PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 :		(11) International Publication Number:
B01D 17/038	A1	WO 92/19348
		(43) International Publication Date: 12 November 1992 (12.11.92)

(21) International Application Number: PCT/US91/02886

(22) International Filing Date: 2 May 1991 (02.05.91)

(71) Applicant *(for all designated States except US)*: CONOCO SPECIALTY PRODUCTS INC. [US/US]; 600 North Dairy Ashford Road, Houston, TX 77252 (US).

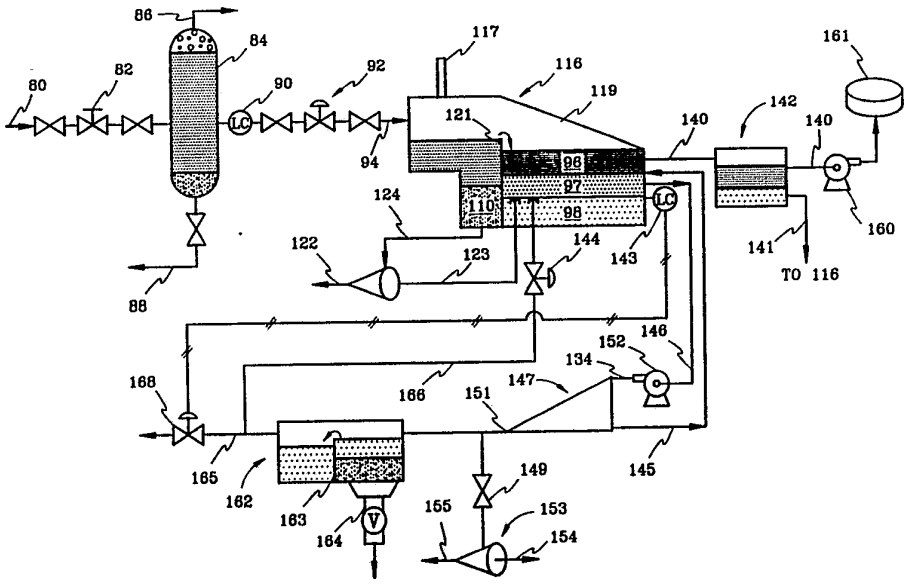
(72) Inventors; and
(75) Inventors/Applicants *(for US only)* : HANSEN, Reimer, Z. [DK/US]; 14803 Royal Birkdale Road, Houston, TX 77095 (US). WOLFENBERGER, Erick, E. [US/US]; 2230 Big Holly, Conroe, TX 77385 (US).

(74) Agents: HOLDER, J., E. et al.; Conoco Inc., 1000 South Pine Street, Ponca City, OK 74603 (US).

(81) Designated States: AT (European patent), AU, BE (European patent), CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), IT (European patent), LU (European patent), NL (European patent), NO, SE (European patent), US.

Published
With international search report.

(54) Title: OIL/WATER SEPARATION SYSTEM



(57) Abstract

An oil/water separation system for separating oil and water components of a suspension formed in an oil/water mixture wherein oil coats solid particles in the mixture to form an oil coated nucleus that is neutrally buoyant to form the suspension. A stream of the suspension is passed through a hydrocyclone (147) wherein the oil coating is removed from the solids. The solids then pass with the water component through an underflow outlet (151) from the hydrocylone while the oil component is separately passed from an overflow outlet (145).

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	**FI**	Finland	**ML**	Mali
AU	Australia	**FR**	France	**MN**	Mongolia
BB	Barbados	**GA**	Gabon	**MR**	Mauritania
BE	Belgium	**GB**	United Kingdom	**MW**	Malawi
BF	Burkina Faso	**GN**	Guinea	**NL**	Netherlands
BG	Bulgaria	**GR**	Greece	**NO**	Norway
BJ	Benin	**HU**	Hungary	**PL**	Poland
BR	Brazil	**IE**	Ireland	**RO**	Romania
CA	Canada	**IT**	Italy	**RU**	Russian Federation
CF	Central African Republic	**JP**	Japan	**SD**	Sudan
CG	Congo	**KP**	Democratic People's Republic of Korea	**SE**	Sweden
CH	Switzerland			**SN**	Senegal
CI	Côte d'Ivoire	**KR**	Republic of Korea	**SU**	Soviet Union
CM	Cameroon	**LI**	Liechtenstein	**TD**	Chad
CS	Czechoslovakia	**LK**	Sri Lanka	**TG**	Togo
DE	Germany	**LU**	Luxembourg	**US**	United States of America
DK	Denmark	**MC**	Monaco		
ES	Spain	**MG**	Madagascar		

Description

Oil/Water Separation System

Background of The Invention

This invention relates to an oil/water separation system and more particularly to a multi-phase separation process, a common use for which is found in oil field drilling, production, and refining operations, to enhance the gravity separation of immiscible liquids by promoting separation of a fluid suspension such as those having a solids component acting as an emulsion stabilizer or oil coated solids with neutral buoyancy.

A variety of separation systems, commonly found in petroleum industry applications are concerned with an emulsion layer formed in various types of systems which provides problems as to economical separation of the primarily oil and water components thereof.

During the production of petroleum hydrocarbons there is often a substantial amount of water produced. The amount of water will vary depending on many factors, such as: (1) the type of reservoir and formations from which the fluids are produced; (2) the age of the well producing the fluids; (3) the type of enhanced oil recovery (EOR) system that is used, as for example waterflood and steam flooding, both of which will increase the amount of water produced.

As oil is produced it must be separated from the water. The ease of this separation is affected by the fluid properties as well as physical and chemical factors. Some factors which may lead to the formation of emulsion and thus adversely affect separation of oil and water are:

1. Tight reservoirs with low porosity and permeability, where oil droplets will be sheared simply by moving through the reservoir as the oil is produced;

2. The addition of chemicals such as may be used in chemical floods or corrosion inhibitors used in the well;

3. Shearing of fluid droplets due to pumps or any number of devices which may cause high turbulence such as a valve; and

4. Solids particles which can serve to stabilize emulsions as in oil wet colloids.

When drilling petroleum reservoirs the solids being drilled from the underground formations can serve to form an oil wet nucleus about which emulsions can form.

Another situation leading to the problems involves world crude supplies getting much poorer in quality. Available crudes are getting heavier, more sour, and dirtier. Heavy, viscous crudes hold more particulate matter, and hold it longer. This adverse change in crude oil feedstocks is having significant operating and corrosion implications on refinery units. There are a number of components which may appear in crude oil stocks even in very low quantities which can cause de-salting and corrosion complications. These components could include solid particulates, oil field producing chemicals and production stimulants. Part of this problem stems from an increase in the use of secondary and tertiary recovery methods which lead to the production of tightly emulsified fluids from water floods, caustic floods, surfactant floods, fire floods and the general use of well stimulant chemicals.

