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(54) **FLOW DIVERTER FOR DRILLING**

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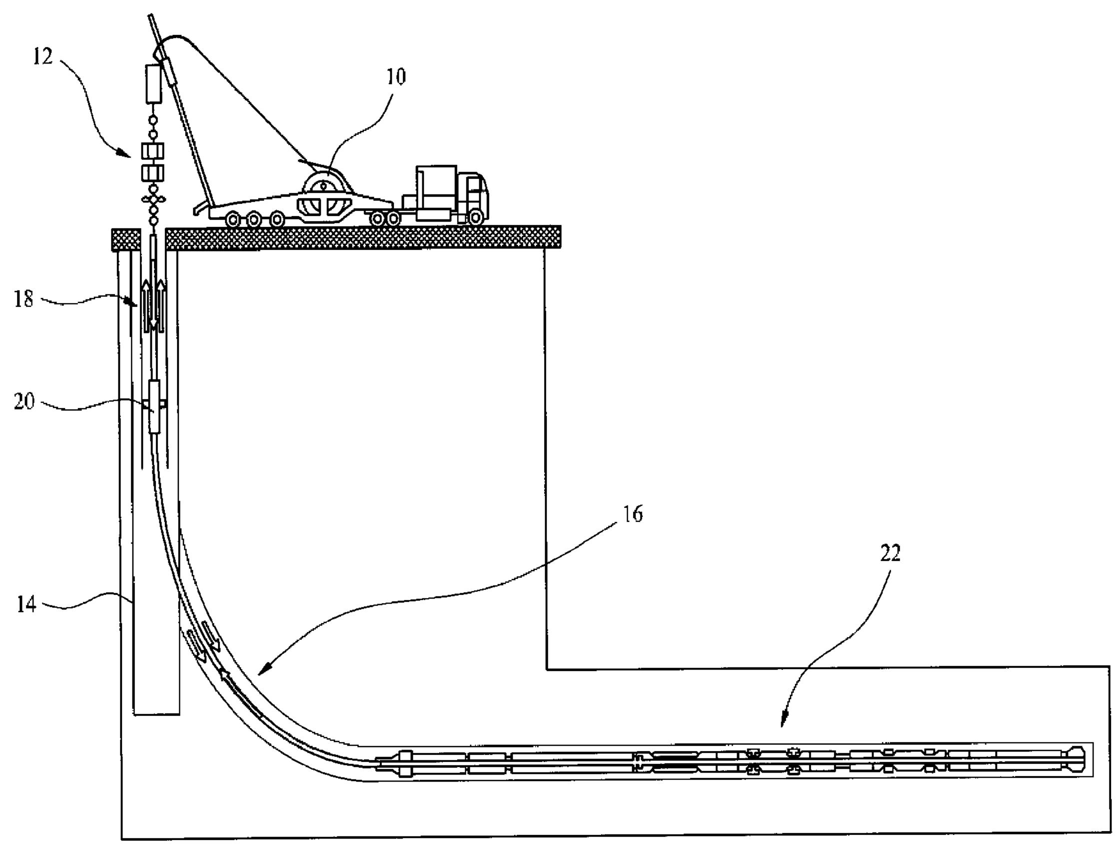
(57) **ABSTRACT**

An apparatus for drilling a borehole in a well is provided. The apparatus comprises a tubular conveyance system; a drilling system connected to one end of the tubular conveyance system and comprising a bottom hole assembly; and a flow diverter positioned in the tubular conveyance system and comprising a first flow channel configured to receive fluid from inside the conveyance system and at least two side flow channels configured to direct fluid from the first flow channel out of the tubular conveyance system. The fluid flow between the first flow channel and each side flow channels is controlled by a valve which is operable to divert fluid out of the tubular conveyance system or to maintain the fluid in the tubular conveyance system.



