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(71) Applicants *(for all designated States except US)*: **VARCO I/P, INC.** [US/US]; 10000 Richmond Avenue, Houston, Texas 77042-4200 (US). **LUCAS, Brian** [GB/GB]; Lucas & Co., 135 Westhall Road, Warlingham Surrey CR6 9HJ (GB).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **KOCH, Richard James** [US/US]; 28817 Dobbin-huffsmith, Magnolia, Texas 77354 (US). **SCOTT, Eric** [US/US]; 8913 Summerdale Lane, Conroe, Texas 77302 (US). **STONE, Lyndon Ray** [US/US]; 7904 Palmer Place Lane, Humble, Texas 77346 (US).

(74) Agent: **LUCAS, Brian**; Lucas & Co., 135 Westhall Road, Warlingham Surrey CR6 9HJ (GB).

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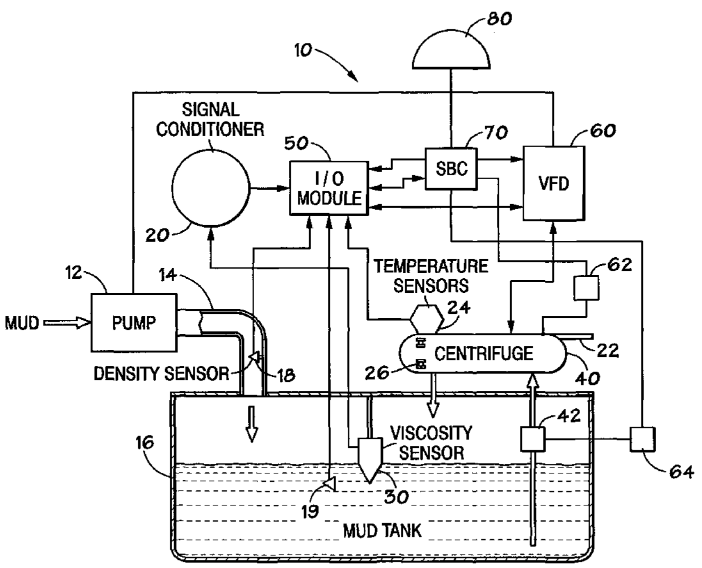
(54) Title: APPARATUS AND METHOD FOR CONTROLLING THE VISCOSITY OR THE DENSITY OF A DRILLING FLUID



(57) Abstract: A method for controlling viscosity (or density) of drilling fluid containing solids, said drilling fluid circulating in a drilling fluid system, which method comprises the steps of: (a) feeding drilling fluid into a container (16); (b) sensing with a viscosity (or density) sensor (19) a viscosity (or density) of drilling fluid in said container (16) and providing a viscosity (or density) signal representative thereof; (c) in response to said viscosity (or density) signal pumping a portion of said drilling fluid to a solids separation apparatus (40); (d) separating with said solids separation apparatus (40) at least some of the solids from said portion of drilling fluid; and (e) returning to said drilling fluid system drilling fluid and/or solids separated in step (d) to adjust the viscosity (or density) of said drilling fluid in said container (16).

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APPARATUS AND METHOD FOR CONTROLLING THE VISCOSITY OR THE DENSITY OF A DRILLING FLUID

The present invention relates to a method of controlling the viscosity or density of a drilling fluid, to an apparatus for performing the same, to a control apparatus and to a kit for performing the method.

During the construction of a wellbore for the extraction of oil and/or gas, drilling fluid (or "mud") is used to control subsurface pressures, lubricate the drill bit, stabilize the wellbore, and to carry the drill cuttings to the surface amongst other functions. Mud is pumped from the surface through the hollow drill string, exits through nozzles in the drill bit, and returns to the surface through the annular space between the drill string and the walls of the hole.

As the drill bit grinds rocks into drill cuttings, these cuttings become entrained in the mud flow and are carried to the surface. In order to re-use the mud once it returns to the surface and to make the solids easier to handle, the solids must be separated from the mud. To do this the mud is sent through a solids separation system. The first step in separating the cuttings from the mud involves passing the mixture of mud and cuttings over vibrating screens known as shale shakers. The drill cuttings remain on top of the shale shaker screens; the vibratory action of the shakers moves the cuttings down the screen and off the end of the shakers to a point where they can be collected and stored in a tank or mud pit for further treatment or management. The liquid mud passes through the screens and is re-circulated back to mud tanks from which mud is withdrawn for pumping downhole. The function of the mud tanks is to provide a ready supply of cleaned mud for the circulation system.

Additional mechanical processing is often used following treatment by shale shakers to further remove as many fine solids as possible since these particles tend to affect the properties of the mud and drilling performance if returned to the circulation system. This mechanical equipment is usually one of more of three types: 1) hydrocyclone-type desilters and desanders; 2) mud cleaners (hydrocyclone discharging on a fine screened shaker), and 3) rotary bowl decanting centrifuges. The separated fine solids are combined with the larger drill cuttings removed by the shale shakers.

Decanting centrifuges can be used to process drilling fluids to separate undesired drilling solids from liquid mud, particularly solids of a size that cannot be removed by shale shakers for example. When such a centrifuge is used to process drilling material (drilling fluid with drilled cuttings therein), changing mud flow conditions often require manual adjustment of centrifuge pump speeds to optimize centrifuge treating performance. Centrifuge operation can be a compromise between performance and intervals between maintenance and repair operations.

Despite this processing by the solids separation system the mud waiting in the mud tanks to be re-used may not have the desired physical properties.

In particular drilling fluid contains various materials and weighing agents, including particularly substantial quantities of clays and other colloidal materials which assist in imparting the required viscosity and gel strength to the mud as required for the entrainment and suspension of the drill cuttings. Whereas the specific gravity or density of the mud can be readily increased by the addition of weighing materials, the drilling mud must have suitable viscosity to perform the aforementioned functions.