Thus, it is seen that a variety of oil industry problems associated with drilling, producing and refining petroleum hydrocarbons, all deal with separating oil and water emulsions. It is likely that oil/water separation in other industrial environments has similar problems which may be treated accordingly as described herein. Many devices and methods have been used to enhance the effectiveness of such oil/water separation. Such devices and methods may involve the use of chemicals to facilitate phase separation, the addition of heat to reduce viscosity of the fluids, the use of structured packing, specially designed flow paths, filters and other such mechanical devices to structure flow that produces contact of the components in a mixture to promote coalescence, or the use of electrostatic devices to create electric fields and charges that

promote coalescence and separation of mixture components.

Desalting

A specific petroleum process which typifies this instant problem has to do with crude oil distillation. Crude stills are the first major processing units in a refinery. They are used to separate the crude oils by distillation into fractions according to boiling point. If the salt content of the crude oil is greater than 10 lb/1,000 bbl, the crude requires desalting to minimize fouling and corrosion caused by salt deposition on heat transfer surfaces and acids formed by decomposition of the chloride salts. In addition, some metals which can cause catalyst deactivation in catalytic processing units are partially rejected in the desalting process.

The trend toward running heavier crude oils has increased the importance of efficient desalting of crude. The salt in the crude is in the form of dissolved or suspended salt crystals in water emulsified with the crude oil. It is important to note that while the term de-salting is used to describe the process, sediment or solids other than salts are of similar importance. These impurities in the crude oil may be natural or induced. The water in crude oil is usually in the form of a water in oil emulsion. The emulsion is stabilized by surface active agents in the oil. Emulsion stabilizers such as asphalts, resins, waxes, solids and organic acids add to the problem of desalting modern crude.

Impurities are often categorized as those which are water soluble and are removable by washing and those which are water insoluble and not readily removable by washing. The oil insoluble impurities are sometimes referred to as the oleophobic or oil-hating impurities. These include water, salt, and some solids.

Among the more common impurities found in crude oil are silt, sand, iron oxide, iron sulfide, arsenic and strontium, sediments, the chlorides of sodium, potassium, calcium and magnesium; the sulfates of potassium, magnesium, calcium and sodium; crystalline salt, carbon, sulfur, salts and water.

In addition to the naturally occurring impurities in crude oils, there

are induced impurities. Induced impurities might be described as those things that become mixed into the crude oil during the process of extracting it from its natural habitat and producing, transporting and processing it on its way to the consumer end uses. The de-salting process which is involved in removing these contaminants and separating the oil and water components of a mixture is based on two premises: (1) oil is lighter than water, and (2) emulsions which are temporarily stabilized by surface active materials can be destabilized by the action of electric field or chemical demulsifiers.

In the simplest form, the desalter is a washing device for oil, with a mix valve providing the scrubbing and the desalter vessel itself being the gravity, settling or separation tank. The mixing that takes place across the valve allows the water to wash the salt out of the crude oil. This mixing also tends to generate a suspension in this environment. As the suspension becomes tighter and more stable it is referred to as an emulsion. The emulsion will accumulate at the interface of the oil and water and may eventually contaminate both oil and water discharge streams. Solids are a powerful emulsion stabilizer and a tremendous consumer of demulsifier or any surface active/adsorptive material. One of the problems in desalting is being able to take the demulsifier to the water and solids interface within the mixture since it is the solids that provide the nucleus for the emulsion. One solid which is found to be a particular problem in this situation is iron which show up eventually downstream in the hydrocarbon products of the oil refinery processes.

Prior art devices for solving de-salting problems utilize conventional horizontal or vertical gravity separation vessels. Several methods have been used to promote coalescence in these vessels, however, these methods usually involve treating the entire fluid stream rather than a side stream of the suspension or emulsified layer. The use of chemicals is the most common practice to break the interfacial tension between droplets and to promote separation. Desalting vessels often incorporate structured packings which allow the fluids to move along corrugated parallel plates or through

narrow openings and contact other droplets which coalesce into larger particles. These particles can then be more easily separated by gravity forces due to increase in buoyancy and reduction in surface area.

Addition of heat is often used to reduce the viscosity of the fluids which will significantly increase the droplets ability to migrate through the continuous phase liquid. Increasing temperature may also increase the density difference between the fluids. The use of an electrostatic potential across the fluids can be used to create a polarity field to charge the liquid droplets much like magnetic poles and thus promote separation. The use of heat or electrostatic potential is typically very energy intensive and costly.

Drilling Fluids

Another example of an industry problem which may be treated by the present separation system concerns the separation of hydrocarbon fluids from drilling fluids. One particular situation that exemplifies the problem in this area involves the separation of components in a drilling fluids system associated with drilling horizontal wells in a chalk formation where hydrocarbon fluids are produced from the formations being drilled, during the drilling operation. The separation problem associated with such drilling is set forth in detail in copending U.S. patent application serial no. 649,382 titled "Method and Apparatus for Separating Drilling and Production Fluids". However, to briefly address the issue addressed in that application, the drilling fluids system is designed to run in an underbalanced condition to allow formation fluids into the wellbore. Pressure on the system at the surface is reduced to let formation fluids flow under reservoir pressures into the borehole. These formation fluids become entrained in the drilling fluids and are brought to the surface. At the surface the hydrocarbon fluids are separated from the water in the system as well as solids such as the drill cuttings. Because hydrocarbon fluids tend to decrease the density of the drilling fluids system, it is desirable to remove those low density fluids from the system in order to maintain control over the drilling fluid weight and thus maintain a proper pressure balance on the formations being drilled. One of the problems that is encountered in this situation is that

produced oil tends to coat fine particles of formation materials such as chalk. These oil coated particles become neutrally buoyant and form a suspension layer in the fluid system and therefore do not readily separate out due to density differences. As a result, they tend to carry over into the recirculated drilling fluids where they may cause problems associated with weight of the system. In addition, such carry over prevents the cuttings from being removed from the system to provide a further burden on the drilling fluids system.

Prior art separation schemes for dealing with the problems described above have disadvantages in that they are space intensive because of their reliance to a great extent on tankage and time to eventually permit gravity separation of the components of the mixture. The operational efficiency of prior devices and systems for adequately separating the components has been hampered by the presence of the oil coated particles forming an oil in water suspension as described above, with such prior art systems either not adequately addressing the problem or addressing the problem at an undesirable economic level. Typically, the addition of heat, chemicals, greater residence time, etc. have been the solution to these problems, with the inherent undesirable characteristics described above.

It is therefore an object of the present invention to provide a simpler, more efficient and less costly method and apparatus for the problem of separating oil and water components of a fluid mixture, particularly where particulate matter is a component of the mixture and combines with the other components in such a manner as to compound the separation problem.

Summary of the Invention

With this and other objects in view the present invention provides a separation system for a fluid mixture that includes oil and water components with solids particles suspended therein as a result of oil in the mixture coating the solids particles to form an oil coated nucleus. The oil coated nucleus is neutrally buoyant and forms a suspension with the water component. The present separation system utilizes a hydrocyclone for separating oil from the

oil coated solids particle nucleus present in the mixture inletted to the hydrocyclone. This removal of oil from the solids particle renders the solids particle non-buoyant to thereby permit the solids particle to separate from the mixture due to its difference in density. The oil thus removed is coalesced into a component that separates out as a less dense phase in the hydrocyclone. The water and solids particles are then discharged from the underflow of the hydrocyclone and the oil is discharged from the overflow.