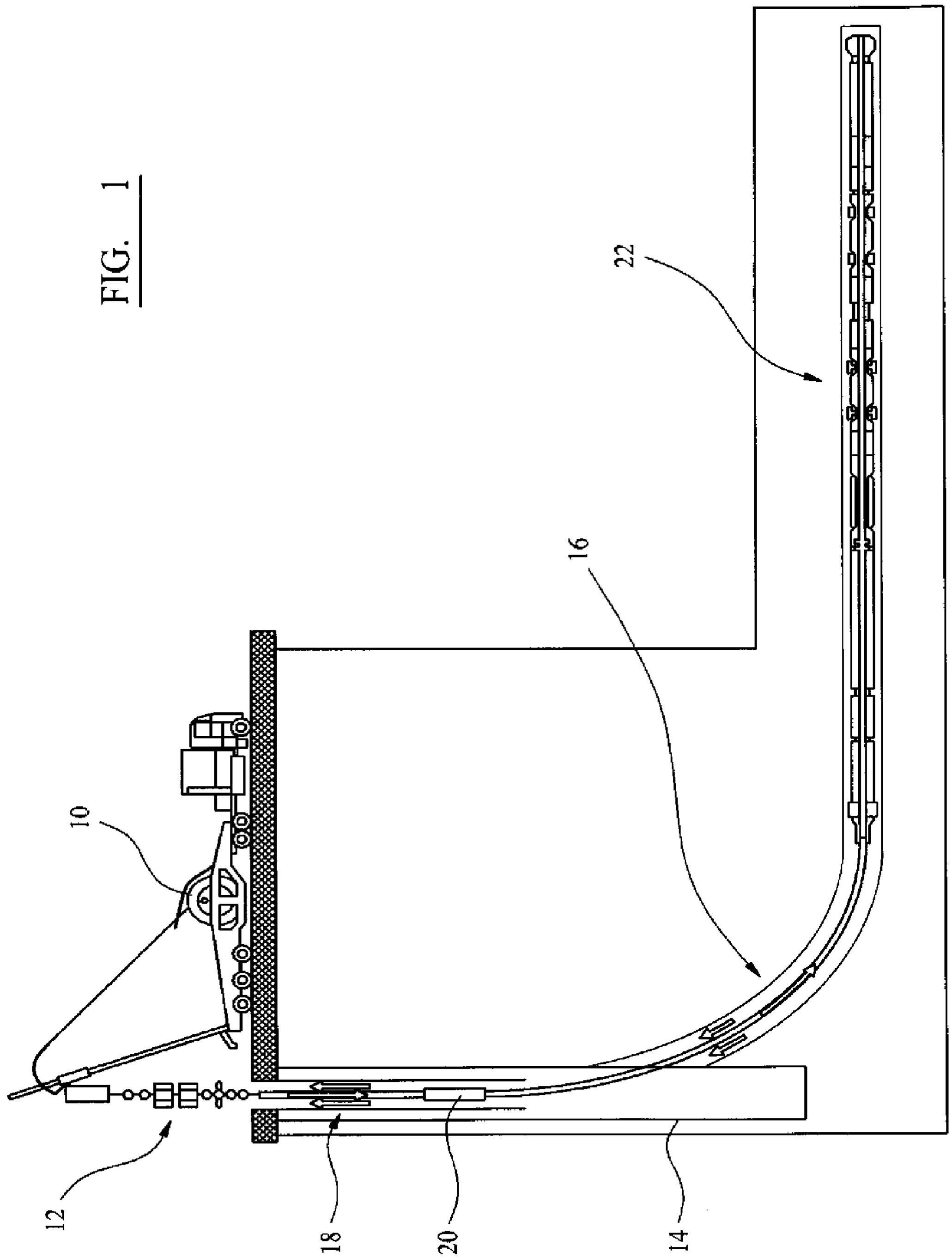


FIG. 1

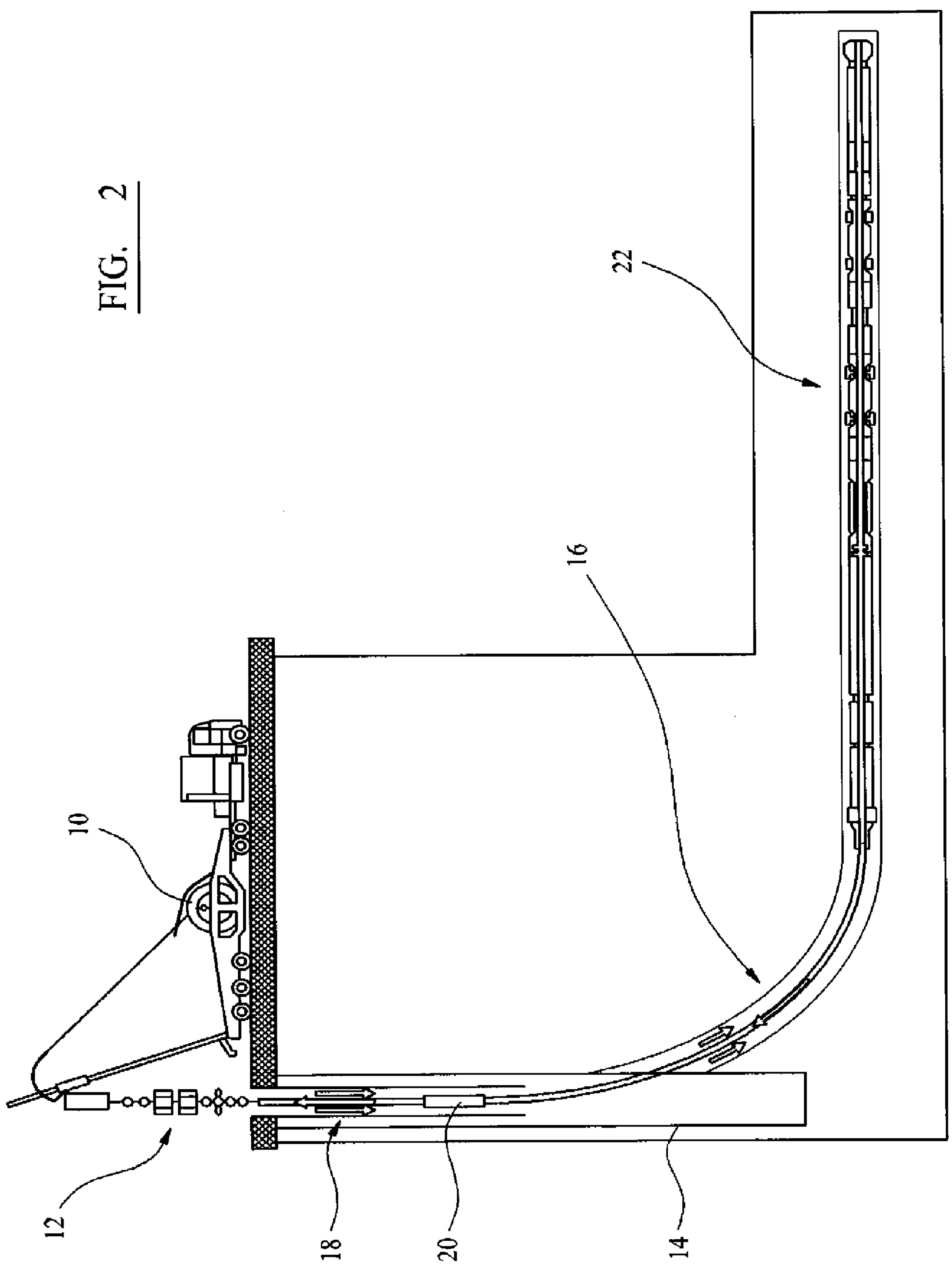


FIG. 2

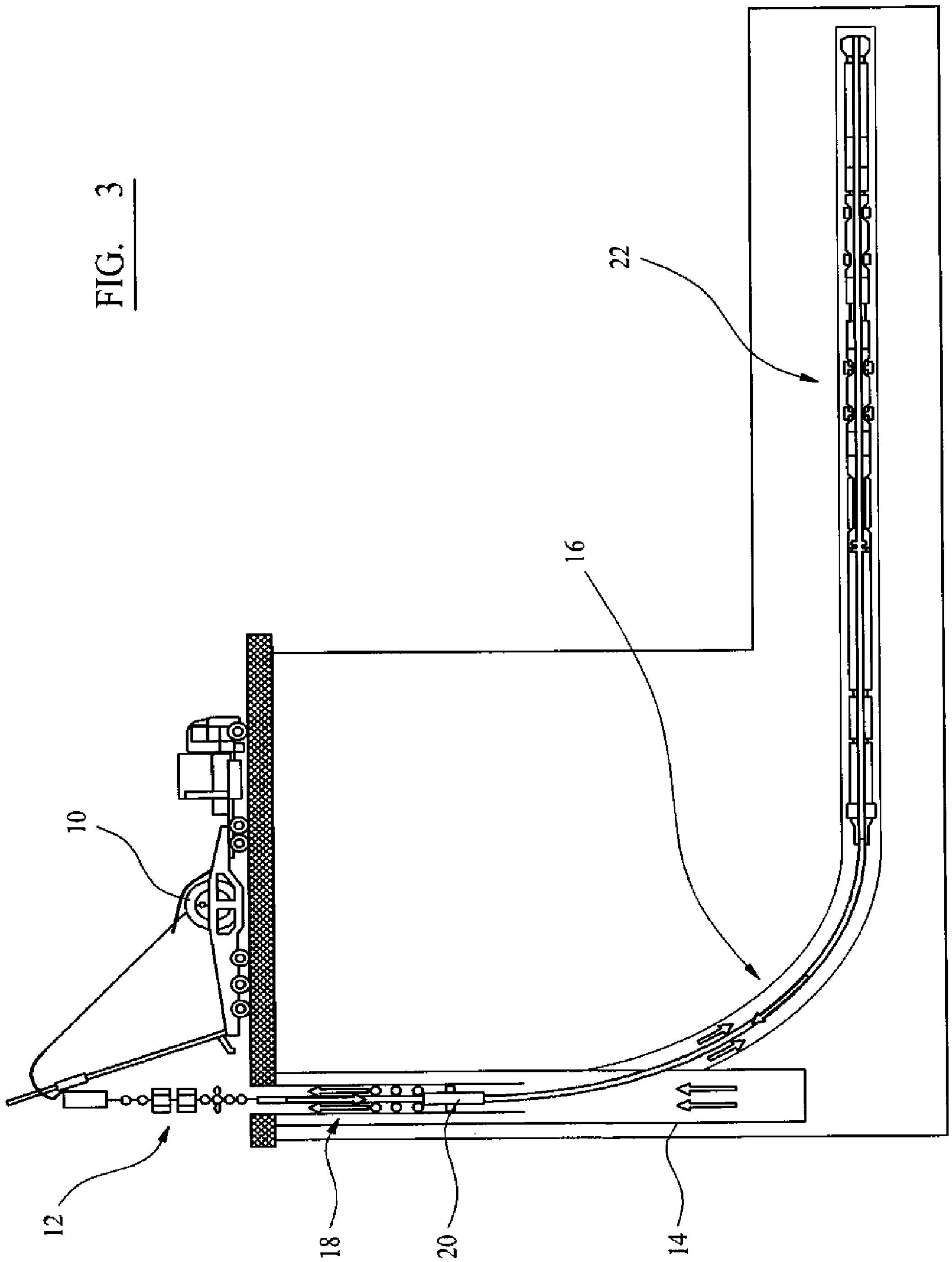


FIG. 3

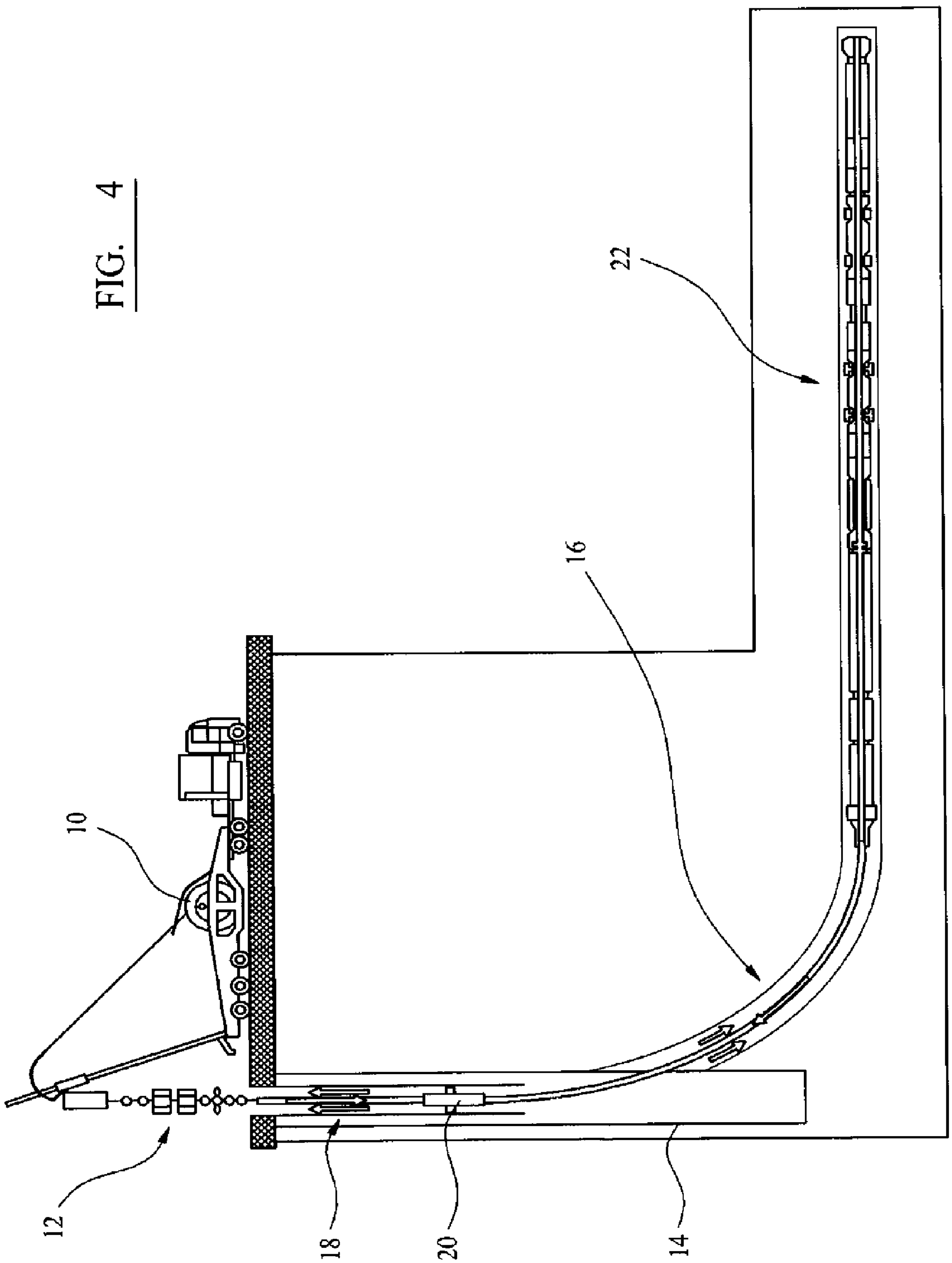


FIG. 4

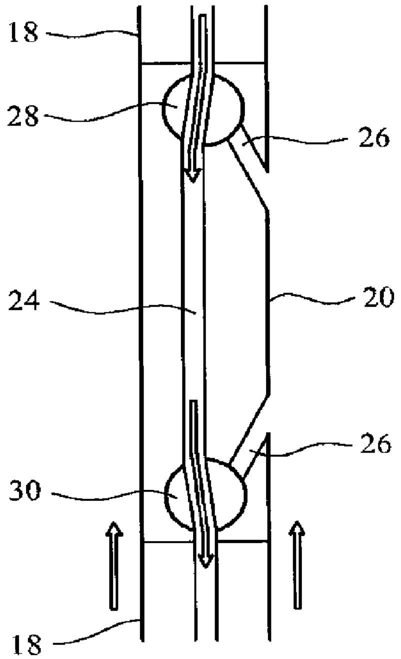


FIG. 5

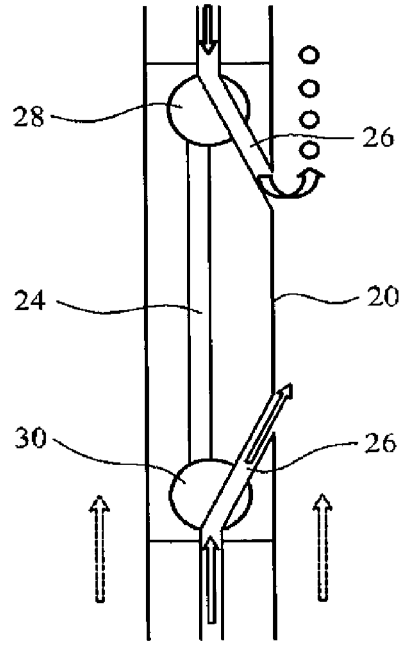


FIG. 6

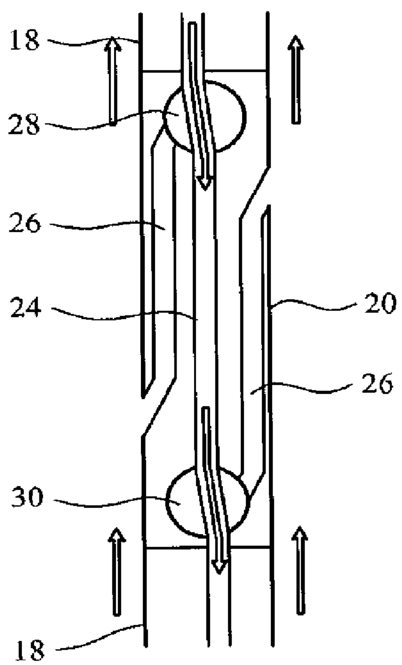


FIG. 7

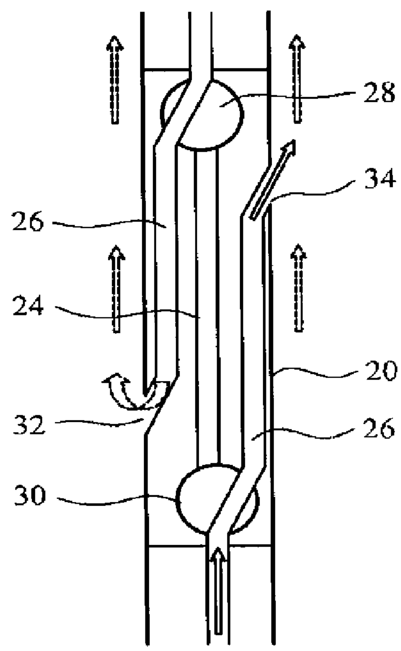


FIG. 8

FLOW DIVERTER FOR DRILLING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is based on and claims priority to GB Application No. 0722882.8, filed 22 Nov. 2007; and International Patent Application No. PCT/EP2008/009809, filed 19 Nov. 2008. The entire contents of each are herein incorporated by reference.

TECHNICAL FIELD

[0002] This invention relates to methods and apparatus for drilling boreholes, in particular to drilling with a coiled tubing system.

BACKGROUND ART

[0003] Drilling using coiled tubing has been going on for many years and hundreds of wells are now drilled every year with this technology. Coiled tubing drilling (CTD) comprises drilling with a continuous pipe coiled onto a reel with a downhole drilling motor typically providing rotation to the drill bit. The tubing is conveyed into a borehole with a special injector system mounted on the surface. Coiled tubing drilling shows many advantages compared to conventional drilling with jointed pipes, including: ability to operate in pressurized wells, fast tripping speed, continuous circulation while tripping and drilling, ability to be used in slimhole and through-tubing applications, and rig-less operations.