The rheological, or flow properties, of a mud invariably change during use, especially viscosity and gel strength. This is due to the nature of the clays, e.g., bentonite, which are readily hydrated during use and which, when hydrated up to the point of maximum hydration of the clay constituents, increase the viscosity and gel strength of the mud. Generally, the clay constituent, or constituents, of a mud gradually absorb or adsorb water and the viscosity and gel strength of the mud is increased. The acceptable range of viscosity and gel strength which a mud can possess, however, is limited, and it cannot be permitted to become too thin or too thick. When a mud becomes too thick, it must be thinned and brought back into an acceptable range of viscosity and gel strength.

In some instances, a centrifuge is used in an effort to control the plastic viscosity of mud. A desired plastic viscosity is a function of the type of mud (water, oil, synthetic-based), the mud density, and other variables. When mud viscosity is too high, the operator will switch on the centrifuge or run it faster. When mud viscosity is too low, the operator will switch off the centrifuge or run it slower. Periodically mud properties are measured manually and corrective action taken by the operator. This can result in a saw-tooth effect on the viscosity of mud re-entering the circulation system which is undesirable.

According to the present invention there is provided a method for controlling viscosity of drilling fluid containing solids, said drilling fluid circulating in a drilling fluid system, which method comprises the steps of:

(a) feeding drilling fluid into a container;

(b) sensing with a viscosity sensor a viscosity of drilling fluid in said container and providing a viscosity signal representative thereof;

(c) in response to said viscosity signal pumping a portion of said drilling fluid to a solids separation apparatus;

(d) separating with said solids separation apparatus at least some of the solids from said portion of drilling fluid; and

(e) returning to said drilling fluid system drilling fluid and/or solids separated in step (d) to adjust the viscosity of said drilling fluid in said container. In one embodiment, desirable larger solids are introduced back into the container (e.g. barite solids with a largest dimension of greater than about ten microns, and/or drilling solids with a largest dimension greater than about twenty microns). In another embodiment drilling fluid may be returned to the container. Which material and how much is returned to the container may be selected automatically by computer control apparatus. The solids separation apparatus may be a decanting type centrifuge which may be controlled by changing speed of rotation and/or feed rate of drilling fluid in order to adjust the viscosity of drilling fluid in the container. In certain aspects, the centrifuge may be controlled to run at a high speed (e.g. greater than about 2200RPM) so that fluid may be returned to the container. In other aspects the centrifuge may be run at a low speed (e.g. less than about 2200RPM) so that solids may be returned to the container.

The solids separation apparatus may either be part of the existing solids separation system, or it may be a stand alone apparatus (e.g. centrifuge) dedicated to receiving drilling fluid from one or more mud tanks and processing it as described above.

Further steps are set out in claims to 2 to 14 to which attention is hereby directed.

According to another aspect of the present invention there is provided a method for controlling density of drilling fluid containing solids, said drilling fluid circulating in a drilling fluid system, which method comprises the steps of:

(a) feeding drilling fluid into a container;

(b) sensing with a density sensor a density of drilling fluid in said container and providing a density signal representative thereof;

(c) in response to said density signal pumping a portion of said drilling fluid to a solids separation apparatus;

(d) separating with said solids separation apparatus at least some of the solids from said portion of drilling fluid; and

(e) returning to said drilling fluid system drilling fluid and/or solids separated in step (d) to adjust the density of said drilling fluid in said container.

According to yet another aspect of the present invention there is provided an apparatus for controlling viscosity of drilling fluid held in a container that forms part of a drilling fluid circulation system, which apparatus comprises:

a viscosity sensor for sensing viscosity of said drilling fluid in said container and for outputting a viscosity signal indicative thereof;

a solids separation apparatus for removing solids from the drilling fluid;

a pump apparatus for pumping drilling fluid to said solids separation apparatus; and

a control apparatus for receiving said viscosity signal from said viscosity sensor, which control apparatus is configured to control the method steps set out above. The control apparatus may be in the form of a computer storing computer executable instructions for operating the aforementioned process.

Further features are set out in claims 17 to 20 to which attention is hereby directed.

According to another aspect of the present invention there is provided for use in an apparatus for controlling viscosity of drilling fluid held in a container that forms part of a drilling fluid circulation system, a control apparatus having a memory storing computer executable instructions for instructing the any of the method steps set out above.

According to yet another aspect of the present invention there is provided an apparatus for controlling density of drilling fluid held in a container that forms part of a drilling fluid circulation system, which apparatus comprises:

a density sensor for sensing density of said drilling fluid in said container and for outputting a density signal indicative thereof;

a solids separation apparatus for removing solids from the drilling fluid;

a pump apparatus for pumping drilling fluid to said solids separation apparatus; and

a control apparatus for receiving said density signal from said density sensor, which control apparatus is configured to control the method steps set out above.

According to another aspect of the present invention there is provided for use in an apparatus for controlling density of drilling fluid held in a container that forms part of a drilling fluid circulation system, a control apparatus having a memory storing computer executable instructions for instructing the method steps set out above.

According to another aspect of the present invention there is provided a kit for controlling viscosity or density of drilling fluid held in a container that forms part of a drilling fluid circulation system, which kit comprises:

(a) a viscosity sensor or a density sensor; and

(b) a control apparatus comprising a memory storing computer executable instructions for instructing any of the method steps set out above.

In certain aspects a centrifuge used in the present invention may be run at a G-force of about 700 G's or greater, e.g. up to 1000 G's, for controlling density; and at less than 700 G's for controlling viscosity.

In certain embodiments, the present invention discloses a centrifuge system that automatically controls drilling mud viscosity in a drilling system. Sensors measure mud viscosity and mud density. The mud density is used to determine an optimal viscosity. The optimal viscosity is used then as a set point for a control system. A value of measured viscosity is compared to the desired set point value. Based on this comparison, action is taken to increase or decrease mud viscosity, resulting in the maintenance of optimum and consistent mud properties. In certain aspects, the need for operator intervention is reduced or eliminated.

For a better understanding of the present invention reference will now be made, by way of example only, to the accompanying drawings in which:

Fig. 1 is a schematic block diagram of an apparatus for controlling a centrifuge system according to the present invention;

Fig. 2 is a schematic block diagram of a first embodiment of a method according to the present invention;

Fig. 3 is a schematic block diagram of a second embodiment of a method according to the present invention;

Fig. 4 is a cross section through a prior art centrifuge; and

Fig. 5 is a third embodiment of a method according to the present invention.