Another separator may be provided downstream of the hydrocyclone for receiving the more dense components and to permit further separation of the water and solids. Provisions are then made to remove the solids from the system and discharge the water for disposal or further use. Alternatively, solids may be outletted from the hydrocyclone through a separate solids outlet or the solids may be recycled with the underflow to a vessel from which the fluid mixture is taken, for further separation such as by gravity.

Brief Description of the Drawings

Figure 1 is a schematic drawing of a separation system in accordance with the present invention for separating a suspension layer formed in a separation process;

Figure 2 is a schematic drawing of a separation system in accordance with the present invention for processing drilling fluids in a well drilling operation; and

Figure 3 is a schematic drawing of a separation system for separating a suspension layer in a desalting operation.

Description of the Preferred Embodiment

Referring first to Figure 1 of the drawings, a desalting operation is shown for treating crude oil to remove excess solids therefrom prior to their being further processed as in a refining operation. A source of crude oil 12 is shown being passed through a pump 14 having an outlet passing through a mixing valve 20 into an inlet 22 of a two-phase separation vessel 23. Water is

provided by an inlet line 16 from a pump 18 for mixing water into the crude to thereby wash the salts or other dissolved materials from the crude. Mixing valve 20 provides a means for mixing the water with the crude to ensure that the washing process takes place. The mixture emerging from the mixing valve 20 is then passed by means of inlet 22 into the separating vessel 23 wherein by gravity separation, the more dense water phase migrates towards the bottom of the vessel into a layer 30 with the less dense oil phase migrating to the top of the vessel into a layer 26. A mid-layer or interface layer 32 is formed in the vessel and is comprised of a suspension or emulsion of oil and water which is sometimes referred to as a "rag" layer. This may be an oil in water or water in oil suspension or emulsion and even have changing characteristics in this respect. This interface or "rag" layer becomes a relatively large part of the fluid mixture in the vessel and substantially decreases the residence times of fluid in the separating vessel due to the increased volume of this emulsion layer. Prior art systems often treat this layer by the use of chemicals in addition to increased residence time in order to separate the suspension or emulsion and recover the constituent fluids. In addition to chemical treatment of these fluids, mechanical devices, as well as the use of heat and electrical potential are used for breaking the emulsion and promoting coalescence of the constituent fluids. In the process of trying to find a solution to the problems involved in the separation process described, it has been found that solids particles which are a constituent part of the fluids being treated, serve to form a nucleus about which oil forms to envelope the solid particle and thereby create a neutrally buoyant particle which is a combination of the more dense solid and the less dense oil coating. This neutrally buoyant component is an integral part of the rag layer which typifies this process and generates the problems of separation associated therewith. In order to better treat this rag layer in a more efficient and simplified manner, an outlet line 34 from the separator vessel 23 feeds the rag layer to a hydrocyclone 40. If necessary this may be facilitated by use of a pump 36 provided in the line 34 between the separation vessel 23 and hydrocyclone 40. The rag layer is admitted to the hydrocyclone by means of

an inlet 38. These fluids are admitted tangentially into the hydrocyclone wherein they are caused to separate by the centrifugal action imposed upon the fluids as a result of the geometrical design of the hydrocyclone. The centrifugal forces in the hydrocyclone are increased to the point that the oil coating the particulate matter becomes dislodged therefrom and the particulate matter is forced to the outer wall of the hydrocyclone while the oil component migrates to the centerline of the hydrocyclone for discharge from an overflow outlet 44. The solid particulate matter thus joins the water component in the system at the outer wall of the hydrocyclone for discharge at an underflow outlet 42. This more dense component of the mixture which is comprised of the solids and water is passed through a control valve 46 into an outlet line 48 and thence into a separation vessel 50. Separation vessel 50 provides a means for separating out the solids from the liquid constituents which have exited the hydrocyclone through the underflow. The solids will have now had the oil coating removed therefrom to provide a sufficient density differential with respect to the liquids accompanying them to effect gravity separation therefrom in the separation vessel 50. The solids are removed by means of a dump outlet 51 on the bottom of the vessel. Liquids in the vessel are passed over a weir 53 to an outlet line 52. The water component which now predominates the effluent into line 52 can be discharged from the system by means of a line 59 by operation of valve 61, or alternatively, may be passed by operation of valves 57 or 58 respectively into return lines 56 and 60 which eventually return the water component to the separation vessel 23. Alternative line 60 passes such a water component into the fluids inletting into the separator 23. Again, alternate routes are provided so that such water can be inletted either before or after the crude passes through the mixing valve 20. Line 64 provides a flow path into the inlet stream ahead of the mixing valve so that this water may be used to remix and thereby wash the crudes. Operation of a valve 66 permits an alternative route for supplying the water to the inletting fluids downstream of the mixing valve. In some situations the mixing valve may be creating more of an emulsion problem for the mixture than is solved by the mixing of the

water and crude. Also, the recycle stream from the hydrocyclone underflow 42 may be too contaminated to provide wash water for the desalter. In those situations, the alternative flow path 62 could be used to introduce the water downstream of the mixing valve.

In certain situations it may be desirable to introduce the water into the separator near the lower level of the rag layer to thereby provide for its entry into the vessel 23 separate from the oil and/or solid components of the mixture. This might be necessary in a situation where it is desirable to continuously remove water from the system such as when the inletting fluid has a substantially large water component in the beginning. In such a situation, it may not be necessary to add wash water to the inletting mixture.

These various alternative schemes for dealing with the water leg being discharged from the hydrocyclone are provided to show that there are any number of separation schemes which may be treated by the system described herein when the basic problem being attacked is that of removing the oil layer from a solid particle to enhance its separation from a fluid mixture. In this respect, another alternative flow arrangement is shown in Figure 3 for a classic desalting operation wherein the system is similar to Figure 1 up to the point of discharge of fluids from hydrocyclone 40. However, instead of passing the underflow stream of the hydrocyclone 40 through a downstream separator for removing solids, the underflow stream is recycled, directly to the input of the vessel 23, which in this case would be a desalting device. Often in a desalting operation, the makeup of the rag layer is such that it will not be separated in one pass through the hydrocyclone and therefore the streams outletting the hydrocyclone will not be pure enough components for discharge from the separation system. Thus, these hydrocyclone outlet streams will be returned to the separation vessel 23. The solid particles which become separated from the oil coating in the hydrocyclone will pass with the underflow stream into the inlet 22 of the separator wherein they will separate such as by gravity for removal through the outlet 28 on the bottom of vessel 23. In this desalting system of Figure 3, the pump 36 provides the pressure necessary to move the

solids in the more dense underflow stream back to the vessel 23 for separation and subsequent disposal. Likewise, the overflow stream is carried by way of line 70 back to vessel 23.

