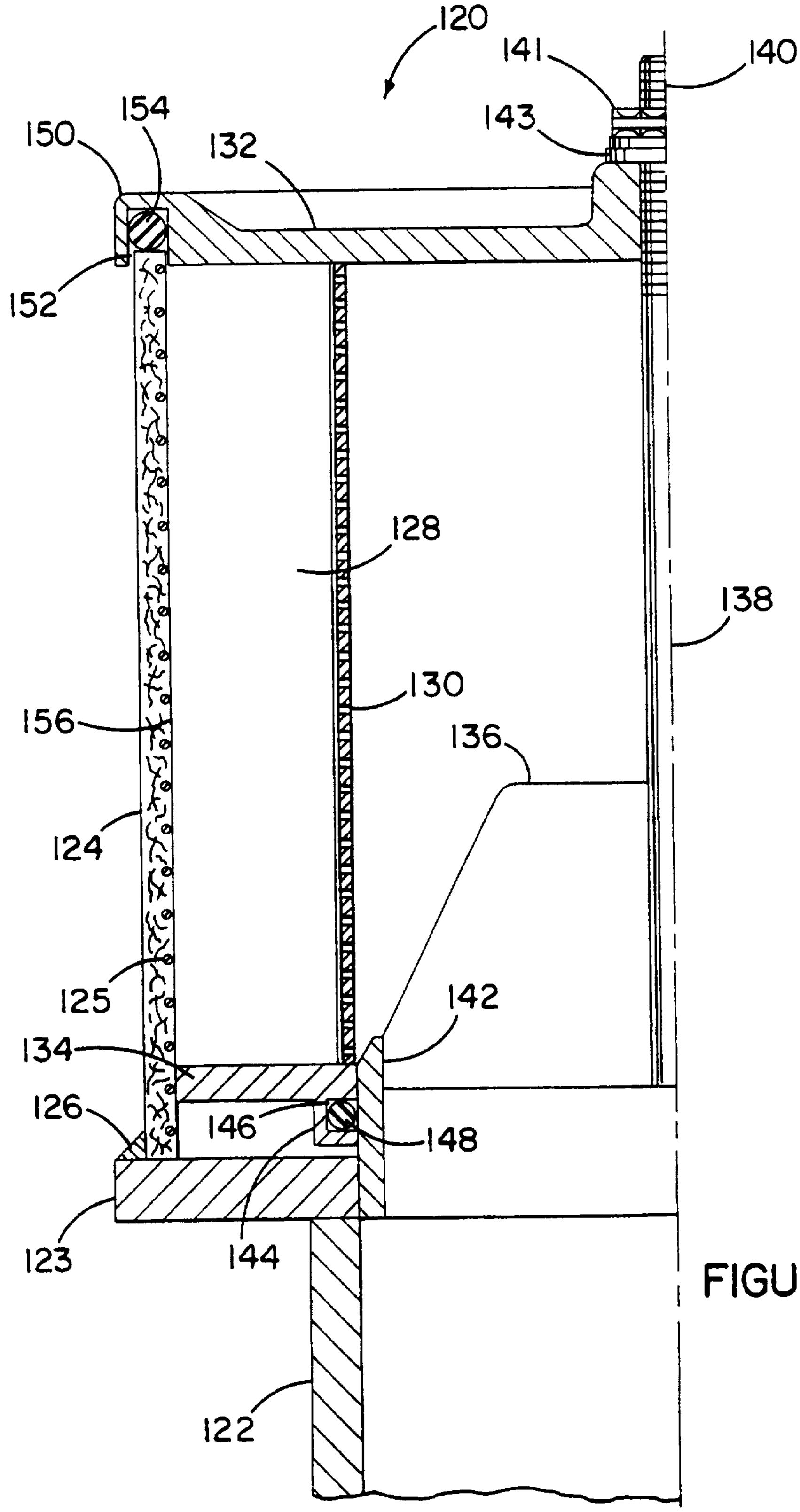

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FIGURE 2

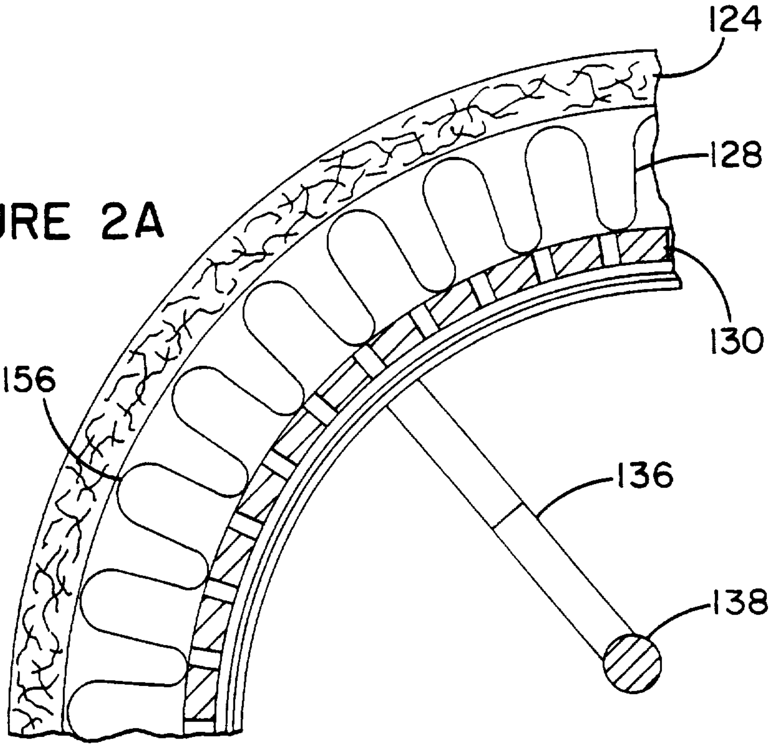

FIGURE 2A