Referring to Fig. 4 a prior art centrifuge system S comprises a bowl 112 supported for rotation about its longitudinal axis, has two open ends 112a and 112b, with the open end 112a receiving a drive flange 114 which is connected to a drive shaft for rotating the bowl. The drive flange 114 has a longitudinal passage which receives a feed tube 116 for introducing a feed slurry, e.g. drilling material such as drilling fluid returned from a wellbore, into the interior of the bowl 112. A screw conveyor 118 extends within the bowl 112 in a coaxial relationship thereto and is supported for rotation within the bowl. A hollow flanged shaft 119 is disposed in the end 112b of the bowl and receives a drive shaft 120 of an external planetary gear box for rotating the screw conveyor 118 in the same direction as the bowl at a selected speed. The wall of the screw conveyor 118 has one or more openings 118a near the outlet end of the tube 116 so that the centrifugal forces generated by the rotating bowl 112 move the slurry radially outwardly and pass through the openings 118a and into the annular space between the conveyor 118 and the bowl 112. The liquid portion of the slurry is displaced to the end 112b of the bowl 112 while entrained solid particles in the slurry settle towards the inner surface of the bowl 112 due to the G' forces generated, and are scraped and displaced by the screw conveyor 118 back towards the end 112a of the bowl for discharge through a plurality of discharge ports 112c formed through the wall of the bowl 112 near its end 112a.

Weirs 119a (two of which are shown) are provided through the flanged portion of the shaft 19 for discharging the separated liquid.

Referring to Fig. 1 a control system 10 according to the present invention comprises a pump 12 that pumps drilling mud through a pipe 14 into a mud tank 16. The drilling mud has already been processed by solids control equipment (not shown) such as shale shakers, hydrocyclones and/or centrifuges prior to arrival at the mud tank 16 through the pipe 14. The mud tank has an outlet (not shown) through which drilling fluid can be drawn to be used again. As such the mud tank 16 provides a storage container for recycled drilling mud before it is used again. As desired, one or more agitators may be used in the mud tank 16.

The mud tank 16 comprises a viscosity sensor 30 for sensing the viscosity of the mud in the tank 16; a density sensor 18 for sensing the density of the mud in the pipe 14; and, optionally, a density sensor 19 for sensing the density of mud in the tank 16. The density sensor 19 can be outside the pipe 14 (e.g. at another location in the drilling fluid circulation system) or in the mud in the tank 16. A solids separation apparatus which in this embodiment is centrifuge 40 (which can be any suitable known centrifuge with a rotatable bowl and a rotatable screw conveyor, including, e.g., a centrifuge as in Fig. 4) is provided for receiving mud pumped by a pump 42 from the mud tank 16 and processes it to remove selected solids, thereby controlling and/or changing the viscosity of the mud leaving the centrifuge 40. Selected solids are discharged from the centrifuge in a line 22 and the processed mud, with desirable solids therein, is reintroduced into the mud tank 16. The pump 42 may run continuously.

A control apparatus in the form of a computer system ("SBC") 70 comprises a microprocessor having access to a memory that store the necessary instructions for controlling the methods described herein. The computer system 70 controls an I/O module 50 and variable frequency drives ("VFD") 60, 62, 64. VFD 60 controls bowl speed of the centrifuge 40. VFD 62 controls the screw conveyor of the centrifuge 40. VFD 64 controls a feed pump 42 that pumps drilling fluid or mud to the centrifuge 40. The system 70 computes a desired pump speed (pumping rate). A signal conditioner 20 controls the viscosity sensor 30 and provides power to it. Temperature sensors 24 monitor the temperature of bearings 26 of a centrifuge drive system and send signals indicative of measured temperatures to the Input/Output module 50. The functions of the I/O module 50 include sending data from the sensors to the system 70 and sending outputs from the system 70 to the VFD 60. In use the signal conditioner 20 processes signals received from the viscosity sensor 30 to estimate an actual viscosity of the mud in the tank 16 and sends signals to the I/O module 50 indicative of actual viscosity values measured by the viscosity sensor 30. The density sensor(s) sends signals indicative of measured mud densities to the I/O module. The I/O module provides viscosity measurements and density measurements to the computer system, which may be done substantially continuously or at pre-determined time intervals. The I/O module provides command signals from the system 70 to a variable frequency drive ("VFD") 60.

Continuous density measurements made by the density sensor(s) are used by the computer system 70 to determine a desired value for a mud viscosity set point (e.g. using known equations or a look-up table). The computer system 70 compares actual viscosity measurements from the viscosity sensor 30 (processed by the signal conditioner 20) to the determined desired value and then the computer system 70 calculates the difference between the predetermined set point and a current actual viscosity value. Following this calculation, the computer system 70 changes the operational parameters of the VFDs to run a bowl and/or conveyor of the centrifuge 40 faster or slower or to control pump speed. The computer system 70, which can run periodically or continuously, provides output(s) to a display device 80 (e.g. a monitor, screen, panel, laptop, handheld or desktop computer, etc.), remote and/or on site.

Fig. 2 illustrates schematically a first embodiment of a method according to the present invention using the control system 10 for the removal of undesirable solids and the return of cleaned mud with desirable solids to a mud tank 16. In certain aspects, a system according to the present invention as in Fig. 2 is useful for controlling the density of drilling material in the mud tank 16.

In Fig. 2, solids returned to the tank 16 from the centrifuge 40 are desirable solids for use in the drilling fluid. In one aspect the centrifuge of Fig. 2 is a "high speed" centrifuge operating at greater than 2200 RPMs. In certain particular aspects when used to control density the centrifuge 40 is run at a G-force of 700 G's or greater.