In the Figure 1 embodiment, the oil or less dense component emerging at the overflow outlet 44 of the hydrocyclone is passed by means of a flowline through alternate flow paths. Alternate flow path 74 serves to discharge the oil component from the system either for further processing of the oil or for its disposal in some manner. Alternatively, by operation of the valve 72 the oil component may be passed back to the separation vessel 23 by means of inlet 70 at or near the upper level of the rag layer to thereby promote its further separation from the incoming mixture. In this case, the oil would be discharged by means of outlet 24 for whatever further processing or disposal would be desirable.

In Figures 1 and 3, inlet lines 68, 54 and 35 are shown for providing a means of injecting chemicals into the separated fluid streams. Chemical injection line 54 is provided for inletting a chemical into the water leg 52 exiting from the separator vessel 50. This would provide further treatment of the water leg to separate any remaining oil components therefrom either before its disposal from the system or prior to recirculating the water leg into the separation system. Injection of chemicals at this point would have the advantage of providing more intense treatment of the fluids in the line 52 prior to recombination of the water leg in line 52 with the inletted fluids to the primary separation vessel 23. In addition, a chemical injection line 68 is shown for injecting chemicals into the oil component shown exiting the hydrocyclone at outlet 44 prior to the readmission of the oil stream into the inlet 70 of the separation vessel 23. Again, introduction of chemicals at this point in the system will provide for more concentrated treatment of that component by the chemical prior to its being remixed with the other fluids in the separation vessel 23. In addition, a chemical injection line 35 is shown feeding into the outlet line 34 from separation vessel 23 to provide a means for injecting chemicals into the mixture passing to the hydrocyclone 40, upstream of the pump 36.

In the operation of this system just described with respect to Figures 1 and 3, as for example, in a desalting operation, the crude oil being treated likely contains a concentration of solids particles in the form of salts or heavy metals which provide downstream problems as to either corrosion of the refining and process systems or in the products derived from the crude. To remove these solids, such fluids are inletted by means of inlet line 12 and pump 14 to the separation vessel 23. In the case of a classical desalting operation, water would be added by means of inlet lines 16 and pump 18 to mix with the crude and by means of mixing valve 20 wash the salts from the crude for subsequent separation in the tank or separating vessel 23. In other operations, there may be sufficient water in the incoming oil line such as in a production separation situation, wherein it would be undesirable to utilize the mixing valve 20 or to add additional water to the system. In any event, the fluids are inletted by means of inlet 22 into the separation vessel 23. Vessel 23 serves as a residence vessel for permitting fluid components of the mixture to separate by density into more dense and less dense layers. The more dense layer, which in this typical system is water, will fall to the bottom of the separation vessel 23 for removal therefrom by means of line 28. The lighter phase of the system will migrate to the upper level 26 for removal therefrom by means of the exit line 24. Typical of the fluids being treated by the system of the present invention is that such fluids have the common problem of developing a suspension or emulsion layer that is stabilized by the effect of solids particles in the fluid mixture. These solid particles act as a nucleus about which oil collects to form a neutrally buoyant component layer described as a rag layer. This emulsion component 32 is taken by line 34 into the inlet 38 of the hydrocyclone 40. An inlet line 35 provides means to inject treating materials into the line 34 prior to the mixture entering the hydrocyclone. Such materials might be demulsifying chemicals or other such chemicals to aid in the separation process by enhancing separation in the hydrocyclone or with the chemical being enhanced by the hydrocyclone for aiding in further separation in or downstream of the hydrocyclone.

The fluids inletted to the hydrocyclone 40 are separated within the

hydrocyclone to form a less dense component exiting the overflow outlet 44 and a more dense component which is comprised of water and solids particles which outlet through the underflow outlet 42 into a discharge line 48. A control valve 46 is provided in the line 48 to control the outlet flow from the underflow of the hydrocyclone. The more dense component of the mixture which is comprised of the water and solids particles is passed into a separation vessel 50 for removing the solids and passing the water component by means of a line 52 for further processing in the system. In the case of a desalting operation such more dense underflow stream would likely be returned directly to the input line 22 to vessel 23 as shown in Figure 3 of the drawings.

In other systems where it is desirable to remove net water from the system, the water outletting from the separation vessel 50 may be discharged to an outside disposal line, by means of an outlet line 59 and valve 61. Alternatively, water outlet 52 can be recycled into the separation vessel 23 by means of vale 57 and recycle line 56. The route returns the water into the vessel 23 near the interface of the suspension/emulsion layer 32 and water layer 30 so that the water returns to water. Again alternatively, the water output from line 52 may be recycled into the emulsion layer 32 by introducing the water stream into the inletting mixture either upstream or downstream of the mixing valve 20. This latter route is chosen by use of valve 58 and line 60, in conjunction with lines 62, 64 and valve 66.

Next referring to Figure 2 of the drawings, a system is described for solving similar problems in a different environment which involves the use of separation equipment for separating fluid components of a drilling fluid system for use in drilling oil wells. Referring now to Figure 2 of the drawings a drilling fluids separation system is shown having a choke manifold 82 which provides for ultimate control over pressure between the wellbore and the separation system. A separator 84 receives fluids from the circulation system of the conventional drilling system and in the drilling operation described herein the pressure from the well being drilled is fully or partially passed into the separator 84 which then serves as a choke on the system. Such a separator

vessel is capable of withstanding relatively higher pressure. As an example, the Ansi Class 600 vessels will accommodate pressures up to 1,480 psi. In the separator 84 most of the gas which is produced is liberated from the fluids, which gas can be flared or passed to a gas receiving system for subsequent disposal through the line 86. Also, in the separator 84, solids which may be in the form of a fine paste of drilling cuttings or the like, such as when drilling is performed in a chalk formation, may gravity separate from the fluids to the bottom of the separator. The bottom of the separator is periodically drained through line 88 to allow the solids to pass to a pit for disposal of the solid fines. A level control 90 opens and closes the valves 92 to maintain a liquid level in the separator 84 to keep gas above the lower level of the separator and thus prevent gas as much as possible from moving out into the remainder of the separator system. If the liquid level of separator 84 should fall below a desired level, the liquid level control 90 will close the valves 92 to permit a buildup of fluids within the separator and thereby keep the gas level at a sufficiently high position in the separator.

The fluids exiting separator 84 are passed through valves 92 to a holding tank 116 which typically is a large portable tank that can be moved easily. The tank 116 is not a pressure vessel normally but is enclosed and has a fan to draw off gas through a stack 117 for venting to the atmosphere. The tank 116 provides a first quiet zone 110 so that the solids or fines in the fluids at this point may gravity separate to the bottom of tank 116. A major portion of the solids may be removed from the drilling fluids in the tank 116. These solids are then pumped or drained from the bottom of tank 116 through line 124 to a solid/liquid centrifuge separator 118 which separates solids from liquids therein, with the solid components from the separator 118 passing to a pit, not shown, through underflow outlet 122. Water and oil from the centrifuge 118 are then passed back to an overflow chamber 119 in the tank 116 where they join the oil and water components that spill over the baffle 121 into chamber 119.