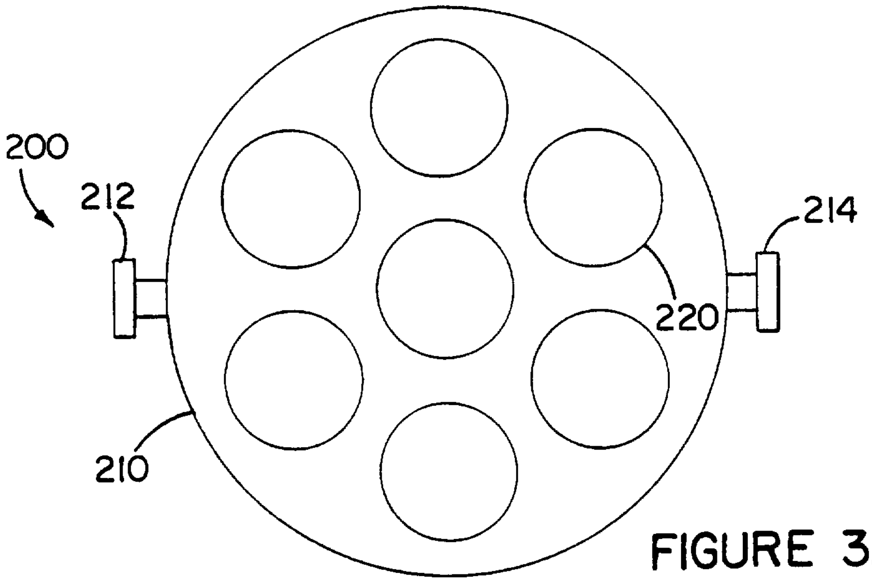

FIGURE 3A

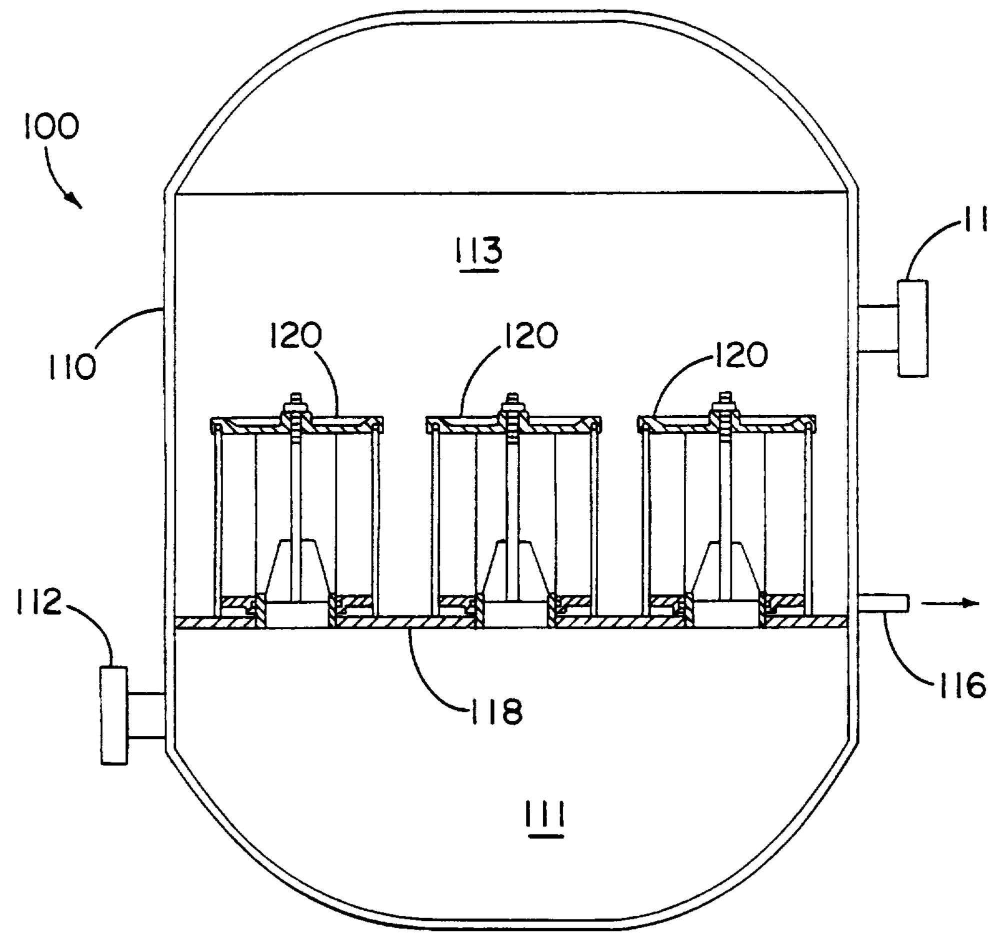

FIGURE 2B

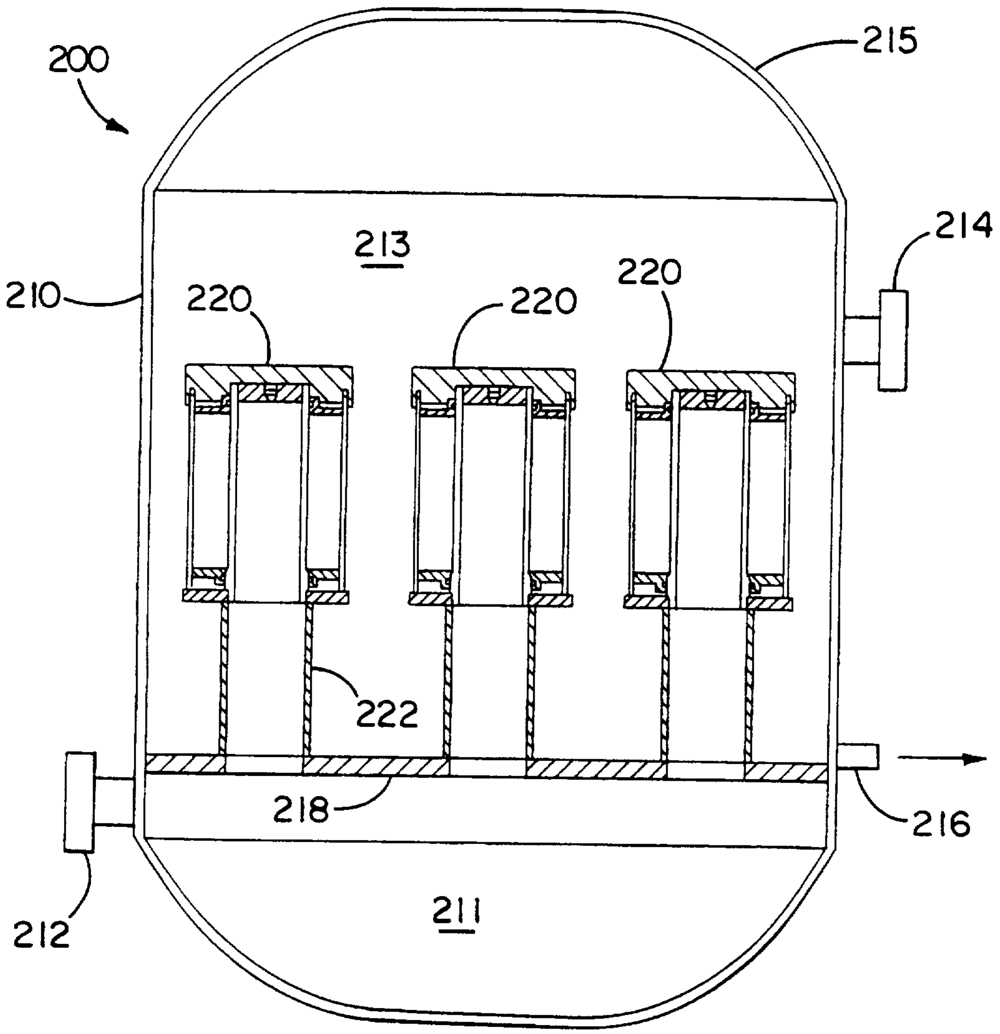

FIGURE 3B