In one particular aspect the system of Fig. 2 is used to control the density of drilling material. The mud tank 16 receives input drilling material from a wellbore mud system (drilling fluid with entrained cuttings, solids, and/or debris pumped up from a wellbore). Typically some desirable solids, e.g. barite solids, have a relative density of about 4.2 and some drilled solids have a relative density of about 2.3. Density of the drilling mud in the tank 16 is controlled by removing some, all or substantially all of the solids in a portion of the mud that is passed through the centrifuge 40, and by returning some or all of the mud back to the tank 16. Viscosity of the material in the tank 16 may be controlled by passing a portion of the mud through the centrifuge 40 and removing small barite solids (less than about ten microns in a largest dimension) and/or small drilled solids (less than about twenty microns in a smallest dimension). Solids from the centrifuge 40 are removed in the "Undesirable Solids - Out" line in Fig. 2, and substantially clean mud is returned back into the tank 16 (comprising no solids or only minimal solids).

In one aspect, in the system of Fig. 2 large solids e.g. barite solids are returned to the tank 16 (e.g. solids with a largest dimension greater than 10 microns). In other aspects, such solids with a greatest largest dimension less than 20 microns are removed. In one aspect, such solids of a desired size, e.g. of or lesser than a selected largest dimension, are removed, e.g. a desired largest dimension between 1 and 20 microns.

Fig. 3 illustrates schematically a method according to the present invention using the control system 10 in which desirable solids, e.g. barite solids, are recovered and reintroduced into the mud in the mud tank 16. The centrifuge 40 removes undesirable solids (e.g. fine solids with a largest dimension less than about 5 microns) and returns desirable solids (e.g. solids with a largest dimension greater than about 5 microns and/or of a specific material, e.g. barite) back to the mud tank 16 for re-use. In one aspect the centrifuge of Fig. 3 is a "low speed" centrifuge operating at less than about 2200 RPMs. In this way the aforementioned desirable solids are separated from the fluid by the centrifuge 40, whilst the undesirable solids remain suspended in the drilling fluid. In one particular aspect in which the system of Fig. 3 is used for viscosity control, the centrifuge is operated at a G-force of less than 1000 G's and, in one particular aspect, less than 700 G's.

In another aspect the system of Fig. 3 is used to control viscosity of drilling material by removing viscosity-increasing solids, e.g. fine solids such as barite solids with a largest dimension less than or equal to about ten microns and/or drilled solids with a largest dimension less than or equal to about twenty microns. These removed solids remain in suspension in the drilling fluid and flow out in the line labelled "Dirty Effluent With Undesirable Solids - Out". There may be some effluent, e.g. oil, with these solids. These solids and/or effluent may be pumped to a reserve pit, to disposal, or, as shown in Fig. 5, to a system as shown in Fig. 2 for further processing in accord with any embodiment of the Fig. 2 system. In this way the undesirable solids are removed using a higher speed centrifuge so that the drilling fluid can be returned to the mud tank or other part of the mud system as desired. Optionally, in a viscosity-control system, recovered barite and/or recovered drilling solids (those not removed) are reintroduced back into the tank 16. Thus a desired viscosity of the drilling material is maintained by removing from the tank 16 at least some of the solids that increase viscosity.

In certain aspects, a system as in Fig. 2 is useful in building, reducing or maintaining a desired weight or desired density of mud.

The centrifuge 40 can be turned on and off automatically in response to inputs from the density sensors 18, 19 and/or viscosity sensor 30 in order to achieve desired drilling mud properties e.g. by building weight, or to lower weight, or to hit or maintain a desired target density or density range.

The centrifuge 40 may be part of the solids control system already existing on site, or it may be dedicated to the functions described herein.

The present invention, therefore, provides in at least some embodiments, a system for controlling viscosity of drilling fluid, the system including a container of drilling fluid material, the drilling fluid containing solids, a viscosity sensor for sensing viscosity of the drilling fluid material in the container and for producing viscosity signals indicative of said viscosity, a centrifuge for removing solids from the drilling fluid material, the centrifuge having a rotatable bowl and a rotatable screw conveyor, pump apparatus for pumping drilling fluid material from the container to the centrifuge, bowl drive apparatus for driving the rotatable bowl, conveyor drive apparatus for driving the rotatable conveyor, pump drive apparatus for driving the pump apparatus, and a control system for receiving viscosity signals from the viscosity sensor and for controlling the centrifuge and the pump apparatus in response to said viscosity signals so that selected solids from drilling fluid material processed by the centrifuge are removed or are reintroducible back into the container to control viscosity of drilling fluid material in the container. Such a system may have one or some, in any possible combination, of the following: wherein the control system and the pump apparatus are operable continuously; wherein each drive apparatus is a variable frequency drive; wherein the pump apparatus is operable at a selected pumping rate; density sensor apparatus for measuring density of the drilling fluid material and for producing density signals indicative of measured density, the control system including computer apparatus for receiving signals indicative of the density measured by the density sensor apparatus and for calculating a desired viscosity value based on said measured density, the computer apparatus for comparing the desired viscosity value to viscosity value as sensed by the viscosity sensor, and the computer apparatus for controlling the drive apparatuses to maintain sensed viscosity value at or near the desired viscosity value; the control system including computer apparatus, and display apparatus for displaying results of operation of the computer apparatus; wherein the centrifuge is a low speed centrifuge; wherein the centrifuge is operable to separate barite solids from the drilling fluid material and said barite solids are returnable to the container; and/or wherein the centrifuge is a high speed centrifuge.

The present invention, therefore, provides in certain, but not necessarily all embodiments, a system for controlling viscosity of drilling fluid, the system including a container of drilling fluid material, the drilling fluid containing solids, a viscosity sensor for sensing viscosity of the drilling fluid material in the container and for producing viscosity signals indicative of said viscosity, a centrifuge for removing solids from the drilling fluid material, the centrifuge having a rotatable bowl and a rotatable screw conveyor, pump apparatus for pumping drilling fluid material from the container to the centrifuge, bowl drive apparatus for driving the rotatable bowl, conveyor drive apparatus for driving the rotatable conveyor, pump drive apparatus for driving the pump apparatus, and a control system for receiving viscosity signals from the viscosity sensor and for controlling the centrifuge and the pump apparatus in response to said viscosity signals so that selected solids from drilling fluid material processed by the centrifuge are reintroducible back into the container to control viscosity of drilling fluid material in the container, wherein the control system and the pump apparatus are operable continuously, wherein the each drive apparatus is a variable frequency drive, wherein the pump apparatus is operable at a selected pumping rate, the control system including computer apparatus, and display apparatus for displaying results of operation of the computer apparatus.