[0004] However the use of coiled tubing drilling is still limited due to: the small portion of the global CT rig fleet capable of handling the large tubing size needed for drilling, the size and weight of a typical spool of coiled pipe is not always compatible with the hosting capacity of the platforms, CTD requires surface-pumping equipments that are comparable in size to those used in conventional drilling, and CTD has a limited reach in horizontal wells and therefore conventional drilling is still required when drilling long horizontal or highly deviated wells. Downhole drilling systems have been described which overcome some of these disadvantages.

[0005] EP1780372 describes an apparatus having a drilling system comprising a drilling drive mechanism that can apply both rotation an axial force to the drill bit and can use coiled tubing having a smaller diameter than that is used in conventional CTD systems.

[0006] It is an object of the invention to provide a drilling apparatus that does not require a large capacity coiled tubing and still have increased performance and efficiency over systems of the prior art. This is achieved using a flow diverter that can be configured during operation to address different conditions that are encountered during drilling.

DISCLOSER OF THE INVENTION

[0007] Accordingly a first aspect of the invention comprises an apparatus for drilling a borehole in a well comprising a tubular conveyance system; a drilling system connected to one end of the tubular conveyance system and comprising a drilling assembly; and a flow diverter positioned in the tubular conveyance system and comprising a first flow channel configured to receive fluid from inside the conveyance system and at least two side flow channels configured to direct fluid from the first flow channel out of the tubular conveyance system; wherein fluid flow between the first flow channel and each side flow channel is controlled by a valve which is operable to divert fluid out of the tubular conveyance system or to maintain the fluid in the tubular conveyance system.

[0008] The flow diverter can be located in the tubular conveyance system such that in use the flow diverter is positioned in the main well. This allows fluid to be released into a cased section of the well, when the diverter is configured to release fluid into the annulus

[0009] The side flow channels of the flow diverter can be arranged to divert flow that has come from inside the drilling system to the annulus above the point at which the side channels divert flow from the surface into the annulus. This allows crossflow so that the flow of the drilling fluid pumped from the surface will lift the flow of the fluid from the drilling system to the surface.

[0010] Alternatively the side channels of the flow diverter can be arranged to divert flow that has come from the surface to the annulus above the point at which the side channels divert flow that has come from inside the drilling system to the annulus. This allows a fluid such as a gas to be pumped into the conveyance system and discharged into the annulus to adjust the density of the fluid column to achieve the desired well parameters.

[0011] Preferably the valves are controlled by an electrical line from the surface. The electric line can run down the tubular conveyance system, along with lines that may power the drilling system. The valves can have a default position such that when a valve actuation signal is lost the valves are configured to return to their position.

[0012] Preferably the diverter is spoolable. The diameter of the diverter can be larger than the diameter of the tubular conveyance system. Alternatively the diameter of the diverter is the same as the diameter of the tubular conveyance system. The diameter of the diverter relative to the tubular conveyance system can be adjusted to the application according to the well conditions. Preferably the diverter can pass through the tubular conveyance deployment system and into the well.

[0013] It is particularly preferred that the tubular conveyance system is coiled tubing.

[0014] The apparatus can further comprise an electric line controlled from the surface running through the diverter and tubular conveyance system to the drilling assembly. The electric line can provide power to the drilling assembly or transmit telemetry to and/or from the assembly.