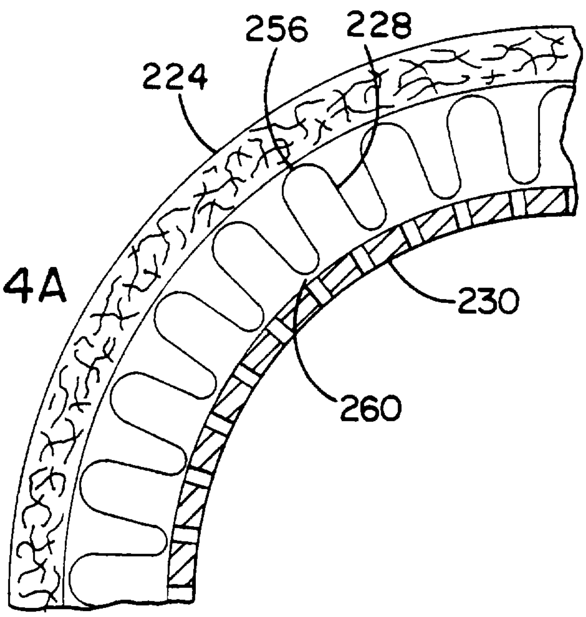

FIGURE 4A

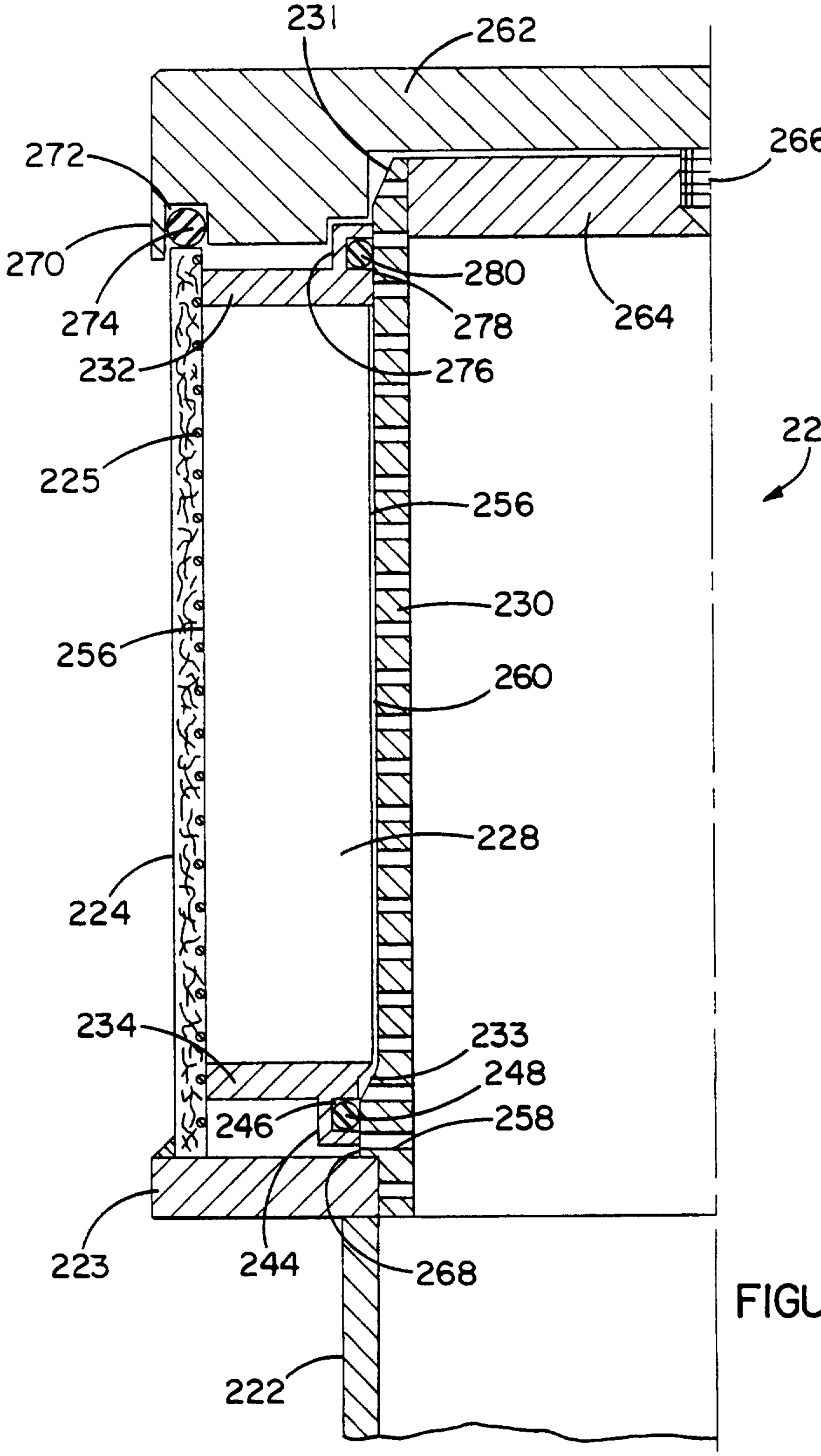
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FIGURE 4