The present invention, therefore, provides in certain, but not necessarily all embodiments, a system for controlling density of drilling fluid, the system including a container of drilling fluid material, the drilling fluid containing solids, a density sensor for sensing density of the drilling fluid material in the container and for producing density signals indicative of said density, a centrifuge for removing solids from the drilling fluid material, the centrifuge having a rotatable bowl and a rotatable screw conveyor, pump apparatus for pumping drilling fluid material from the container to the centrifuge, bowl drive apparatus for driving the rotatable bowl, conveyor drive apparatus for driving the rotatable conveyor, pump drive apparatus for driving the pump apparatus, and a control system for receiving density signals from the viscosity sensor and for controlling the centrifuge and the pump apparatus in response to said density signals so that selected solids from drilling fluid material processed by the centrifuge are reintroducible back into the container to control density of drilling fluid material in the container.

The present invention, therefore, provides in certain, but not necessarily all embodiments, a method for controlling viscosity of drilling fluid, the method including feeding drilling fluid material to a system for processing, the system as any disclosed herein for controlling viscosity, and controlling the centrifuge in response to viscosity signals to control the viscosity of the drilling fluid material in the container.

The present invention, therefore, provides in certain, but not necessarily all embodiments, a method for controlling density of drilling fluid, the method including feeding drilling fluid material to a system for processing, the system as any disclosed herein for controlling density, and controlling the centrifuge in response to density signals to control the density of the drilling fluid material in the container.

Claims: -

1. A method for controlling viscosity of drilling fluid containing solids, said drilling fluid circulating in a drilling fluid system, which method comprises the steps of:

(a) feeding drilling fluid into a container;

(b) sensing with a viscosity sensor a viscosity of drilling fluid in said container and providing a viscosity signal representative thereof;

(c) in response to said viscosity signal pumping a portion of said drilling fluid to a solids separation apparatus;

(d) separating with said solids separation apparatus at least some of the solids from said portion of drilling fluid; and

(e) returning to said drilling fluid system drilling fluid and/or solids separated in step (d) to adjust the viscosity of said drilling fluid in said container.

2. A method according to claim 1, further comprising the step of processing said drilling fluid with solids separation equipment prior to performing steps (a) to (e).

3. A method according to claim 1 or 2, wherein said solids control apparatus comprises a centrifuge, the method further comprising the steps controlling a separation efficiency of said centrifuge in order to adjust said viscosity of said drilling material in said container.

4. A method according to claim 3, wherein said centrifuge is adjusted so that solids intended to control viscosity of drilling fluid are separated from said portion of drilling fluid, whilst solids not intended to control said viscosity remain in suspension in said portion of drilling fluid, the method further comprising

the step of returning at least some of said solids separated from said drilling fluid to said container.

5. A method according to claim 4, wherein said solids comprise drilled solids, the method further comprising the step of separating said drilled solids from said portion of drilling fluid with said centrifuge such that each separated drilled solid has a largest dimension of about twenty microns or more and each drilled solid remaining in suspension in said portion of drilling fluid has a largest dimension of about twenty microns or less.

6. A method according to any of claims 3, 4 or 5, further comprising the step of separating barite solids suspended in said portion of drilling fluid with said centrifuge.

7. A method according to claim 6, wherein each of said barite solids has a largest dimension of about ten microns or greater.

8. A method according to any of claims 3 to 7, further comprising the step of operating said centrifuge at a G-force of about 700 G's or less.

9. A method according to claim 3, further comprising the steps of separating substantially all solids suspended in said portion of drilling fluid, and returning at least some of said drilling fluid to said container.

10. A method according to claim 9, wherein the step of separating substantially all solids suspended in said portion of drilling fluid is performed after the steps of any of claims 3 to 8.

11. A method according to any preceding claim, wherein said solids control apparatus comprises a centrifuge, the method further comprising the steps controlling a pumping rate at which drilling fluid is pumped thereto in step (c) in order to adjust said viscosity of said drilling material in said container.

12. A method according to any preceding claim, further comprising the steps of:

(a) sensing a density of said drilling fluid and providing a density signal representative thereof;

(b) receiving said density signal with a computer apparatus and using said computer apparatus to determine a desired viscosity value based on said density signal;

(c) comparing said desired viscosity value to the viscosity of drilling fluid represented by said viscosity signal; and

(d) controlling said solids separation apparatus so as maintain said viscosity signal at or near said desired viscosity value.

13. A method according to any preceding claim, further comprising the step of substantially continuously adjusting viscosity of said drilling fluid in said container with said solids separation apparatus.

14. A method according to any preceding claim, wherein step (c) comprises the step of pumping said portion of drilling fluid from said container.

15. A method for controlling density of drilling fluid containing solids, said drilling fluid circulating in a drilling fluid system, which method comprises the steps of:

(a) feeding drilling fluid into a container;

(b) sensing with a density sensor a density of drilling fluid in said container and providing a density signal representative thereof;

(c) in response to said density signal pumping a portion of said drilling fluid to a solids separation apparatus;

(d) separating with said solids separation apparatus at least some of the solids from said portion of drilling fluid; and

(e) returning to said drilling fluid system drilling fluid and/or solids separated in step (d) to adjust the density of said drilling fluid in said container.

16. An apparatus for controlling viscosity of drilling fluid held in a container that forms part of a drilling fluid circulation system, which apparatus comprises:

a viscosity sensor for sensing viscosity of said drilling fluid in said container and for outputting a viscosity signal indicative thereof;

a solids separation apparatus for removing solids from the drilling fluid;

a pump apparatus for pumping drilling fluid to said solids separation apparatus; and

a control apparatus for receiving said viscosity signal from said viscosity sensor, which control apparatus is configured to control the method steps of any of claims 1 to 14.

17. An apparatus as claimed in claim 16, wherein said solids separation apparatus comprises a centrifuge having a rotatable bowl, a rotatable screw conveyor, bowl drive apparatus for driving said rotatable bowl, and conveyor drive apparatus for driving the rotatable conveyor, the arrangement being such that, in use, said bowl drive apparatus and said conveyor drive apparatus are controllable by said control apparatus.