[0015] The apparatus can also comprise a second flow diverter. The second flow diverter can form part of the bottom hole assembly or may be positioned adjacent the bottom hole assembly.

[0016] A second embodiment of the invention comprises a method for drilling a borehole in an underground formation comprising; deploying the apparatus as described above down a borehole; pumping a fluid through the tubular conveyance system; and using the drilling assembly to drill the borehole.

[0017] Preferably the method also comprises positioning the apparatus such that the flow diverter is positioned in the main well.

[0018] The method can comprise pumping drilling fluid from the surface through the tubular conveyance system. Alternatively the method can comprise injecting gas from the surface through the tubular conveyance system into the annulus or comprising injecting a fluid gas mixture from the surface through the tubular conveyance system to the diverter.

[0019] The method can comprise adjusting the valves of the diverter to direct the received flow from the tubular conveyance system into the annulus. Alternatively the method can comprise adjusting the valves of the diverter to maintain the received flow within the conveyance system.

[0020] The method can comprise pumping produced well fluids with cuttings from the drilling assembly to the surface through the diverter or from the drilling assembly to the diverter and into the annulus such that they can then be lifted to surface.

[0021] Drilling fluids laden with cuttings can be pumped from the drilling assembly to surface through the diverter or from the drilling assembly to the diverter and into the annulus such that they can then be lifted to the surface.

BRIEF DESCRIPTION OF FIGURES IN THE DRAWINGS

[0022] FIG. **1** shows a drilling operation using standard circulation;

[0023] FIG. **2** shows a drilling operation using reverse circulation;

[0024] FIG. **3** shows a drilling operation using a gas lift system;

[0025] FIG. **4** shows a drilling operation using a mud lift system;

[0026] FIG. **5** shows details of a flow diverter for use in the drilling apparatus of FIG. **3**;

[0027] FIG. **6** shows the flow diverter of FIG. **5** in a gas lift configuration;

[0028] FIG. **7** shows details of a flow diverter for use in the drilling apparatus of FIG. **4**; and

[0029] FIG. **8** shows the flow diverter of FIG. **7** in mud lift configuration.

MODE(S) FOR CARRYING OUT THE INVENTION

[0030] With reference to FIG. **1** a drilling operation is conducted using a conventional coiled tubing unit **10** and injector/pressure control setup **12** at the surface of the well **14** and is being used to drill a lateral well **16** extending away from the main well **14**. The drilling apparatus comprises a coiled tubing conveyance system **18**, a diverter **20** and a drilling system **22**. The diverter **20** is adjustable to control the path through which the fluid can flow through the coiled tubing depending on the drilling conditions. The diverter is positioned in the main well **14**, such that when the diverter is configured to direct fluid into the annulus the fluid will be released into a cased portion of the well.

[0031] As shown in FIG. **1** the coiled tubing conveyance system **18** can carry fluid from the surface to the section of the well being drilled. The fluid passes directly through the diverter **20** from the upper region of the CT conveyance system **18** above the diverter to the lower region of the CT conveyance system below the diverter and then into the drilling system **22** connected to the conveyance system. Whereby the fluid is discharged from the drilling assembly into the well and can return to the surface via the annulus around the coiled tubing.

[0032] The apparatus can also be used in a reverse circulation application as shown in FIG. **2**. The fluid is pumped down the annulus around the drilling system and drill bit and then the fluid is returned to the surface by being pumped up inside the drilling system **22**, through the lower region of the coiled tubing conveyance system **18**, directly through the diverter **20** into the upper region of the conveyance system and to the surface.

[0033] The coiled tubing conveyance system comprises a coiled tubing having an electrical cable running inside from the surface to the drilling system. A drilling fluid supply forms part of the coiled tubing unit at the surface and can pump fluid down the inside of the coiled tubing. The drilling system comprises a bottomhole drilling assembly and includes the drill bit and drill driving mechanism, for example as described in EP1780372. The system can also include other features such as a crawler system to provide axial drive to the drill bit, and a pump, such as electric or jet pump to draw fluid and drill cuttings up through the drill bit and inside the bottomhole drilling assembly.

[0034] In the situations shown in FIGS. **1** and **2** the valves of the flow diverter will be configured so that the fluid can flow directly through the diverter from the upper region of the coiled tubing to the lower region of the coiled tubing (FIG. **1**) and from the lower region of the coiled tubing through the diverter to the upper region of the coiled tubing (FIG. **2**).

[0035] Using a reverse circulation application to carry cuttings away from the drill bit avoids the risks associated with using standard circulation to transport cuttings in open hole regions of boreholes with low fluid flow. The fluid carrying cuttings are transported inside the coiled tubing in the open hole region of the drainhole being drilled, into the casing section of the main bore. Once the fluid flow has reached the flow diverter which is positioned in the coiled tubing conveyance system in the casing section of the main borehole, the flow diverter can divert the cuttings from the coiled tubing into the annulus between the coiled tubing and the casing. The fluids with cuttings are then carried away to the surface up the annulus.

[0036] The cuttings can be carried away by a number of methods. If the natural fluid flow from the well is sufficient the flow from the well can carry the cuttings to the surface and then to the production facilities or a fluid treatment system. If the natural flow is not sufficient the pressure in the well bore can be decreased by decreasing the weight of the fluid in the main well bore. As shown in FIG. **3** this can be achieved by using a gas lift system. Gas is injected into the coiled tubing **18** from the surface and the valves of the diverter are adjusted so that the gas injected from the surface into the coiled tubing **18** is diverted into the annulus once it reaches the flow diverter **20**. Fluid flowing up the coiled tubing **18** below the flow diverter **20** from the drilling system **22** will also be diverted into the annulus. The mixing of the gas with the fluid in the annulus will adjust the density of the fluid column and allow the cuttings to be carried to the surface while maintaining the desired bottom hole pressure in the drain section during drilling. This increases drilling performance and avoids formation damage.