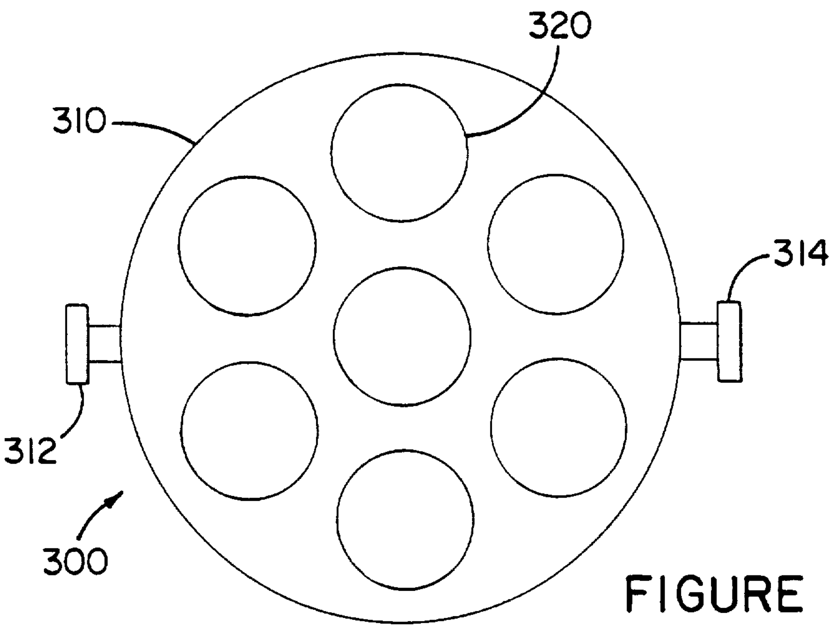

FIGURE 5A

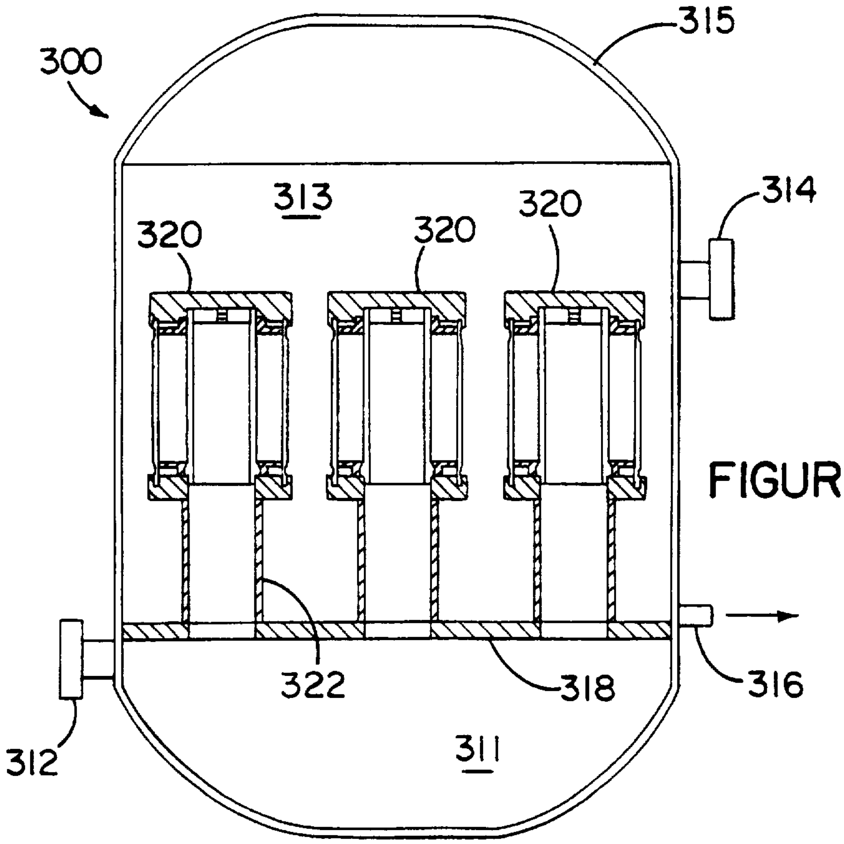

FIGURE 5B