18. An apparatus as claimed in claim 17, wherein said bowl and/or conveyor drive apparatus comprises a variable frequency drive.

19. An apparatus as claimed in any of claims 16, 17 or 18, wherein said control apparatus comprises a programmable logic controller (PLC), the apparatus further comprising display apparatus for displaying results provided by said PLC.

20. An apparatus as claimed in any of claims 16 to 19, further comprising a density sensor for measuring density

of said drilling fluid and for producing a density signal indicative thereof, said density signal useable by said control apparatus for determining a desired viscosity value.

21. For use in an apparatus for controlling viscosity of drilling fluid held in a container that forms part of a drilling fluid circulation system, a control apparatus having a memory storing computer executable instructions for instructing the method steps of any of claims 1 to 14.

22. An apparatus for controlling density of drilling fluid held in a container that forms part of a drilling fluid circulation system, which apparatus comprises:

a density sensor for sensing density of said drilling fluid in said container and for outputting a density signal indicative thereof;

a solids separation apparatus for removing solids from the drilling fluid;

a pump apparatus for pumping drilling fluid to said solids separation apparatus; and

a control apparatus for receiving said density signal from said density sensor, which control apparatus is configured to control the method steps of claim 15.

23. For use in an apparatus for controlling density of drilling fluid held in a container that forms part of a drilling fluid circulation system, a control apparatus having a memory storing computer executable instructions for instructing the method steps of claims 22.

24. A kit for controlling viscosity of drilling fluid held in a container that forms part of a drilling fluid circulation system, which kit comprises:

(a) a viscosity sensor; and

(b) a control apparatus comprising a memory storing computer executable instructions for instructing the method steps of any of claims 1 to 14.

25. A kit for controlling density of drilling fluid held in a container that forms part of a drilling fluid circulation system, which kit comprises:

(a) a density sensor; and

(b) a control apparatus comprising a memory storing computer executable instructions for instructing the method steps of claim 15.

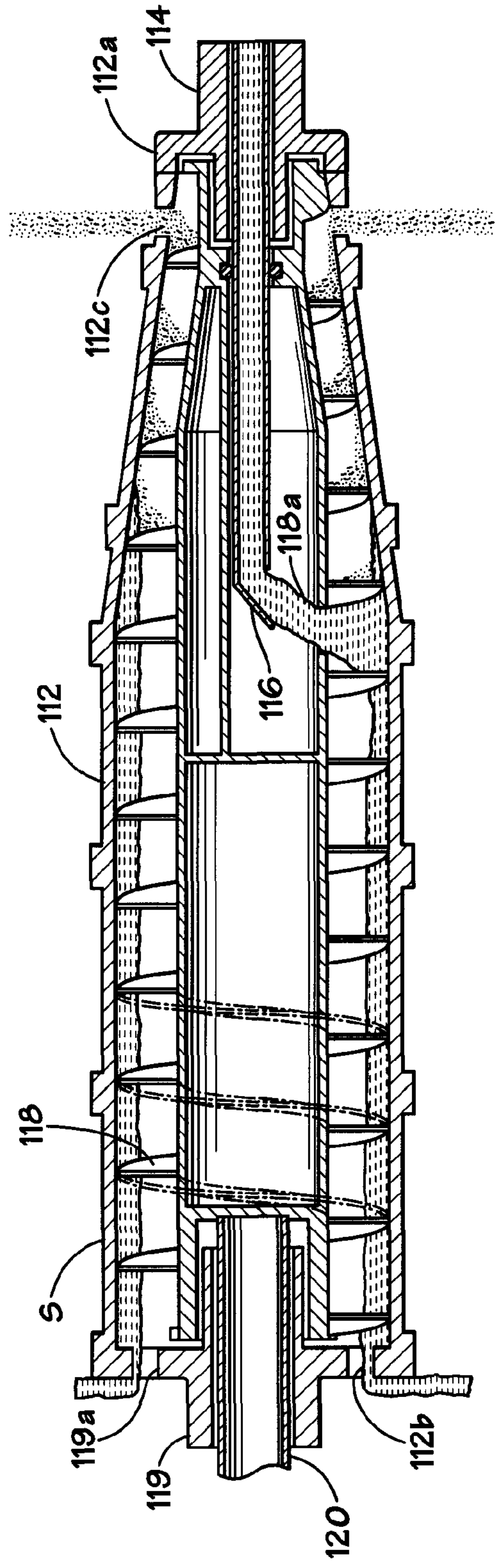
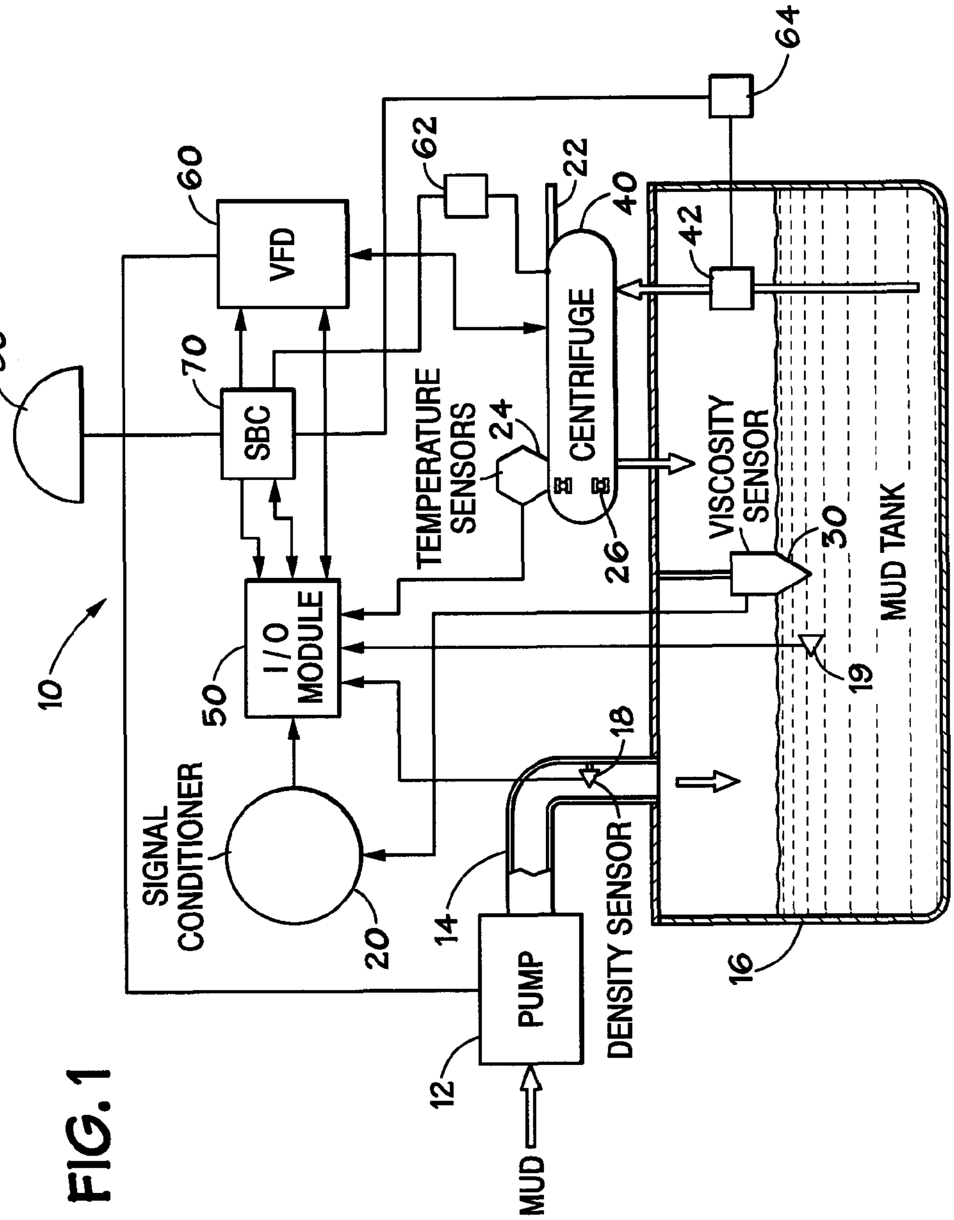