[0037] Alternatively, if the natural fluid flow from the well is not sufficient, a mud lift system can also be used to help carry the cuttings to surface as shown in FIG. **4**. Fluid is circulated down the coiled tubing **18** from surface to the diverter **20** and out into the annulus. Fluid carrying cuttings are transported in the lower region of the coiled tubing conveyance system **18** from the bottom hole and directed into the annulus at the diverter **20**. The flow of the drilling fluid around the diverter is such that it will mix with the cuttings carrying fluid, from the drilling system, in the annulus around the diverter and carry the cuttings back to surface. At surface the fluid can be treated, cuttings removed and the fluid subsequently reinjected into the conveyance system.

[0038] The configuration of the flow diverter used will depend on the drilling conditions. The flow diverter **20** is formed by flow channels as shown in more detail in FIGS. **5** to **8**. A first flow channel is **24** connected at both ends to the interior of the coiled tubing **18** so that fluid flowing in the coiled tubing can flow into and out of the diverter. Side flow channels **26** extend from the first flow channel **24** to the outside the coiled tubing to direct fluid into the annulus between the casing and coiled tubing. A series of valves **28**, **30** are used to control the pathway of the fluid flow through the flow diverter. Depending on the requirements for drilling the fluid can be maintained in the first flow channel **24** for the fluid to flow through the conveyance system **18** or the fluid can be directed into the side flow channels **26** into the annulus. The valves can be standard ball valves or they may be sleeve valves or seat valves or a combination of these types. The valves can be actuated electrically through an a electrical line running from the surface through the conveyance system, or may be actuated manually or with the effect of pressure or pressure pulses. This enables the configuration of the diverter to be controlled from the surface such that the valves can be adjusted during an operation depending on the drilling conditions encountered.

[0039] The valves in the diverter will have a preset default position. In the event the acutation signal is lost the valves will automatically return to this position to allow safe retrieval from the well.

[0040] As shown in FIGS. **5** and **7** when standard circulation during a drilling operation is required the valves **28**, **30** are positioned so that the fluid will be maintained in the first flow channel **24**. Fluid in the upper region of the coiled tubing **18** is transported to the flow diverter **20** where it is maintained in the first flow channel **24** and flows directly through the flow diverter and into the lower region of the coiled tubing conveyance system **18** positioned below the diverter **20** and then will continue down to the drilling assembly. The fluid will be released into the wellbore from the drill bit where it carries the drilling cuttings from around the drill bit and transports them to the surface via the wellbore annulus. Alternatively the fluid circulation can be done in reverse circulation mode.

[0041] When using standard circulation methods drill cuttings are transported through the uncased portion of the lateral borehole. In some drilling conditions it is beneficial to return the fluid through the conveyance system directly to surface. It is also beneficial to return the fluid through the tubular conveyance system until the fluid reaches the cased section of the main well; whereby the fluid is released into the main well and returned to the surface in the annulus of the main well.

[0042] Returning the cuttings-laden fluid to surface can require artificial lift means when the well's natural fluid flow is not sufficient to transport the cuttings to the surface as discussed above. Therefore the diverter can be configured such that artificial lift means can be used. The valves of the diverter are positioned so fluid entering the flow diverter from the surface is directed into the annulus while fluid entering the diverter from the drilling assembly is also directed into the annulus.

[0043] FIG. **6** shows one configuration of the flow diverter **20** when a gas lift system is used to facilitate the transport of the fluid to the surface. Gas is injected from the surface into the coiled tubing system **18** and is transported down to the flow diverter **20**. The valves **28** of the diverter are positioned so that the gas is diverted from the first flow channel **24** into a side flow channel **26** and out into the annulus. Fluid is also transported up the lower region of the coiled tubing system **18** from the drilling system to the diverter **20**. Valves **30** of the diverter are positioned to divert the fluid from the first flow channel **24** to a side flow channel **26** and out into the annulus. The introduction of the gas into annulus adjusts the density of the fluid column such that the well begins to flow at the desired rate. The produced fluids then carry the cuttings to surface. The amount of gas injected controls the well's bottom hole and surface pressures as well as the its production rate. The amount of injected gas required is specific to the well being drilled and can be continuously adjusted at surface to adjust to changing drilling or well conditions. For example as the diverter moves down in the main well, during the drilling process, injecting gas at the same sustained rate will result in a continual decrease of the bottom hole pressure. Thus it is necessary to adjust the rate from surface depending on the conditions required.

[0044] FIG. **8** shows a configuration of the flow diverter when a mud lift system is used to transport fluid with cuttings to the surface. Fluid is pumped from the surface into the coiled tubing system **18** and into the flow diverter **20**. The valves **28** of the diverter are positioned so that the fluid is diverted from the first flow channel **24** to a side flow channel **26** out into the annulus. Fluid is also transported up from the lower region of the coiled tubing system **18** from the drilling system to the flow diverter **20**. Valves **30** of the diverter are positioned to divert fluid from the first flow channel **24** to a side flow channel **26** and out into the annulus. The side flow channel openings **32** through which fluid from the surface via the upper region of the coiled tubing system is released into the annulus are positioned below the side flow channel openings **34** through which the cuttings carrying fluid is released into the annulus, such that there is crossflow of the two fluids. This enables the flow from the surface fluid to help lift the cuttings to the surface. As the mud lift system requires a crossflow of the fluids the diameter of the diverter can be made larger than the size of the coiled tubing used. In this situation where the diverter is larger in diameter than the coiled tubing, the apparatus is required to be assembled and deployed using a lubricator at the wellhead.