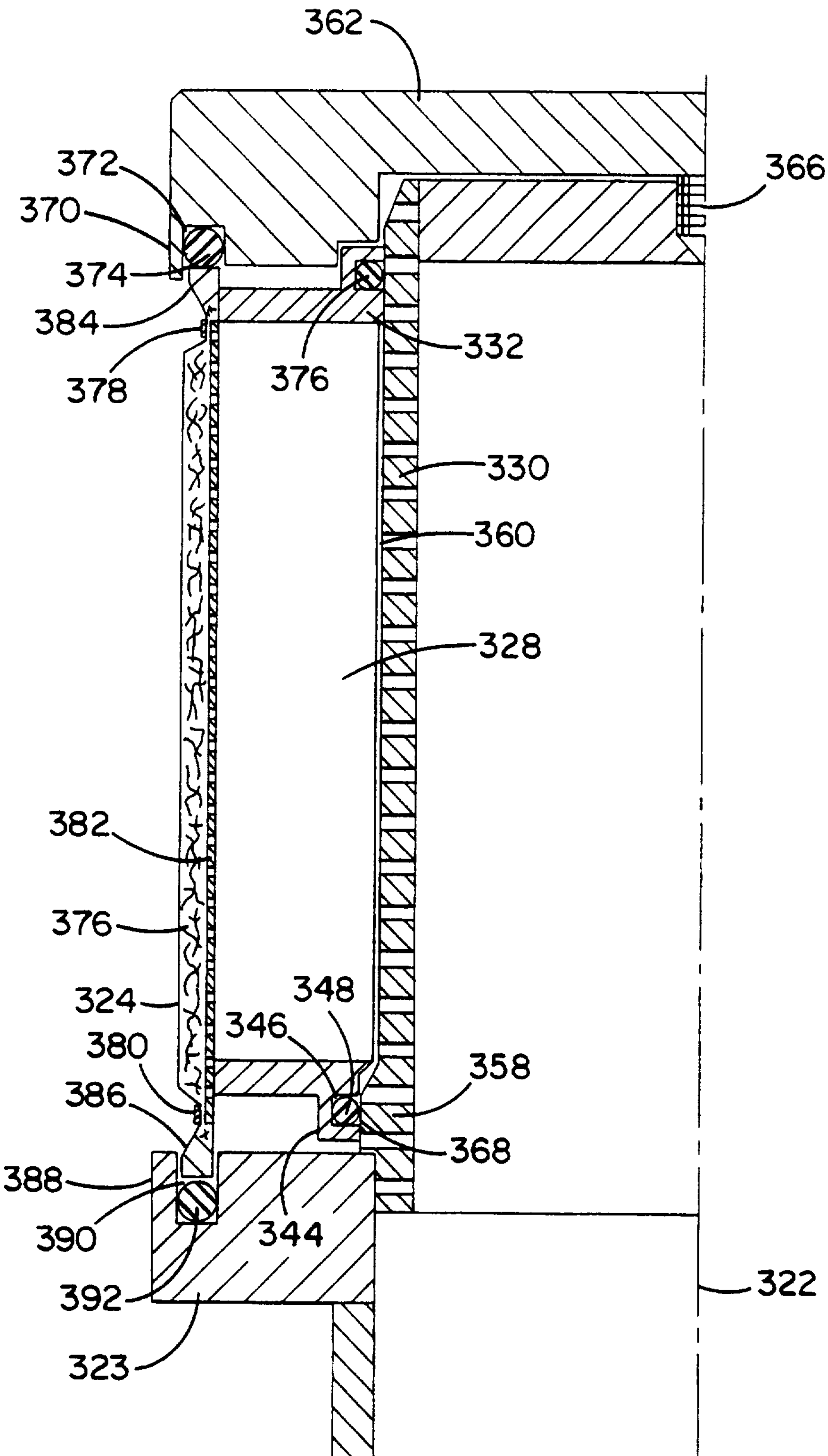
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FIGURE 6