FIG. 4
(PRIOR ART)



10
80
70
SBC
60
VFD
62
64
22
40
CENTRIFUGE
42
TEMPERATURE
SENSORS
24
26
VISCOSITY
SENSOR
30
I/O
MODULE
50
19
MUD TANK
18
SIGNAL
CONDITIONER
20
14
DENSITY SENSOR
16
PUMP
12
MUD

FIG.1

FIG. 2

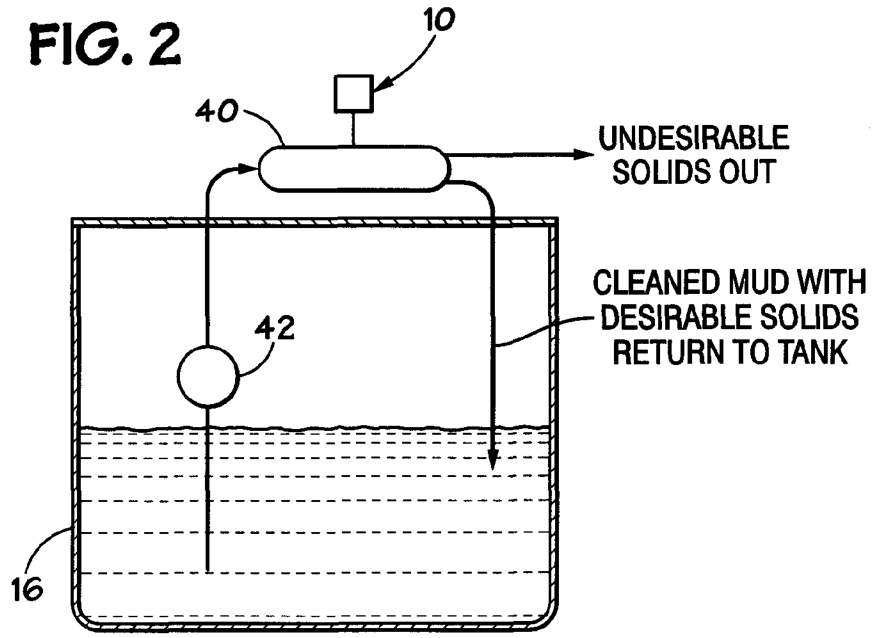
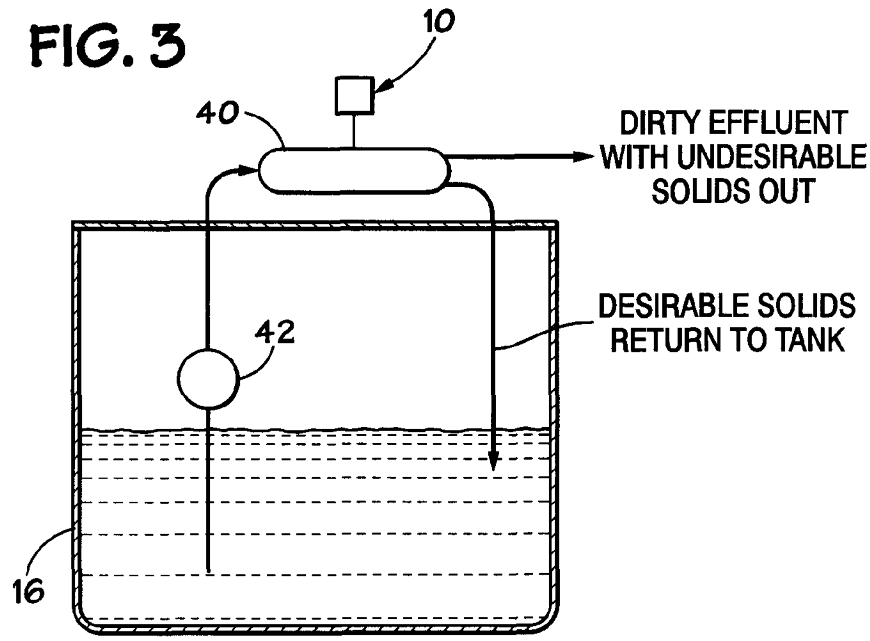