[0045] Similar to the above embodiments the diverter can be also be used to inject a fluid-gas slurry or foam into the annulus below the exit point of the cuttings-laden fluid from the drilling assembly. A gas slurry or foam can be used in wells that cannot produce enough fluids to carry cuttings back to surface or when doing so may damage the formation or jeopardize the drilling process. It may also be desirable to use a foam or fluid-gas slurry to help control bottom hole pressure.

[0046] Using a flow diverter that is adjustable depending on the drilling conditions allows the flow of fluids to be optimised in the wellbore without the use of conventional well intervention methods and allows drilling with smaller coiled tubing with better performance and efficiency. The same drilling apparatus can be used as different drilling conditions are encountered by configuring the flow diverter.

[0047] While the figures exemplify the apparatus having only one diverter, that in use is positioned in the main well, the apparatus may further comprise a second diverter. This second diverter can be positioned just above the bottom hole assembly, such that in use it is placed in an uncased section of the well. Alternatively the second diverter can form part of the bottom hole assembly. The second flow diverter may be a diverter that can be configured to alter the pathway of the fluid flow, as for the main flow diverter described above. Alternatively the flow diverter may be a simple non-configurable diverter for example as described in EP1780372. Having a second diverter positioned just above the bottom hole assembly is desirable for well control, pumping pills, controlling losses or when trying to free a stuck tool.

[0048] Other changes within the scope of the invention will be apparent.

1. An apparatus for drilling a borehole in a well, comprising:

a tubular conveyance system;

a drilling system connected to one end of the tubular conveyance system and comprising a bottom hole assembly; and

a flow diverter positioned in the tubular conveyance system and comprising a first flow channel configured to receive fluid from inside the conveyance system and at least two side flow channels configured to direct fluid from the first flow channel out of the tubular conveyance system;

wherein fluid flow between the first flow channel and each side flow channel is controlled by a valve which is operable to divert fluid out of the tubular conveyance system or to maintain the fluid in the tubular conveyance system.

2. The apparatus according to claim **1**, wherein the flow diverter is located in the tubular conveyance system such that, in use, the flow diverter is positioned in the main well.

3. The apparatus according to claim **1**, wherein the side flow channels of the flow diverter are arranged to divert flow that has come from inside the drilling system to the annulus above the point at it which the side channels diverts flow from the surface into the annulus.

4. The apparatus according to claim **1**, wherein the side flow channels of the flow diverter are arranged to divert flow that has come from the surface to the annulus above the point at which the side channels divert flow that has come from inside the drilling system to the annulus.

5. The apparatus according to claim **1**, wherein the valves are controlled by an electrical line from the surface.

6. The apparatus according to claim **1**, wherein the valves have a default position such that when a valve actuation signal is lost the valves are configured to return to their default position.

7. The apparatus according to claim **1**, wherein the diverter is spoolable.

8. The apparatus according to claim **1**, wherein the diameter of the flow diverter is larger than the diameter of the tubular conveyance system.

9. The apparatus according to claim **1**, wherein the diameter of the flow diverter is the same as the diameter of the tubular conveyance system.

10. The apparatus according to claim **1**, wherein the tubular conveyance system is coiled tubing.

11. The apparatus according to claim **1**, further comprising an electric line controlled from the surface running through the diverter and tubular conveyance system to the bottom hole assembly.

12. The apparatus according to claim **1**, further comprising a second flow diverter, wherein the second flow diverter forms part of the bottom hole assembly.

13. The apparatus according to claim **1**, further comprising a second flow diverter, wherein the second flow diverter is positioned adjacent the bottom hole assembly.

14. A method for drilling a borehole in an underground formation, comprising the steps of:

deploying the apparatus according to claim **1** down a borehole;

pumping a fluid through the tubular conveyance system; and

using the drilling system to drill a borehole.

15. The method according to claim **14**, further comprising positioning the apparatus such that the flow diverter is positioned in the main well.

16. The method according to claim **14**, further comprising pumping drilling fluid from the surface through the tubular conveyance system.

17. The method according to claim **14**, further comprising pumping gas from the surface though the tubular conveyance system to the diverter.

18. The method according to claim **14**, further comprising pumping a fluid-gas slurry mixture from the surface through the tubular conveyance system to the diverter.

19. The method according to claim **14**, further comprising adjusting the valves of the diverter to direct the received flow from the tubular conveyance system into the annulus.

20. The method according to claim **14**, further comprising adjusting the valves of the diverter to maintain the received flow within the tubular conveyance system.

21. The method according to claim **14**, further comprising pumping produced well fluids laden with drilling cuttings from the bottom hole assembly to the surface through the diverter.

22. The method according to claim **14**, further comprising pumping produced well fluids laden with drilling cuttings to the diverter and into the annulus such that they can be lifted to surface.

23. The method according to claim **14**, further comprising pumping drilling fluids laden with drilling cuttings from the bottom hole assembly to surface through the diverter.

24. The method according to claim **14**, further comprising pumping drilling fluids laden with drilling cuttings to the diverter and into the annulus such that they can be lifted to surface.

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