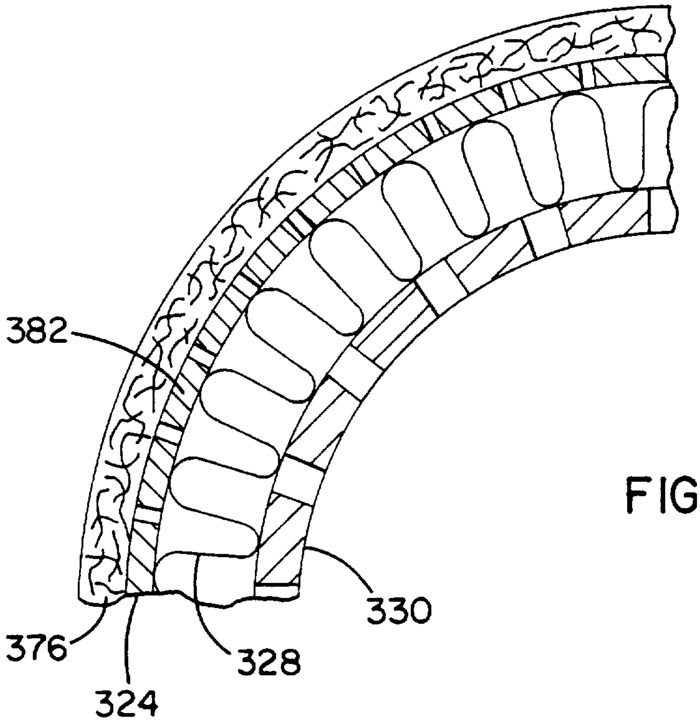

FIGURE 6A

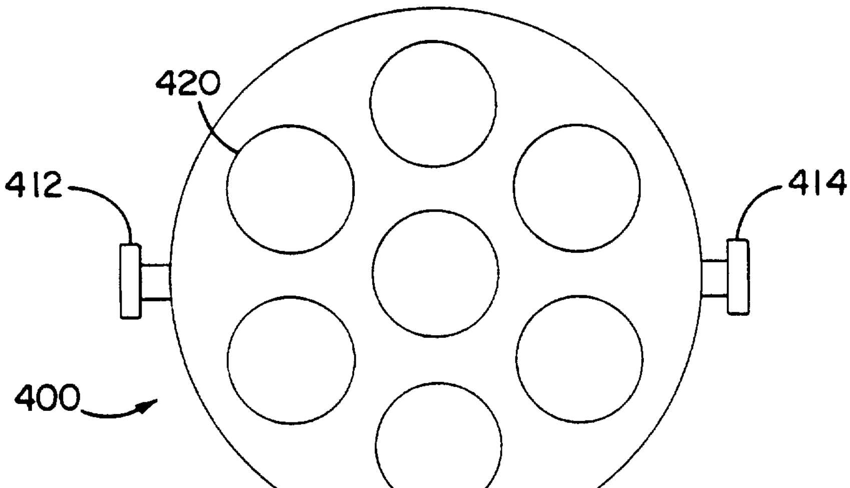

FIGURE 7A

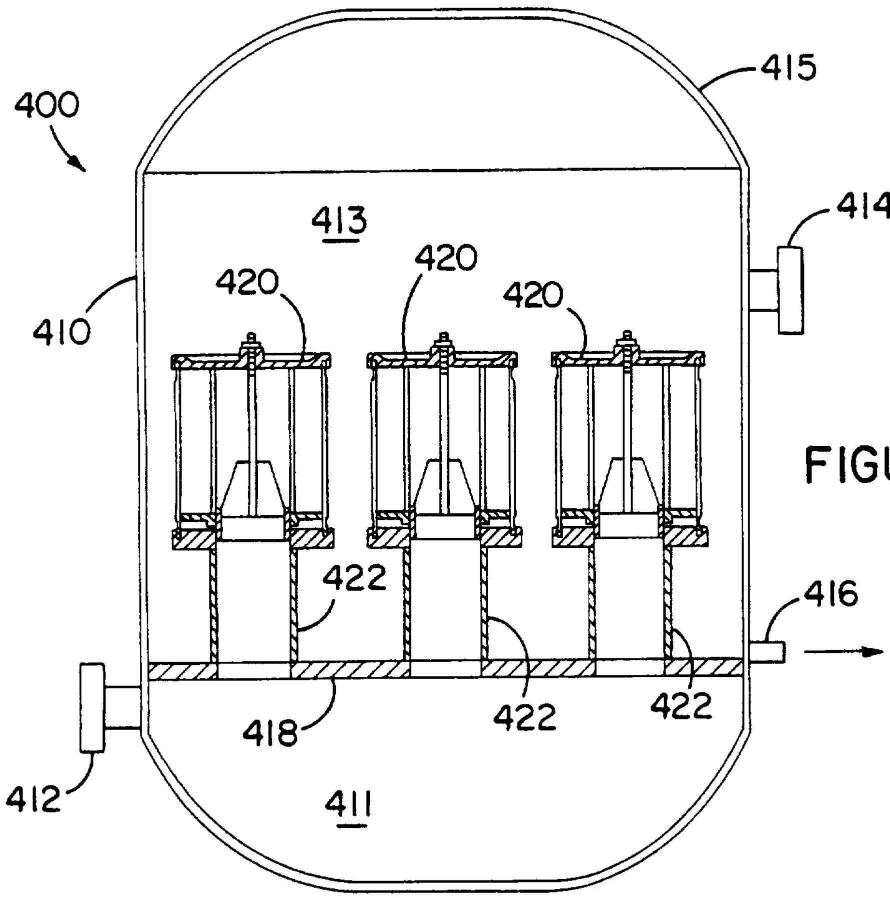

FIGURE 7B