10
40
UNDESIRABLE
SOLIDS OUT
CLEANED MUD WITH
DESIRABLE SOLIDS
RETURN TO TANK
42
16

FIG. 3


10
40
DIRTY EFFLUENT
WITH UNDESIRABLE
SOLIDS OUT
DESIRABLE SOLIDS
RETURN TO TANK
42
16

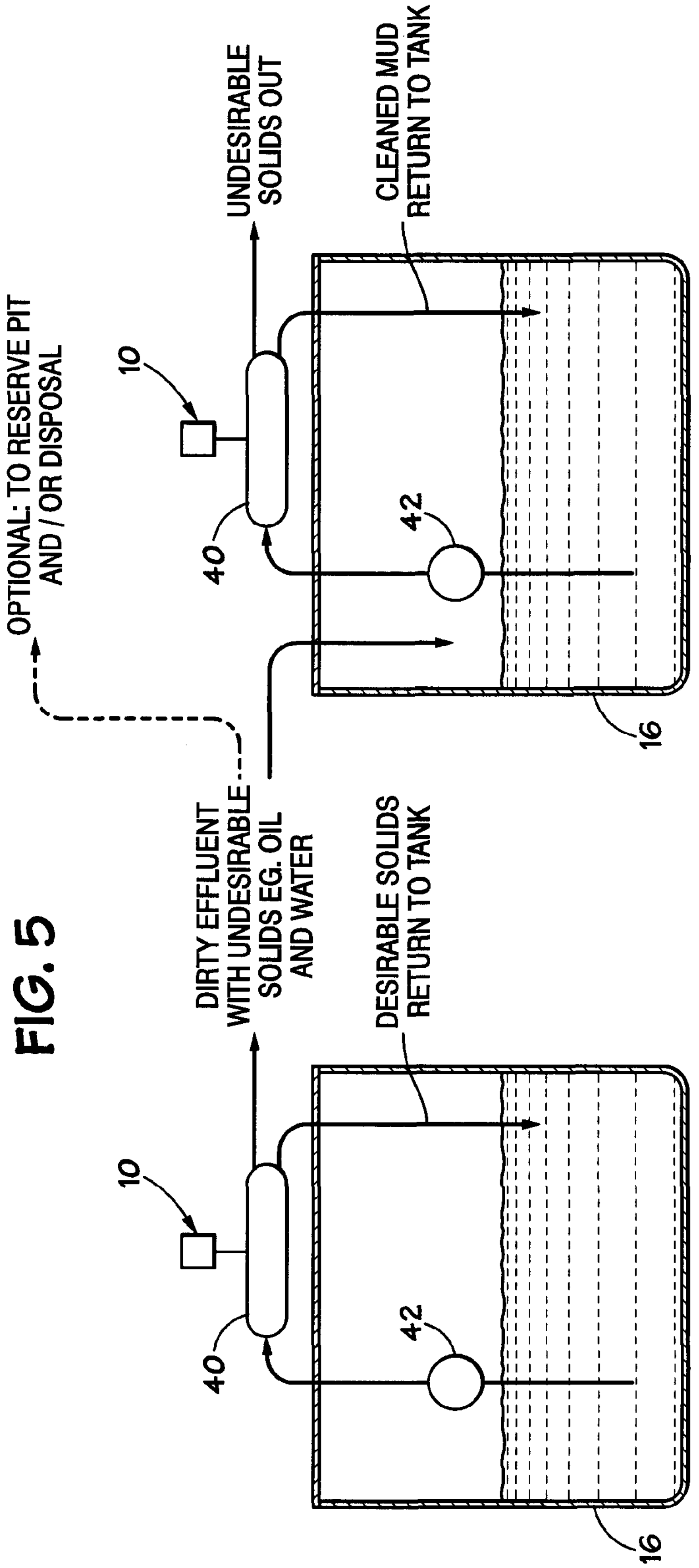

OPTIONAL: TO RESERVE PIT AND / OR DISPOSAL
10
UNDESIRABLE SOLIDS OUT
CLEANED MUD RETURN TO TANK
40
42
16
DIRTY EFFLUENT WITH UNDESIRABLE SOLIDS EG. OIL AND WATER
DESIRABLE SOLIDS RETURN TO TANK
10
40
42
16

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/050334

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B21/06

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)
E21B

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)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 219 312 A (HAYWARD JOHN T ET AL) 29 October 1940 (1940-10-29)	1,2,9, 10, 12-14, 16,20
Y		3-8,11, 17-19, 21,24
Y	WO 89/09091 A (MELLGREN STEINAR E [NO]) 5 October 1989 (1989-10-05) page 4, line 33 - page 5, line 2	3-8,11
Y	US 5 857 955 A (PHILLIPS VICTOR [US] ET AL) 12 January 1999 (1999-01-12) column 1, lines 24-30 column 7, lines 14-16 claim 4; figure 1	17-19, 21,23-25

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

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"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 when the document is taken alone

"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

Date of the actual completion of the international search	Date of mailing of the international search report
24 January 2007	01/02/2007

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	BELLINGACCI, F

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	EP 0 936 344 A2 (TUBOSCOPE VETCO INT [US]) 18 August 1999 (1999-08-18) paragraphs [0032], [0036]; figure 1	1,15,16, 22
A	US 2 954 871 A (LUMMUS JAMES L ET AL) 4 October 1960 (1960-10-04) column 2, lines 17-21 column 4, lines 19-41 column 5, lines 35-74; figure 2	1,15,16, 22
A	US 2002/074269 A1 (HENSLEY GARY L [US] ET AL) 20 June 2002 (2002-06-20) paragraphs [0002], [0022]	1,15,16, 22

1

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Information on patent family members

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US 2954871	A	04-10-1960	NONE			
US 2002074269	A1	20-06-2002	NONE			