Tank 116 is arranged to control the level of oil and water layers

96, 98 respectively in the tank, using a level control 143. The top of the oil layer 96 in chamber 119 of tank 116 is passed through a line 140 to a settling tank 142 for further separation before pumping to sales represented by the tank 141. Any water taken from the surge tank 142 is passed back to the water layer 98 of tank 116 by way of line 141.

It has been found that particulate matter in the drill cuttings such as particles of chalk become wetted by the produced oil which passes from the formations being drilled into the drilling fluids stream. These solid particles thus form a nucleus which when covered with oil becomes a neutrally buoyant particle that forms the basis of a suspension or emulsion layer in the fluid mixture. Thus, the water phase that is taken from tank 116 which passes through line 146 into the inlet 134 of a hydrocyclone 147, has such neutrally buoyant oil coated particles as a part of the makeup of the mixture which is inletted to the hydrocyclone. An oil phase exits through the reject or overflow outlet 45 of the hydrocyclone and is passed back to the oil layer 96 of the tank 116 to enter the tank at the top edge of the suspension layer 97. This suspension layer 97 being separated by the hydrocyclone 147 may be for example in the range of 65% oil and 35% water but at this point the oil phase portion of the stream represents only 1 1/2 to 2% of the total fluid volume of the system. A pump 152 may be provided in the line 146 in the system to provide sufficient inlet pressure of fluids entering the hydrocyclone to effect proper separation of the oil and water phases in the mixture passing into the hydrocyclone. The underflow outlet 151 from the hydrocyclone 147 connects with alternate flow paths. One such path passes the water leg to a residence vessel 162 which serves as a means for separating solids from the primarily water component exiting from the underflow (151) of the hydrocyclone. This residence vessel has a weir 163 therein for trapping solids in a first portion of the vessel which may be removed by means of a drain outlet 164. The water component passes over the weir into the remainder of the vessel 162 and is outletted through a flow line 165 to a drilling fluid pit at the drill site to await recirculation in the drilling fluids system. If the level control 143 on tank 116 is

calling for recycle of the water stream, then this water stream passes by way of a line 166 through valve 144 back to tank 116 where it enters the tank at or below the interface of the water layer 98 and the emulsion layer 97. The outlet line 165 to the drilling fluid pit is closed by means of control valve 168 likewise operated by the level control 143.

The level control 143 on tank 116 operates as follows: as the level of water in tank 116 rises to a predetermined level, the level control closes the recycle valve 144 and opens valve 168, since enough water is being received with the incoming fluids from the well. Thus, the water passing from the tank 116 and separated by hydrocyclone 147 and residence vessel 162, is passed to the drilling fluids tank or pit through line 165. Alternatively, when the water level in tank 116 drops to a predetermined level, the level control 143 opens valves 144, closes valve 168, and thereby maintains the oil/water interface within a predetermined limit range. In theory, valves 144, 168 will be opened and closed in a throttling fashion, attempting to maintain a relatively constant level within the predetermined range.

An alternative arrangement is shown in Figure 2 for treating fluids emanating from the underflow outlet 151 or hydrocyclone 147. A valve 149 may be opened to permit fluids from the underflow to pass through a flowline 150 to a centrifugal separator 153 for separating solids from the underflow component. The solids would leave the centrifugal separator 153 by means of an underflow 155 for further disposal wherein the water component therein would pass by means of an overflow outlet 154 for recirculation in the drilling fluids system. A still further alternative arrangement might include a hydrocyclone in place of or in addition to centrifuge 153 for separating the underflow stream into solid and liquid components.

In the operation of the apparatus just described fluids are circulated from a borehole drilling operation into the present system by means of a flowline passing such fluids from the borehole annulus through a choke manifold 82. These fluids are typically comprised of drilling fluids such as brine, water, or the like; drill cuttings; and petroleum fluids which have produced from

underground formations being traversed by the borehole. These fluids comprising the makeup of the drilling fluid system, are then passed into a separator 84 where a substantial portion of any gas present in the fluids is liberated. This equipment is sometimes called a "gas buster". This liberation of gas from the fluids substantially reduces the pressure on the fluids system so that further processing is done at a reduced pressure. Some of the drill cuttings in the fluid system may also separate out in the separator 84 and are then removed for subsequent disposal through a line 88 at the bottom of the separator. A level control 90 is operatively connected to an output line from the separator 84 to pass liquids therefrom through a valve system 92. These valves are operated by the level control. These dirty fluids which have now been depleted of most gas and some solids (drill cuttings) are next passed into a large tank 116 where they are received in a first sump or quiet zone 110 separated by a baffle 121 from the main chamber portion 119 of the tank. This first quiet zone serves to separate out a substantial portion of the solids in the form of drill cuttings in the fluids. These solids are then discharged by way of a line 124 to the inlet of a centrifuge 118 which is effective to separate any fluids in the materials discharging through line 124 from solids therein. The solids are passed to a pit, or the like (not shown) for subsequent disposal. Water or other liquids which are separated in the centrifuge 118 are discharged through the overflow 123 into chamber 119 in the tank 116. Here they are treated with the other fluid components of the fluid system which spill over the baffle 121 into chamber 119. These system fluids are permitted to gravity separate in this chamber so that a predominantly water layer 98 develops in the bottom of chamber 119 with an oil layer 96 on top. An intermediate layer 97 forms between the oil and water layers and is principally comprised of a suspension or emulsion of oil and water which is stabilized by the presence of solid particles. These solid particles act as a nucleus about which oil collects to thereby form a neutrally buoyant particle in the fluid system.

The oil layer 96 in the tank 116 passes through an overflow line 140 exiting from the upper portion of chamber 119 which directs the oil

component of the fluids to a settling tank 142. The settling tank permits further separation which can be assisted by the additions of chemicals such as demulsifiers. Any water which accumulates in tank 142 may be returned by way of a line 41 to the chamber 119 in tank 116 for further processing or alternatively, may be passed back to the drilling fluid system for reuse therein. An upper outlet of tank 142 is fed to a pump for transferring the oil to a tank 161 for sale thereof.

The suspension component 97 in chamber 119 is taken from the tank by way of a line 146 and is thus passed to a hydrocyclone 147. A pump 152 may be used to increase pressure on the inlet fluids to the hydrocyclone in order to provide sufficient swirl to effect separation therein. Such a pump can be constructed in accordance with the low shear type pump disclosed in U.S. patent 4,844,817.

These fluids passing through the hydrocyclone 147 are typically comprised of droplets forming a disperse oil or water phase in a continuous oil or water phase which separate within the hydrocyclone into the respective phases. In addition, as described above, solids particles which are present in the drilling fluids system and which have been coated by oil become neutrally buoyant because of the combined composition of a more dense solids particle and a less dense oil coating to provide a combined substance that is neutrally buoyant. This neutrally buoyant substance then passes with the continuous phase having the droplets dispersed therein. In the hydrocyclone the oil coating about the solids particles is forcibly removed by the excessive gravity forces that are present in the hydrocyclone which liberates the solids particle thus providing a less dense oil component and a more dense solids particle. The solid particles then combine with the more dense water phase and exit the hydrocyclone through the underflow outlet 151. This underflow stream which comprises the water phase and the solid particles is passed into the residence vessel 162 to remove the solids therefrom so that the water phase can be recirculated into the drilling fluids system for reuse in the drilling operation. The less dense oil phase is passed through the overflow outlet for return to the tank

119 or alternatively, could be passed directly to sales if the oil phase therein were sufficiently dry. However, if the oil phase is returned to the tank 116 the oil therein will readily deploy to the oil layer 96 within the chamber 119 for subsequent processing of the oil phase passing therefrom.