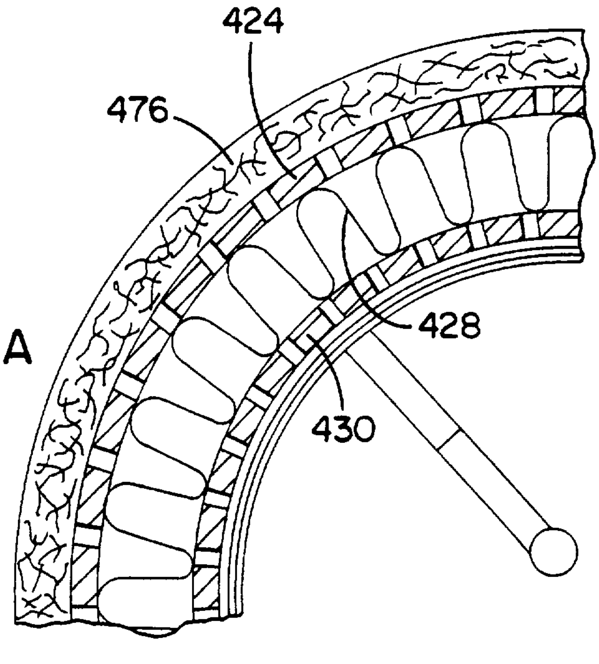

FIGURE 8A

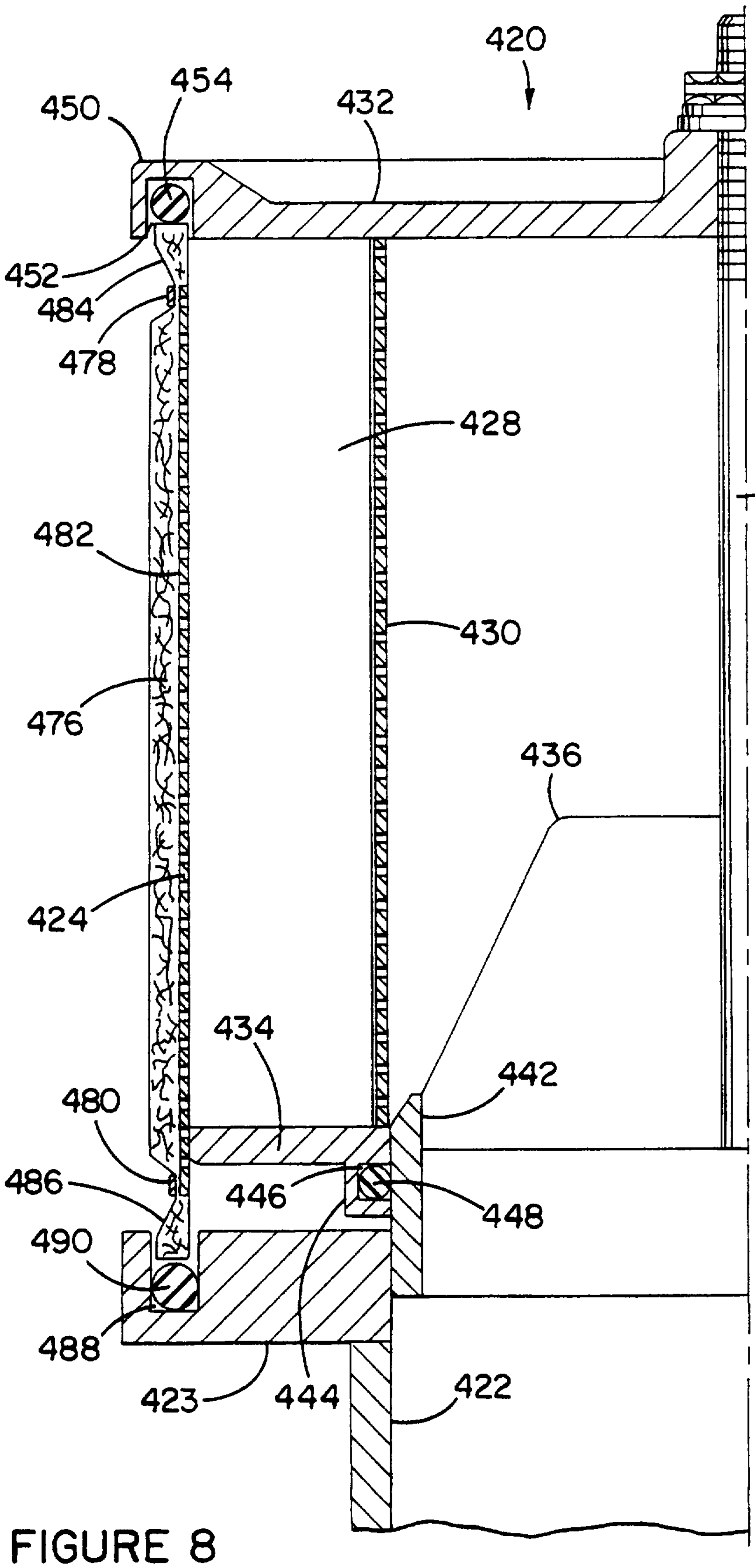
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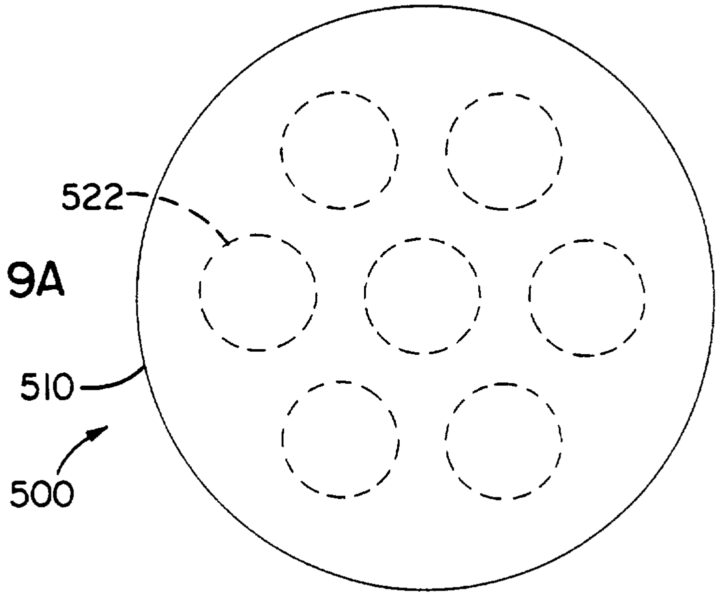
FIGURE 8