The hydrocyclone 147 which is shown in this system would typically be a dewatering hydrocyclone or a deoiling hydrocyclone which is arranged to handle a substantial amount of water, and which are described more particularly in United States patent 4,749,490 and United States patent application Serial No. 415,316. In an alternative arrangement the hydrocyclone 40 of Figures 1 and 3 and hydrocyclone 147 shown in Figure 2, may be of the type disclosed in U.S. Patent 4,810,382 which is incorporated herein by reference and which shows a circumferential slotted outlet in the outer wall of the hydrocyclone which is effective to outlet solids into an annular gallery for separate removal from the hydrocyclone. Other arrangements for solids removal from a hydrocyclone outlet are, of course, not precluded.

Therefore, while particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects, and therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

We claim:

1. In a drilling fluids separation system for use in a wellbore drilling operation for processing a drilling fluids stream comprised of a fluid mixture including oil and water components with solids particles suspended therein which has been circulated from the bottom of a wellbore to the surface and wherein oil which is produced from earth formations being drilled is present in the mixture at the surface and has coated or impregnated the solids particles to form an oil coated or impregnated nucleus which is substantially neutrally buoyant in the drilling fluids mixture, means for facilitating separation of the components in the mixture, which means comprises;

upstream separator means comprised of a hydrocyclone designed, constructed and arranged for separating oil and water components of the fluid mixture and for separating oil from the neutrally buoyant solids particle nucleus which is present in the fluid mixture inletted to the hydrocyclone to render the solids particles non-buoyant, said hydrocyclone having a separating chamber with an inlet means for inlet of the fluid mixture to be separated, an underflow outlet for outletting more dense materials in the mixture comprised substantially of water, non-buoyant solids particles and residual oil droplets, and an overflow outlet for outletting a less dense oil component of the mixture; and

downstream separator means provided downstream of the hydrocyclone for receiving the materials from the underflow outlet of the hydrocyclone;

said downstream separator means further having means for collecting and discharging solids particles passing with the materials from the underflow of the hydrocyclone into said downstream separator means, and also having means for recirculating a clarified water component to the drilling fluids stream.

2. The fluid separation system of Claim 1 wherein said downstream separator means includes a holding vessel for permitting gravity separation of solids particles and liquids from the underflow outlet materials.

3. The fluid separation system of Claim 1 wherein said downstream

separator means includes a centrifugal separator.

4. The fluids separation system of Claim 1 wherein said downstream separator means includes a hydrocyclone.

5. The fluid separation system of Claim 1 wherein said upstream separator is a dewatering type hydrocyclone which is of the type for handling a relatively high percentage of oil.

6. The fluid separation system of Claim 1 including a first gravity separation vessel upstream of the hydrocyclone wherein the drilling fluids are passed into said first gravity separation vessel prior to the upstream separator for gravity separating the fluids into an oil layer near the top portion of the vessel, a water layer at the bottom portion of the vessel, and a suspension layer containing the neutrally buoyant oil coated particles, between the oil and water layers.

7. The fluid separation system of Claim 6 and further including flowline means for taking the fluids from the suspension layer into the inlet of the hydrocyclone.

8. The fluids separation system of Claim 7 including means for returning the clarified water component to the first gravity separation vessel.

9. The fluid separation system of Claim 8 and further including means for returning the clarified water components into the water layer of the first gravity separation vessel.

10. In a fluid separation system for processing a fluid mixture including oil and water components with solids particles suspended therein and wherein oil in the mixture has coated the solids particles to form an oil coated

nucleus which is neutrally buoyant and forms a suspension with the water component, means for facilitating separation of the components in the mixture, which means comprises;

upstream separator means comprised of a hydrocyclone designed, constructed and arranged for separating oil and water components of the fluid mixture and for separating oil from the oil coated nucleus which is present in the fluid mixture inletted to the hydrocyclone to render the solids particles non-buoyant, said hydrocyclone having a separating chamber with an inlet means for inlet of the fluid mixture to be separated, an underflow outlet for outletting more dense materials in the mixture comprised substantially of water and non-buoyant solids particles, and an overflow outlet for outletting a less dense oil component of the mixture;

downstream separator means provided downstream of the hydrocyclone for receiving the materials from the underflow outlet of the hydrocyclone; and

means cooperating with the downstream separator mean for discharging solids particles passing with the materials from the underflow of the hydrocyclone into said downstream separator.

11. The fluids separating system of Claim 10 wherein residual oil droplets are passed with the more dense materials passing from the underflow outlet and further including means on the downstream separator for providing oil and water exit streams that are separate, one from the other.

12. The fluid separation system of Claim 10 wherein said downstream separator means includes a holding vessel for permitting gravity separation of solids particles and liquids from the underflow outlet materials.

13. The fluid separation system of Claim 10 wherein said downstream separator means includes a centrifugal separator.

14. The fluids separation system of Claim 10 wherein said

downstream separator means includes a hydrocyclone.

15. The fluid separation system of Claim 10 wherein said upstream separator is a dewatering type of hydrocyclone which is of the type for handling a relatively high percentage of oil.

16. The fluid separation system of Claim 10 and further including a first gravity separation vessel upstream of the hydrocyclone wherein the fluid mixture is passed into said first gravity separation vessel prior to the upstream separator for gravity separating the mixture into an oil layer at the top of the vessel, a water layer at the bottom of the vessel, and a suspension layer containing the oil coated solids particles, between the oil and water layers.

17. The fluid separation system of Claim 16 and further including flowline means for taking fluids from the suspension layer to the inlet of the hydrocyclone.

18. The fluid separation system of Claim 17 including means for returning water and solids outletting from the underflow outlet of the hydrocyclone to the first gravity separation vessel.

19. A method for separating components of a fluid mixture including oil and water components with solids particles which are coated with oil suspended therein to form a neutrally buoyant suspension, comprising the steps of;

passing the suspension containing the oil coated solids and water into the inlet of a hydrocyclone, which hydrocyclone is constructed and arranged for separating oil and water components of a fluid mixture and has overflow and underflow outlet means for outletting less dense and more dense components respectively;

separating the oil coating from the solids particle in the hydrocyclone;

passing the uncoated solids and water form the hydrocyclone through the underflow outlet means; and

passing the oil from the hydrocyclone through said overflow outlet means.

20. The method of Claim 19 wherein said underflow outlet means includes separate underflow outlets for predominantly separate solid particle and water components and further including passing the solid particles from a solids underflow outlet for predominantly outletting solid particles and passing predominantly water from a separate underflow outlet.

21. The method of Claim 19 wherein the fluid mixture is taken from a vessel having an oil layer and a water layer with a suspension layer formed at the interface of said oil and water layers wherein the suspension inletted to said hydrocyclone is taken from said suspension layer, and further including passing the uncoated solids and water from the underflow outlet back into said suspension layer.

1/3

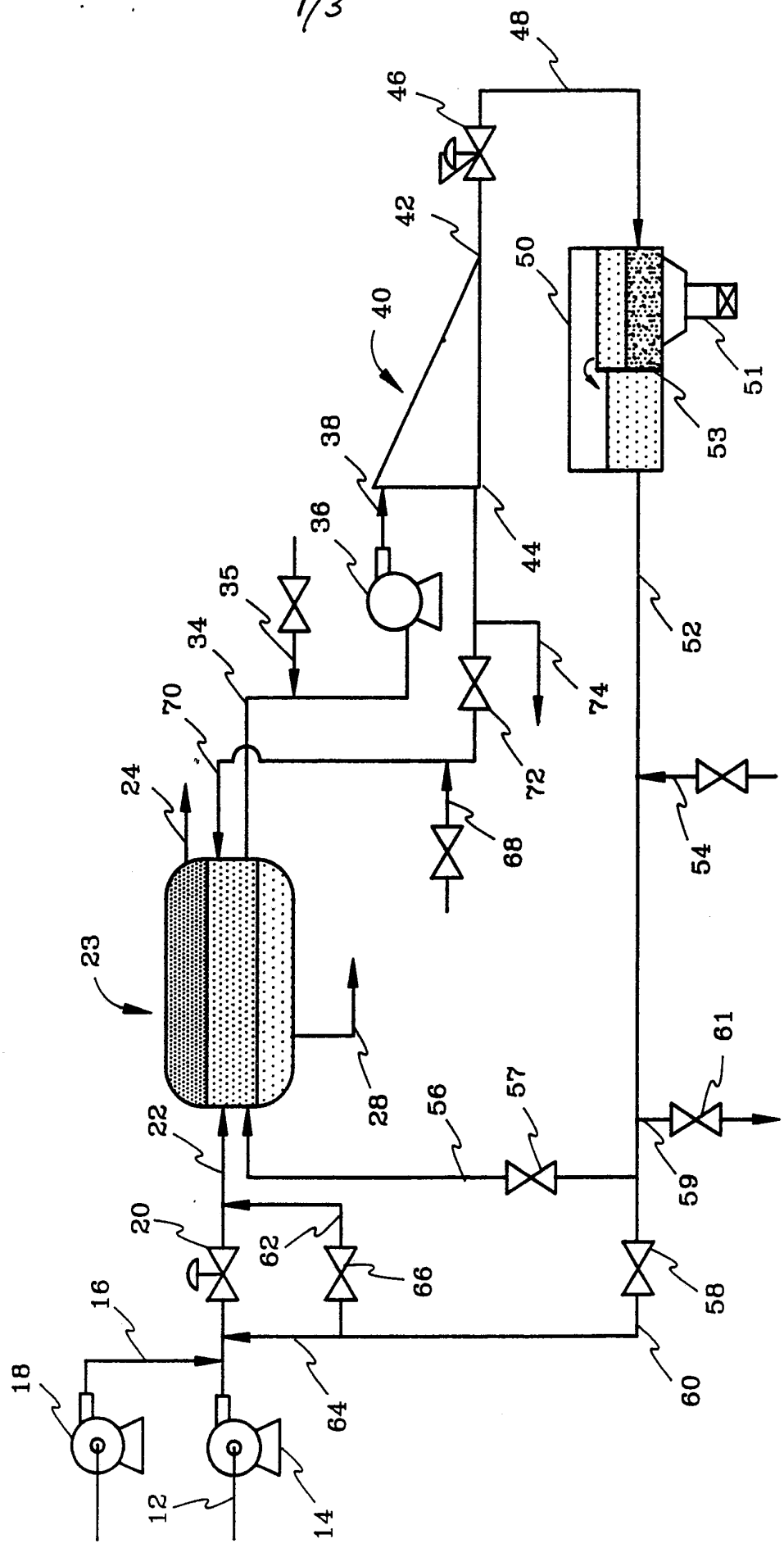

48
46
42
50
40
51
53
38
36
44
35
34
52
74
70
72
24
68
54
23
28
61
56
57
22
59
20
62
66
58
16
18
64
60
12
14