FIGURE 9A



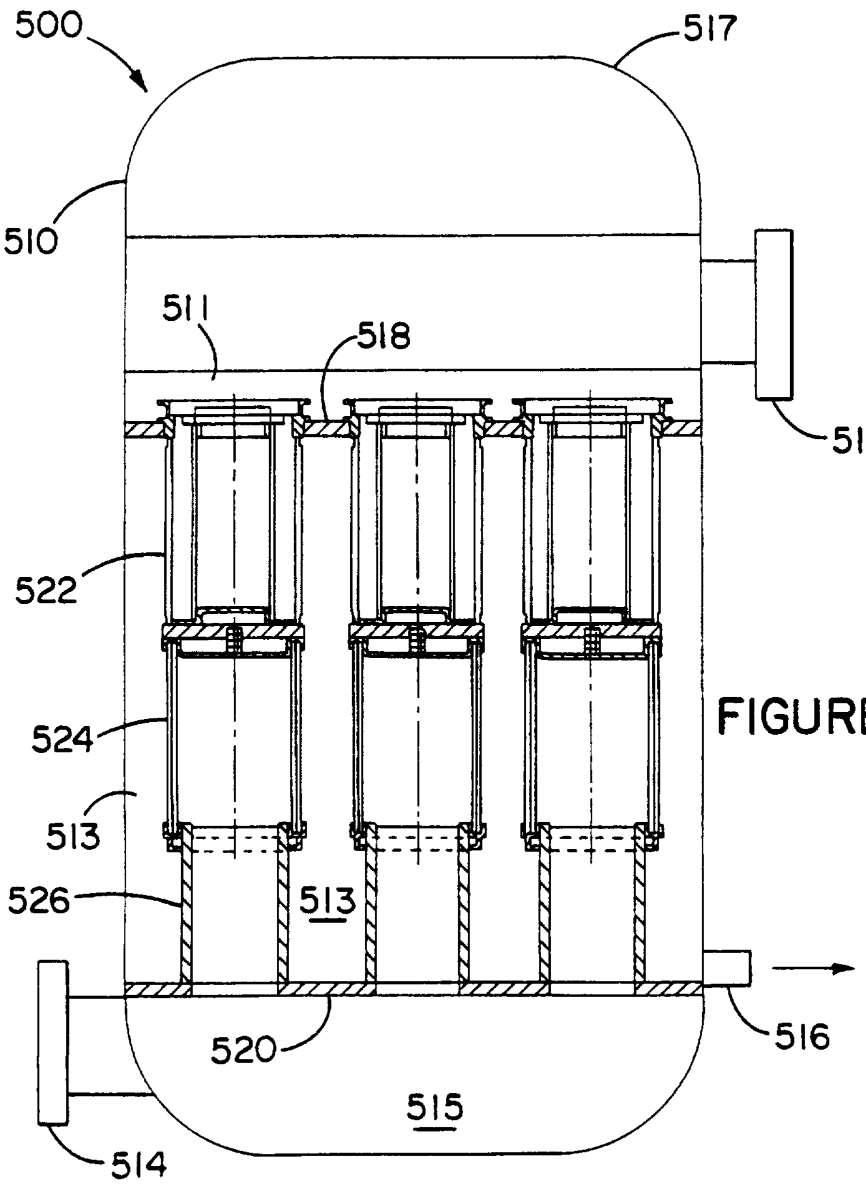


FIGURE 9B

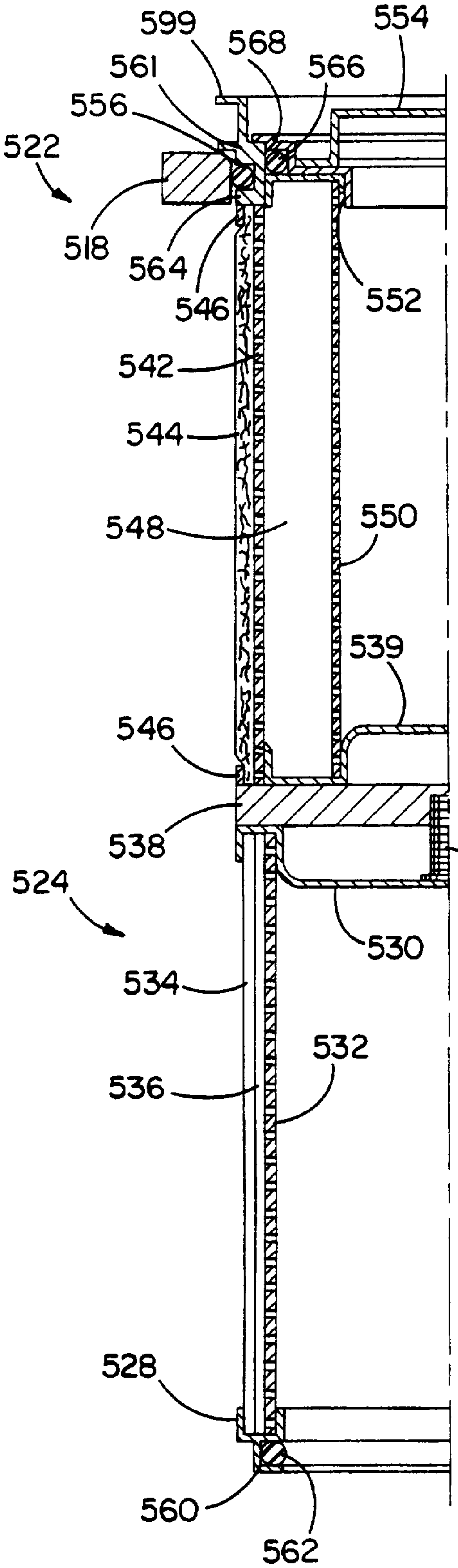


FIGURE 10

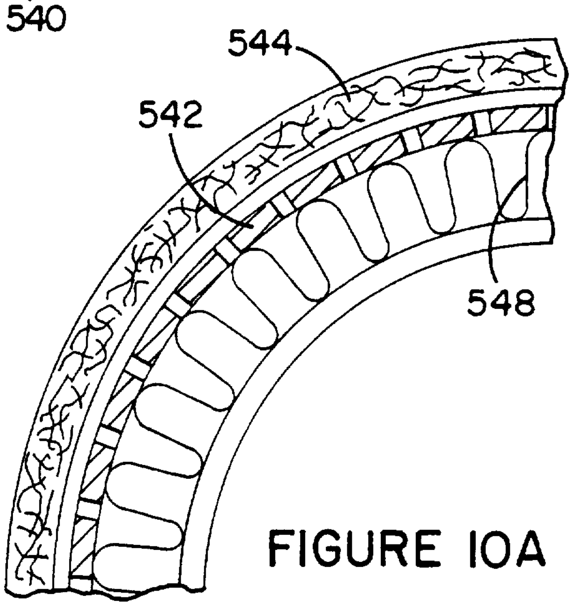


FIGURE 10A

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/08374

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B01D46/24 B01D17/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B01D F15B B60T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 443 724 A (WILLIAMSON KENNETH M ET AL) 22 August 1995 cited in the application see claims 1-22; figure 4	1-6
Y	DE 91 03 400 U (HARNISCH GMBH) 29 May 1991 see claims 1-5; figures 1-3A	1-6
A	US 4 303 426 A (BATTIS ROBERT) 1 December 1981 see the whole document	1-6
A	GB 2 261 830 A (PROCESS SCIENT INNOVATIONS) 2 June 1993 see claims 1-5; figures 1,2	1
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
13 August 1997	26. 08. 97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Cubas Alcaraz, J

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INTERNATIONAL SEARCH REPORT

International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 5 480 547 A (WILLIAMSON KENNETH M ET AL) 2 January 1996 see claims 1-24; figures 1-4 -----	1-6

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