Fig. 1

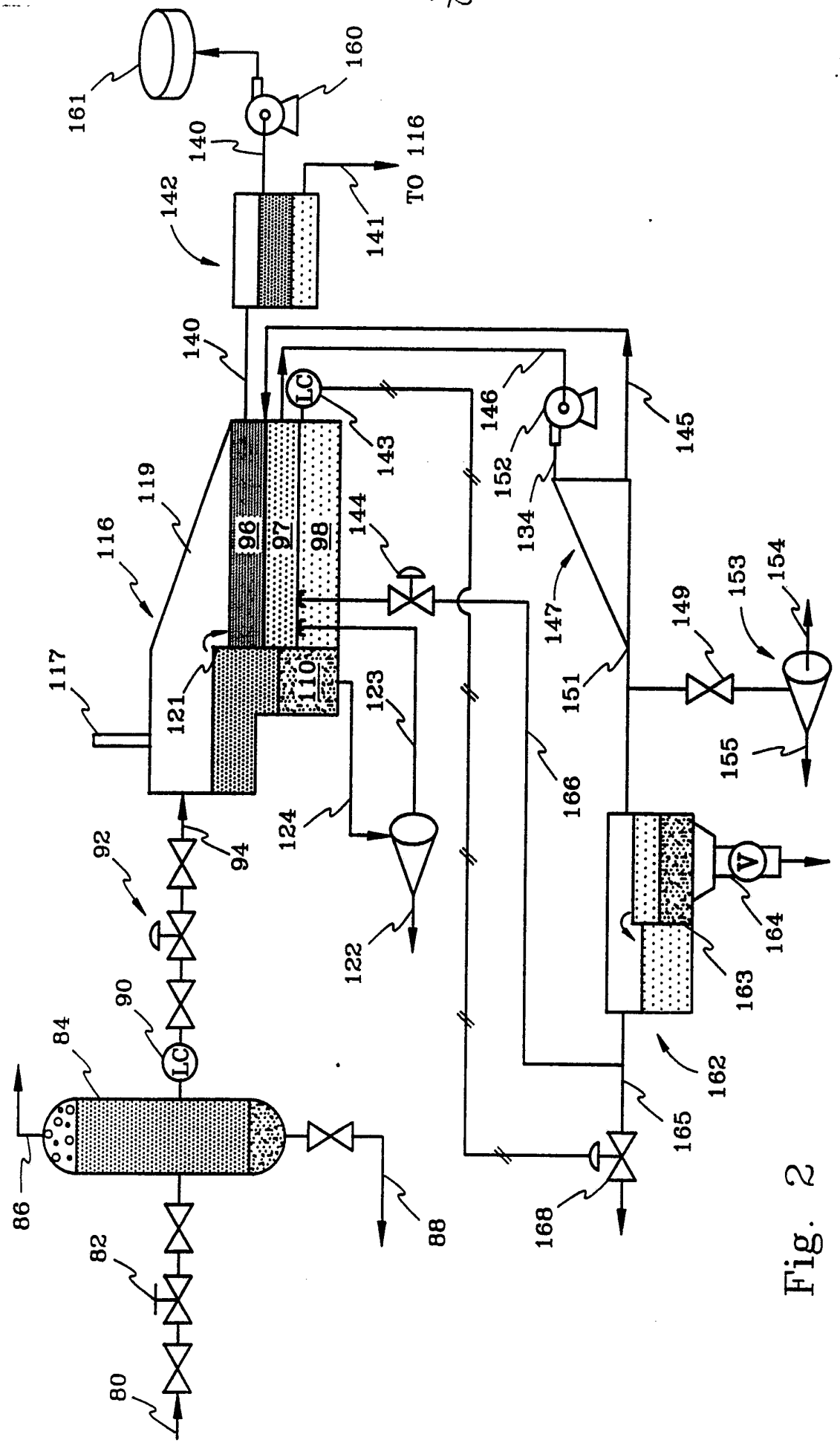

161
160
140
TO 116
142
141
140
LC
143
146
145
152
134
119
116
96
97
98
144
147
153
154
149
117
121
110
123
151
155
166
124
92
94
122
164
163
90
LC
84
162
165
86
88
168
82
80

Fig. 2

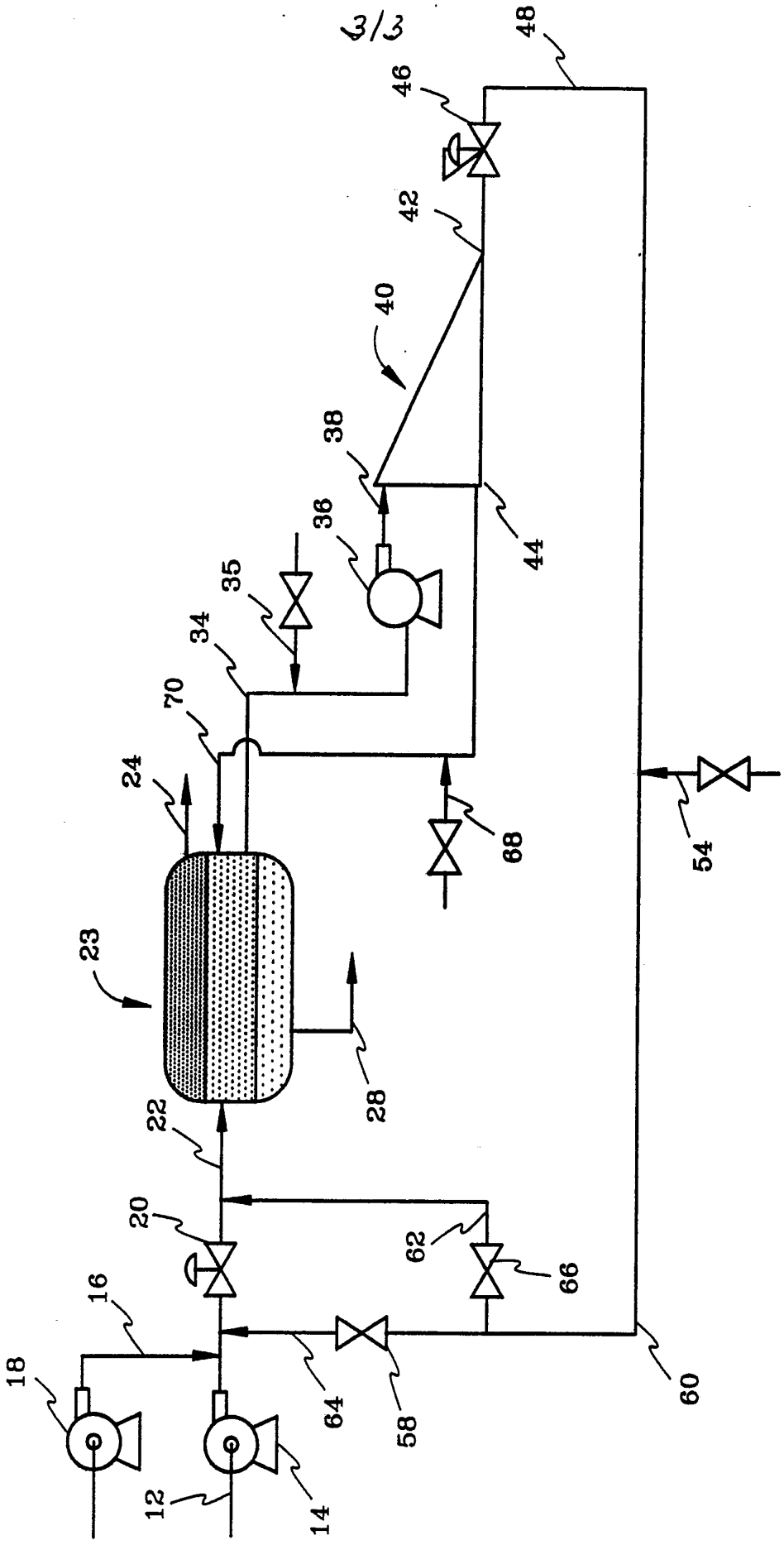

48
46
42
40
38
44
36
35
34
70
24
68
54
23
28
22
20
62
66
16
18
64
58
60
12
14

Fig. 3

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US91/02886

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): B01D 17/038

U.S. CL: 210/787

II FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S. CL.	166/267; 208/187; 210(197,259,360;512.1,502.2,513, 537,787 800.805,806)

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X Y	US, A, 3,764,008 DARLEY ET AL. 09 October 1973. See entire document.	1,3,4,6,10-14 and 16 2,5,7-9,15,17-19 and 21
Y	US, A, 4,738,779 CARROLL ET AL. 19 April 1988. See abstract.	5 and 15
Y	US, A, 4,721,565 CARROLL 26 January 1988 See entire doument.	1-19 and 21
Y	US, A, 4,698,152 CARROLL 06 October 1987 See entire document.	2,6,7,16,17 & 21
Y	US, A, 4,548,707 WOLF ET AL. 22 October 1985 (See column 3, line 64-column 4, line 27).	2,6,7,16,17 & 21
Y	SU, A, 874,096 NEFTEKHIMPROMAYTOMA 23 October 1981 See entire document.	6,16 and 21
Y	US, A, 4,243,528 HUBBARD ET AL 06 January 1981. See column 1, lines 1-55.	2,6-9,15-18 and 21
Y	US, A, 3,516,490 SMALLING ET AL 23 June 1970. (See column 1, lines 14-70 and column 3, lines 5-19).	19,21

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
13 JUNE 1991	12 JUL 1991
International Searching Authority	Signature of Authorized Officer
ISA/US	for NGUYEN NGOC-HO JOSEPH DRODGE INTERNATIONAL DIVISION

Form PCT/ISA/210 (second sheet) (Rev.11-87)